Hungarian University of Agriculture and Life Sciences

The Thesis of PhD Dissertation

Adnan Eser

Gödöllő

2022

Hungarian University of Agriculture and Life Sciences

IMPACT OF NITROGEN TOPDRESSING ON THE QUALITY PARAMETERS OF WINTER WHEAT (*TRITICUM AESTIVUM L.*) YIELD

DOI: 10.54598/003390

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2022

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1.Table of Contents

2.Background of the work and its aims

The Earth's rising population growth is contributing to increasing hunger, as well as creating insufficient and unbalanced nutrition, all of which continue to be major problems for human survival. Although different opinions are put forward for the solution, the most notable consensus among experts has been to engineer an increase in plant and animal products. Wheat, the most widely grown plant species in the world, is a plant of high strategic importance due to the fact that it has been grown since the earliest times; its agricultural process is easier than other plants; the product is more adaptable to transportation and storage conditions; and its inherent high nutrition solves one of the most pressing economic problems. Wheat is also one of the most predominant cereal grains in Hungary and Turkey, and it retains high economic value. The goal of wheat production is two-fold: to provide both quantity and quality.

The milling and baking qualities of wheat are mainly determined by its genetic basis; however, it can be influenced by management techniques as well (Pollhamer, 1981; Grimwade et al., 1996; Vida et al., 1996; Pepó, 2010). The determination of wheat milling quality is complex because the quality measurements depend on the kernel hardness, protein, starch, internal insect infestation, color, disease, size, and moisture parameters (Posner, 2003). One of the most important parameters, in terms of nutritional content, is the protein ratio in wheat. Although it is determined genetically, the protein ratio is a feature that can also be increased by Nitrogen fertilizer applications. The desired ratio is 11-14% for red hard winter wheat. For optimum grain yield, the critical protein ratio was specified as 11.5% (Goos et al., 1982). However, it is required that this rate should not be less than 12.5% in order to increase the quality of bread. Baking quality of wheat flour is determined by grain protein concentration (GPC) and its composition, and is highly influenced by environmental factors such as Nitrogen (N) fertilization management (Xue et al., 2019). The protein content of wheat crops has an important impact on the nutritional quality for humans and livestock and on the crops' functional properties in food processing (Shewry and Halford, 2002). The economic value of winter wheat is affected by the genotype, cropping year, agro-climatic parameters, as well as the agronomic applications and coordination (Győri, 2006; Várallyay, 2008).

Varieties that differ greatly in terms of yield cause less variation in grain protein yields. Since the grain protein concentration is strongly related to the relationship between protein yield and grain yield, there is a somewhat significant inverse relationship between yield and protein concentration from this combination. The protein yield of wheat has increased significantly throughout its breeding history but could not keep up with the genetic yield increase in protein yield. The result was low protein concentrations (Van Lill and Purchase, 1995). Nitrogen (N) is one of the macronutrients required for plant growth, with high effect on quality and quantity values of winter wheat. The quality of wheat varieties is strongly influenced by crop year, season, genotype effects, and the effects of the management systems are also determinative of some physical and gluten quality characteristics of the grain (Rakszegi et al., 2016). Horváth and co-workers (2014) also established that increasing levels of N topdressing and increased number of applications had beneficial effects on the protein content as well as on wet gluten values of wheat grain. Szentpétery and co-workers (2005) proved that increasing fertilizer dose applications had a beneficial effect on the protein and gluten contents, as well as improvements in quality. Kismányoky and Tóth (2010) explained that the increasing rate of N fertilization application, as well as the additional organic fertilizers, has influenced the biomass production and N uptake of winter wheat. Additionally, as a result of intensive chemical fertilization, the amounts of organic matter and humus in the soil will decrease, and the fertilizers will be washed away as they cannot hold in the soil. Plant nutrients (fertilizer) will not be transformed into a chemical form in the soil that the plant could uptake; thus, the physical and chemical properties of the soil will deteriorate. As a result, the upper parts of the soil will be sandy while the lower parts will be stony. One of the biggest factors that cause environmental pollution and deterioration of the natural balance is agricultural activity where chemicals are used extensively. Moreover, the agricultural methods in which chemicals are used not only cause environmental pollution and deterioration of the natural balance, but also threaten the lives of all living things via the food chain. It is possible to divide the development period of wheat into three periods depending on the nitrogen intake amount. The first period is from emergence to tillering, when nitrogen uptake is low (5-20%). Research has shown that the nitrogen of wheat is taken most intensively in the (Figure 1) period of tillering and earing (Zadoks' 25-58) according to the Figure 2 growth period in Zadoks (Brown et al., 2005; Orlof et al., 2012). Nitrogen in this period contributes positively to the amount of tillering and the number of grains per ear, which directly affects the yield. As seen in Figure 1, the third period is the period from spiking to harvest, and nitrogen uptake is slow in this period as well. The main purpose of fertilization is to keep the nitrogen needed by the wheat plant in the soil ready in time during its growth and development periods. For this reason, making fertilization according to growth periods increases the efficiency of nitrogen use. On the negative side, applying more nitrogen than the appropriate nitrogen dose can encourage vegetative growth, which causes a decrease in yield. The aim of this study is to investigate the changes in qualitative parameters of the winter wheat varieties sown in four crop seasons, each of which had different levels of split and/or undivided dose applications of Nitrogen fertilizers. This practice would determine the optimum Nitrogen ratio required in order to reach the optimum protein rate in Nitrogen fertilizer applications with variable ratios. With the help of the equations obtained within the research, the aim is to determine the most appropriate Nitrogen dosage, to reach the highest level of efficiency and quality, and to apply the Nitrogen use at the best possible levels. Due to the fact that the Nitrogen requirement of the plant is not fully met, the results would include low yield, excessive fertilization, pollution of the environment, and economic losses due to the cost of fertilizers. A study conducted in France stated that Nitrogen fertilizer costs constitute 28% of wheat production (Quievreux, 1997). In temperate regions, wheat is the main crop grown for both human and animal consumption. Therefore, all research that focuses on raising wheat production efficiency, crop quantity, and quality characteristics is of utmost significance. The aim of this study is to find the quality changes on tested winter wheat varieties with the application of Nitrogen fertilizer. As Nitrogen fertilization has a considerably high economic and environmental effect on wheat farming and wheat quality, we therefore should find the most appropriate formula for supplying fertilizer to get the best results to be able to improve the quality of the winter wheat products, as well as consider the economic and environmental side effects of this kind of farming approach.

3.Materials and methods

3.1. Field features of experiments

In these three-year sets: 2015-2016, 2016-2017 and 2018-2019, growing seasons for a field trial of high milling and baking quality winter wheat (*Triticum aestivum* L.*)* varieties were set up under identical agronomic conditions using split-plot design (10 m^2/plot). The trials were established at the experimental fields of the Hungarian University of Agriculture and Life Sciences, Crop Production Institute, Hungary in two different sites. The 2015-2016 and 2016 - 2017 crop seasons at Nagygombos-Hungary was the experimental site of Hungarian University of Agriculture and Life Sciences, Crop Production Institute. This site in Nagygombos lies between latitude 47°40'53.00 "N and 47°41'90.00", longitude 19°40'30.00"E and 19°40'20.00"E, shown in Figure 1 and soil parameters of the experimental field on Table 1.

1. Figure The experimental field view by satellite at 2016-2017, Nagygombos, Hungary

Soil type of the trial site at Nagygombos was chernozem (calciustoll).

	Humus %	pH (H_2O)	K_A	Sand %	Silt %	Clay %	$CaCO_3$
Medium	2.65	7.30	45	49	25	26	1.86

1. Table Soil type of the experimental field at Hungarian University of Agriculture and Life Sciences, Crop Production Institute, Nagygombos, Hungary

- Organic matter content %: 2,65
- CaCO3 %: 1,86
- pH (KCl): 7,30
- KA: 45
- P2O5 (mg/kg): 643
- K2O (mg/kg): 293

The is the Gödöllő-Hungary experimental site of the Hungarian University of Agriculture and Life Sciences, Crop Production Institute, used for 2018–2019 and 2019–2020 crop seasons. The experimental site in Gödöllő lies between latitude 47°59'39.88"N and 47°59'60.54"N, longitude 19°37'13.26" and 19°36'82.81", shown in Figure 2.

2. Figure The experimental field view by satellite at 2019-2020, Gödöllő, Hungary

The soil type of the experimental field was sand-based brown forest soil (Chromic Luvisol). The textural classification of the soil was sandy loam with parameters shown in Table 2. The agronomic characteristic of the soil was neutral sandy soil with variable clay content. The soil structure was susceptible to compaction issues. The water retention characteristics were poor due to the high sand content. The soil was exposed to the impacts of drought.

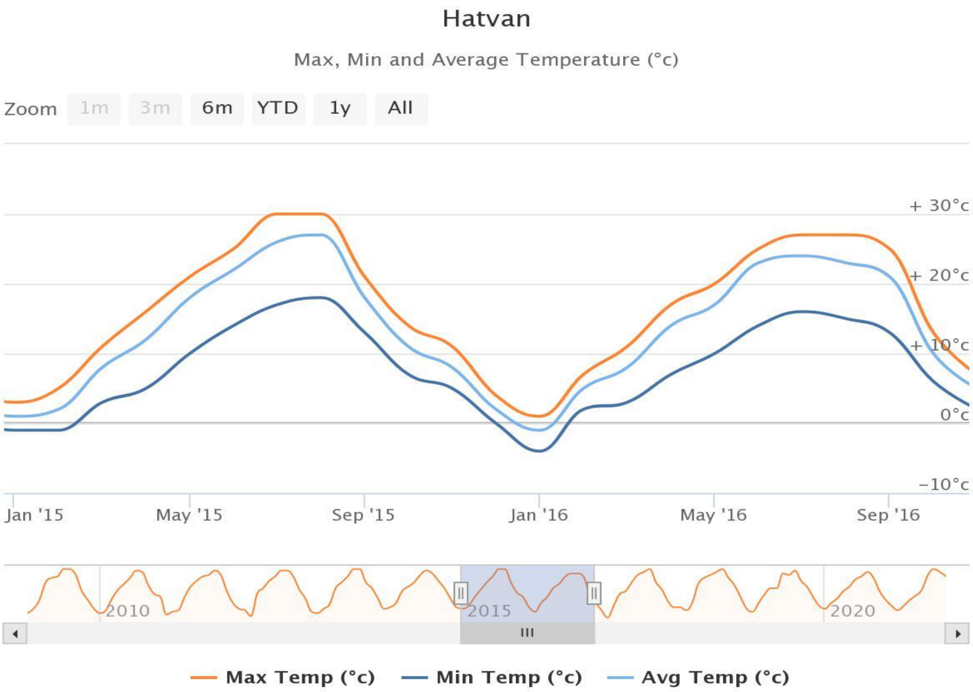
	Humus %	pH (H2O)	K A	Sand %	Silt %	Clay %	CaCO3
Medium	1.32	7.08	40	49	25	26	0

2. Table Soil type of the experimental field at Hungarian University of Agriculture and Life Sciences, Crop Production Institute, Gödöllő, Hungary

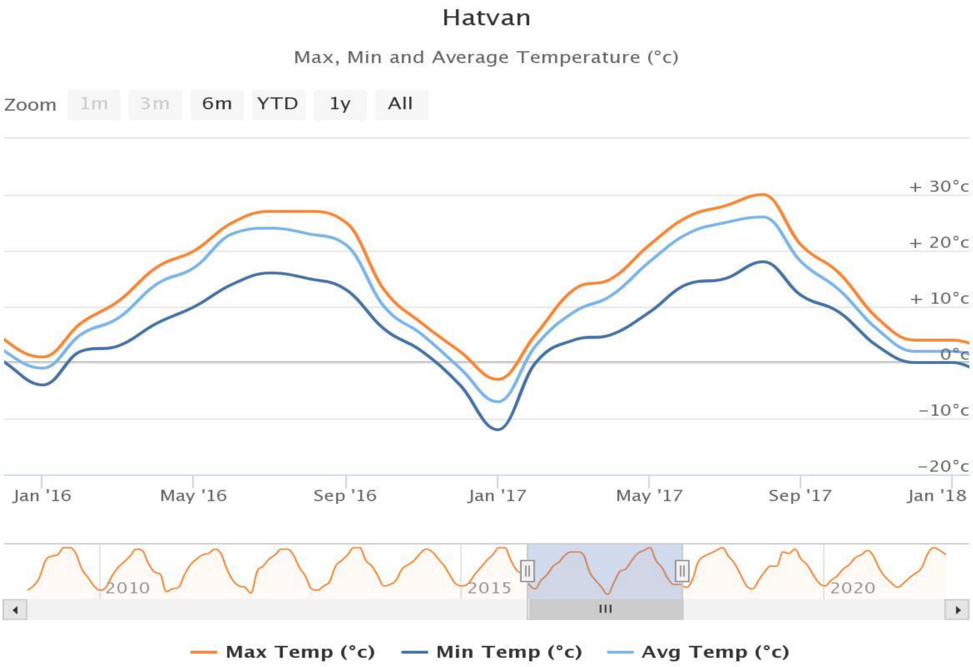
3.2. Meteorological properities of the experimental fields

3.2.1. Hatvan-Nagygombos meteorological properities

Figure 3 and Figure 4 provide information about the weather temperature, and Figure 5 and Figure 6 show rainfall amounts and rainy days of experimental site #1.

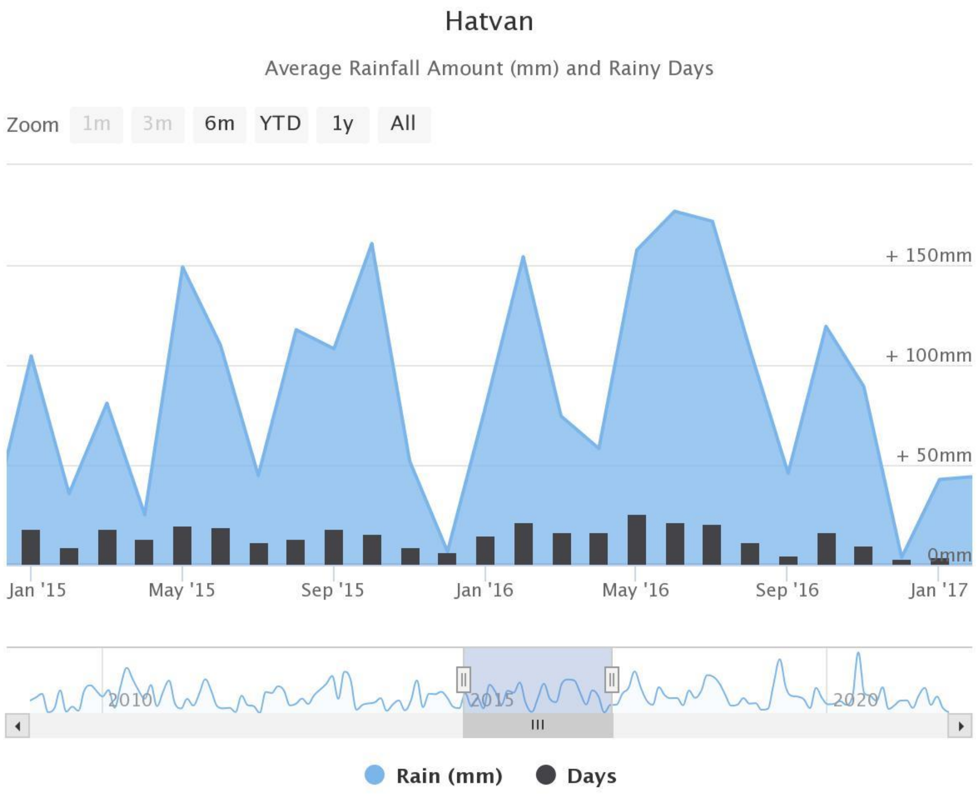


3. Figure Max, Min and Average Weather Temperature 2015-2016 (Nagygombos, Hungary). worldweatheronline.com

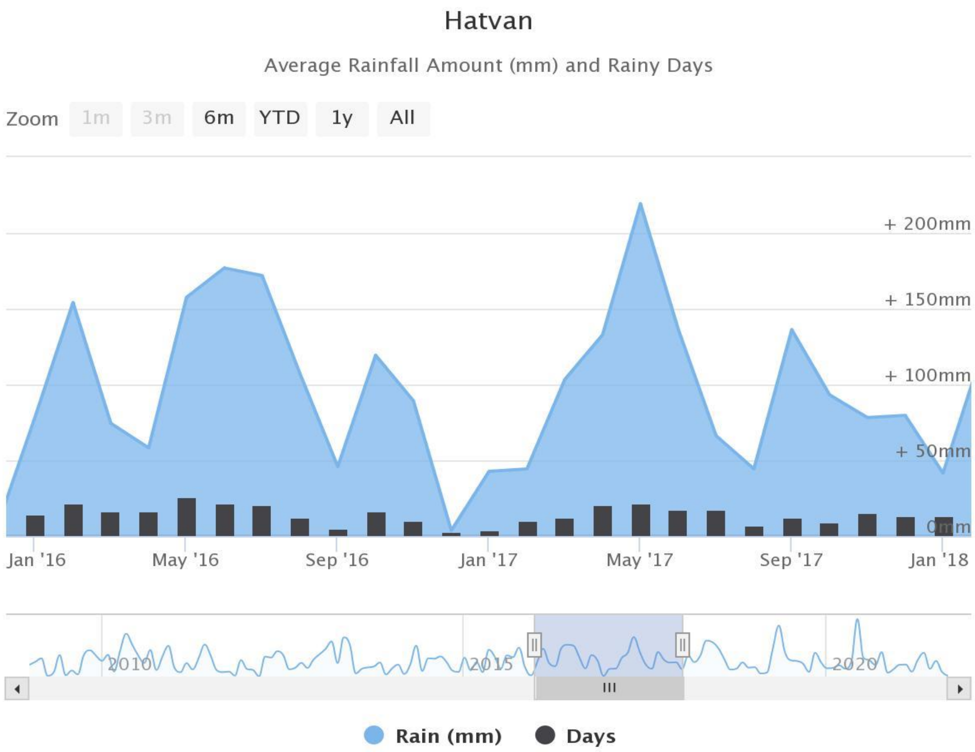


4. Figure Max, Min and Average Weather Temperature 2016-2017 (Nagygombos, Hungary). worldweatheronline.com

The experimental field #1's weather data showed differences between trial years: in 2016 summer the average temperature recorded approximately 3°C lower than the 2015 and 2017 weather average temperatures; however, in 2016 winter also was 6 °C colder than the 2015 and 2017 winter average.



5. Figure Rainfall and Rain Days 2015-2016 (Nagygombos, Hungary). worldweatheronline.com

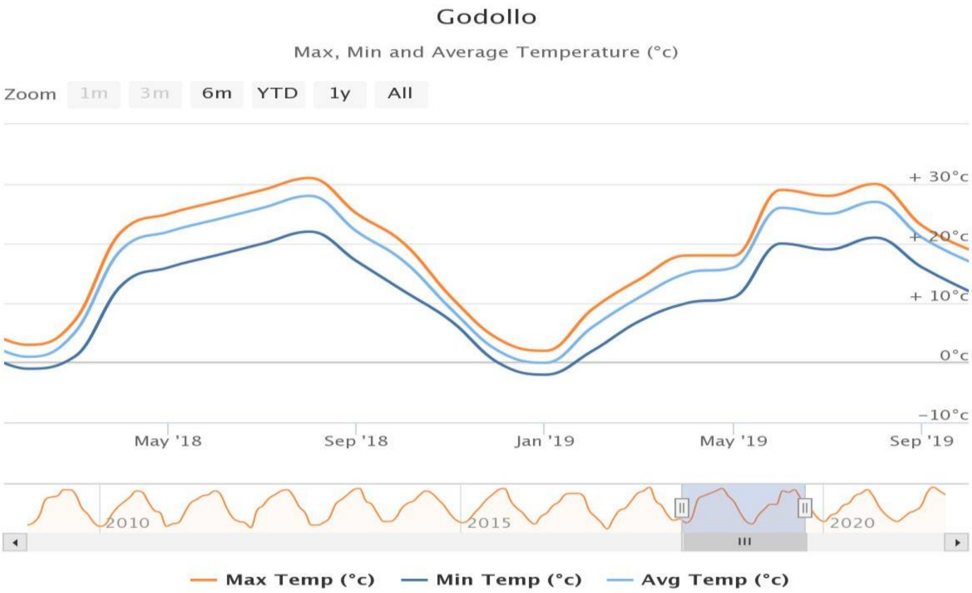


6. Figure Rainfall and Rain Days 2016-2017 (Nagygombos, Hungary). worldweatheronline.com

Recorded rainfall amounts show that experimental site #1 had 994,54 mm rainfall in 2015, 1.236,68 mm in 2016, and 1.176,47 mm. in 2015 -- which was drier than 2016 and 2017 crop years.

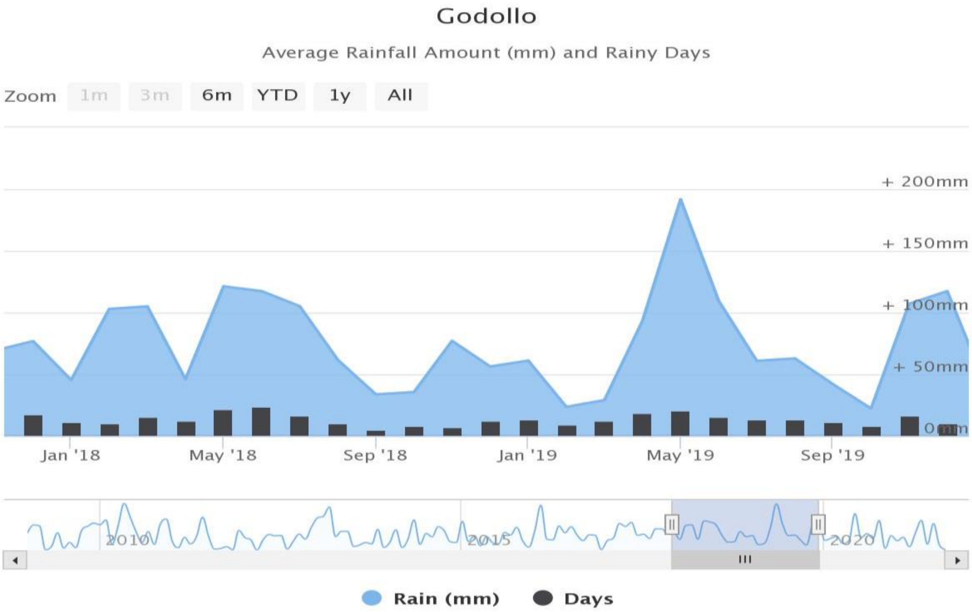
3.2.2. Gödöllő meteorological properties

Figure 7 provides information about the weather temperature, and Figure 8 shows the rainfall amount and rainy days of experimental site #2.



7. Figure Max, Min and Average Weather Temperature 2018-2019 (Gödöllő, Hungary). worldweatheronline.com

Summer and winter in site #2 was approximately 2°C warmer compared to site #1 on average.



8. Figure Rainfall and Rain Days 2018-2019 (Gödöllő, Hungary). worldweatheronline.com

Site #2 received 906,64 mm rainfall in 2018 and 920 mm in 2019.

3.3. Studied winter wheat varieties

The present study examined the performance of five high baking quality winter wheat varieties:

2015-2016 and 2016-2017 crop seasons in Nagygombos - Hungary

-Alföld
-Mv Karéj
-Mv Nádor
-Mv Toldi
-Mv Toborzó

2018–2019 in Gödöllő - Hungary

-Alföld

-Mv Karéj

Variety	Alföld	Mv Karéj	Mv Nádor	Mv Toldi	Mv Toborzó
Ripening time	Early	Medium	Medium	Early	Early
Kernel type	Hard	Hard	Hard	Hard	Hard
Height (cm)	75-95	80-90	60-80	80-90	80-90
Yield (t/ha/)	5,5-7,0	7,0-8,0	7,5-9,5	6,0-7,5	6,0-7,5
TKW (gr)	39-44	45-50	45-50	40-45	48-54
Resistance (1-9)	8	7	9	8	7
Test weight (kg hl^{-1})	78-82	82-85	77-82	78-82	79-82
Protein %	14-17	11-13	12-14	13-15,5	13-15
Gluten %	34-40	29-32	28-32	30-36	32-36

3. Table Martonvásári Fajtakatalógus 2020

3.4. Treatments

The three-year experiment was set up in split-plot design with nine plot replications regarding each experimental factor such as variety and N application (time and dose) in each investigated year. The plots were sown and harvested with plot machines. Apart from N topdressing, all other agronomic treatments as well as sowing and harvesting were identically applied to all plots to study the impact of N treatments independently. N fertilizer topdressing was applied in single or split doses. N was applied in the form of ammonium nitrate (NH_4NO_3); the amounts indicate the N content in this paper, not the molecule. The applied fertilizer was granular ammonium nitrate with 34% content of the active ingredient. N was investigated in 6 different variants: 4 levels single and 2 levels split-dose treatments. Single application: 0, 80, 120, and 160 kg ha^{-1} N, split-dose application: 80+40 kg ha^{-1} and 120+40 kg ha^{-1} in two applications. Single applications were done at the tillering stage, while split-dose treatment was applied at the stage of tillering and heading. There was no N application in autumn in any of the crop years.

3.4. Investigations

Grain yields of the winter wheat varieties were sampled and measured from each harvested plot. The protein, test weight, thousand grain weight, and baking quality parameters were measured from harvested wheat grain. Analyses were done at the research laboratory of the Hungarian University of Agriculture and Life Sciences, Crop Production Institute.

Dickey-john® Instalab® 600 Analyser, Near-infrared (NIR) spectroscopic equipment Mininfra Scan-T Plus 2.02 version (Arana, 2016) were used to measure gluten, protein, and Zeleny sedimentation values of whole grains. Falling Number was also studied to determine amylase enzyme activity in the flour. The Hagberg Falling Number (HFN) Perten Type:1400 system, which meets the requirements of the AACC (American Association of Cereal Chemists) No.56- 81.04, ICC (International Cereal Chemists) No. 107/1 (2010), and PN EN ISO 3093:2010 standards, was used to determine the Falling Number. The OS 1 type equipment by the ISO 7971-3:2019 standard was used to measure test weight. Thousand grain weight and test weight were measured with the KERN EMS and the Sartorius MA-30 precision scales. Farinograph (Valorigraph) instrument had been used to describe baking quality of the dough.

3.6. Statistical analyses

For the statistical evaluation of the results, we used the Explore and ANOVA modules of the IBM SPSS V.23 software. For data analysis, part Independent Sample T Test, ANOVA, and Pearson Correlation Analysis were used to test the hypotheses of the study. The effect of the different treatments on seed germination was analyzed using one-way ANOVA at a 0,05 level of significance. Values are given as the mean ± standard deviation of four measurements. LSD (least significant difference) tests were used to determine the significant difference among the data. The statistical significance level was p<0,05. That enabled us to determine the differences between the studied doses -- whether or not the obtained results had significant variations.

4. RESULTS

4.1. Test Weight Results

Table 4-5 and 6 as well as Figure 24-27 (Appendix 1) provide information on nitrogen application effects on test weight of the tested winter wheat varieties with the impact of undivided/split dose of N supply on two experimental sites during three years. The results obtained from experiment site #1 during first two years of the experiment shown on Table 6, test weight (kg hl^{-1}) values slightly decreased in some of the tested varieties by the increasing level of undivided N application, but the changes found were not significant. In addition, a positive effect of split-dose treatment had been detected, except in case of Mv Nádor 80+40 kg ha^{-1} to 120 kg ha^{-1} N application. The highest result had been recorded for the Alföld 80 kg ha^{-1} single dose application with 81.5 kg hl^{-1} at 2016-2017th experimental year and the lowest for MV Toborzó 80 kg ha^{-1} single dose application with 70.95 kg hl^{-1} at 2016-2017th experimental year. However, split dose N application did not present significant changes among the tested winter wheat varieties, similar results were reported by Pollhamer (1981) and Horváth and co-workers (2014).

Test weight (kg hl^{-1})					
N topdressing	Alföld	MV Nádor	MV Karéj	MV Toborzó	MV Toldi
0+	79.15	75.79	75.57	76.47	77.97
80+	79.17	74.95	75.68	76.19	77.29
80+40	78.86	75.13	77.03	76.49	77.50
120+	78.54	75.13	75.39	76.37	76.81
120+40	79.20	75.36	75.84	76.59	76.83
160+	78.26	74.90	75.57	76.26	76.79

4. Table Impact of N topdressing applications on wheat grain test weight. 2015-2016 and 2016–2017 (Nagygombos, Hungary)

The results obtained from experiment site #2 in the experiment shown on Table 5, were that the test weight (kg hl^{-1}) values slightly decreased in some of the tested varieties via the increasing level of undivided N application, but the changes found were not significant. In addition, a positive effect of split dose treatment was detected. The highest result recorded was for the Alföld 120 kg ha^{-1} single dose application and MV Karéj 80 kg ha^{-1} single dose application with 74.55 kg hl^{-1} at 2018-2019th experimental year, and the lowest was for MV Karéj 40 kg ha^{-1} single dose application as 67.80 kg hl^{-1} at 2018-2019th experimental year.

Test weight (kg hl^{-1})		
N topdressing	**Alföld**	**MV Karéj**
0+	70,73	69,32
80+	72,88	71,10
80+40	73,12	71,55
120+	73,35	71,62
120+40	72,45	69,75
160+	70,80	69,23

5. Table Impact of N topdressing applications on wheat grain test weight. 2018–2019 (Gödöllő, Hungary)

Regarding the study employed during three crop years in two different experimental fields showed that maximum test weight was recorded in both sites was in the Alföld variety with single dose application of the Nitrogen fertilizer. Minimum test weights varied on different sites with different varieties, and the minimum test weights were recorded on single dose applications of Nitrogen fertilizer. Alföld and MV Karéj had higher numbers at Site 1 than Site 2: Alföld 9.19% and MV Karéj 7.70% were the higher values on site 1. Test weight showed significant differences between site, genotype and year; however, level and type of the treatment did not show significant effect from the one-way ANOVA statistical analysis shown on Table 36-54.

The significant level of the difference based on year, site, genotypes and treatment in means of test weight measured in the sample of all genotypes was examined through ANOVA and outcomes were reflected in Table 6.

Test Weight (hl)		N	M	SD	F/t	df	p	Difference
Year	2016	90	76.80	1.75	84.353	2-213	.000	1, 2 > 3
	2017	90	76.52	2.57				
	2019	36	71.33	2.52				
Site	Hatvan	180	76.66	2.20	12.971	214	.000	1 > 2
	Gödöllő	36	71.33	2.52				
Genotypes	Alföld	54	76.63	3.39	10.596	4-211	.000	1 > 2 > 3
	Karéj	54	73.91	3.42				
	Nador	36	75.21	1.00				
	Toborzo	36	76.39	2.09				
	Toldi	36	77.19	2.36				
Treatment	0 kg/ha	36	75.83	3.32	.242	5-210	.943	
	80 kg/ha	36	75.88	3.00				
	80+40 kg/ha	36	76.03	2.82				
	120 kg/ha	36	75.79	2.69				
	120+40 kg/ha	36	75.79	3.07				
	160 kg/ha	36	75.30	3.23				

6. Table Comparison of the Means of Test Weight Parameters Measured in the Sample of All Genotypes Based on Categorical Variables, 2016, 2017 Hatvan and 2019 Gödöllő crop years.

As seen in Table 6, according to the outcomes it is found out that there is no significant difference in statistical level in test weight based on treatment (F(5-210) = .242, p > .05), however, there is a significant difference in statistical level in test weight based on year (F(2-213) = 84.353, p < .001), site (t(214) = 12.971, p < .001) and genotypes (F(4-211) = 10.596, p < .001) in the sample of all genotypes. Accordingly, the mean values of test weight in 2016 and 2017 tend to be higher than in 2019; Hatvan tends to be higher than in Gödöllő. In addition; Alföld and Karej tend to be higher than in Nador; Alföld tends to be higher than in Karej.

4.2. Thousand Kernel Weight Values

Table 7-8-9 as well as Figure 28-31 (Appendix 1) provide information on nitrogen application effects on thousand kernel weight varieties of the tested winter wheat, with the additional impact of an undivided/split-dose of N supply. The results obtained from experiment at site #1 during first two years of the experiment shown on Table 7, the thousand kernel weight value decreased slightly in most of the cases for the increasing undivided/split level of N applications: however, increasing number of N treatments had better effect in the comparison of 80+40 kg ha^{-1} to 120 kg ha^{-1} and 120+40 kg ha^{-1} to 160 kg ha^{-1}, except for Mv Toborzó comparison of 120+40 kg ha^{-1} to 160 kg ha^{-1}. Mv Nádor and Mv Toldi showed significant differences via a one-way ANOVA test of thousand kernel weight. Similar results were reported by Szentpétery and co-workers (2005) and Horváth and co-workers (2014). The highest thousand grain weight was recorded on the untreated (0 kg kg ha^{-1} N) MV Toborzó plot with 51,90 g/thousand kernel weight, and the lowest was detected on an Alföld plot treated with undivided 160 kg ha^{-1} N application resulting 31.40 g/thousand kernel weight.

7. Table Impact of N topdressing applications on thousand kernel weight of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary)

Thousand kernel weight (g/1000 kernel)					
N topdressing	**Alföld**	**MV Nádor**	**MV Karéj**	**MV Toborzó**	**MV Toldi**
0	39.73	44.78	46.70	45.05	45.81
80	38.73	43.16	45.58	42.64	44.20
80+40	38.63	42.79	45.82	42.42	45.07
120	38.56	42.10	45.40	41.44	43.77

120+40	38.83	42.21	45.36	42.40	44.40
160	38.02	41.09	43.78	42.60	42.88

The results obtained from experiment on site #2 during the 2018-2019 experiment shown on Table 8, the thousand kernel weight value increased up to 120 kg/ha^{-1} N undivided, and split application accordingly with a rising level of Nitrogen amount. However, after 80+40 kg/ha^{-1} and 120 kg/ha^{-1} N applications, increasing level of the N supply had a slightly negative effect on the thousand kernel weight at the 120+40 kg/ha^{-1} and 160 kg/ha^{-1} N applications compared to the 80+40 kg/ha^{-1} and 120 kg/ha^{-1}. The highest thousand grain weight was recorded on the 80 kg kg ha^{-1} N MV Karéj plot with 45.08 g/thousand kernel weight, and the lowest was detected on an Alföld plot treated with undivided 80 kg ha^{-1} N application, resulting in 38.00 g/thousand kernel weight.

Thousand kernel weight (g/1000 kernel)		
N topdressing	**Alföld**	**MV Karéj**
0	38,75	40,99
80	39,43	42,22
80+40	40,07	42,45
120	40,53	44,24
120+40	40,37	42,21
160	40,07	41,46

8. Table Impact of N topdressing applications on thousand kernel weight of wheat varieties. 2018-2019 (Gödöllő, Hungary)

Comparing the two sites, Alföld had 2.89% higher numbers at site #2 than site #1, and the MV Karéj had 7.52% higher numbers at site #1 than site #2, however, in general comparison the sites did not have significant differences between each other. Thousand kernel weight showed a significant effect on year and genotype, but no correlation was found with a different dose and type of N applications, as tracked on Table 36-54. The significance level of the difference, based on year, site, genotypes, and treatment in terms of thousand kernel weight measured in the sample of all genotypes, was examined through ANOVA and outcomes were reflected in Table 9.

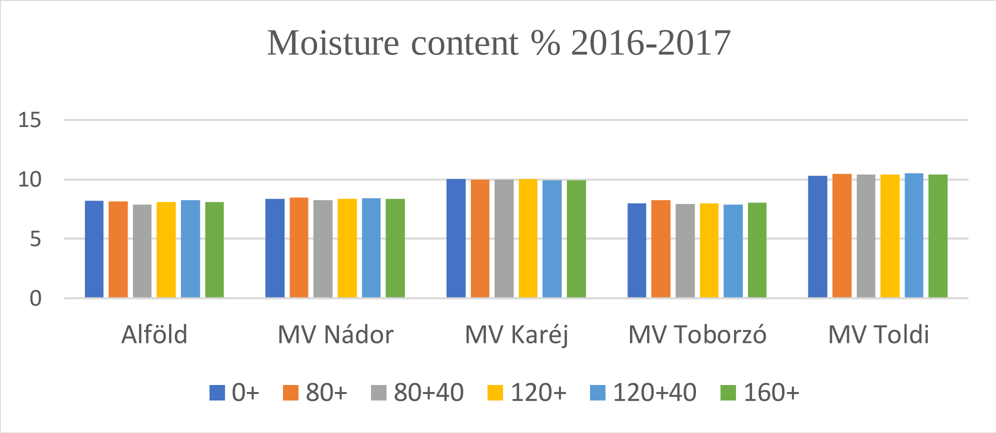
Thousand Kernel Weight (g)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	90	44.53	2.26	30.280	2-213	.000	1 > 2, 3
	2017	90	41.14	4.15				
	2019	36	41.07	2.07				
Site	Hatvan	180	42.84	3.74	2.752	214	.006	1 > 2
	Gödöllő	36	41.07	2.07				
Genotypes	Alföld	54	39.12	2.60	28.322	4-211	.000	2 > 3 > 1
	Karéj	54	44.51	2.45				
	Nádor	36	42.69	2.15				
	Toborzó	36	42.76	4.73				
	Toldi	36	44.35	2.19				
Treatment	0 kg/ha	36	43.66	3.50	1.154	5-210	.333	
	80 kg/ha	36	42.52	3.43				
	80+40 kg/ha	36	42.67	3.64				
	120 kg/ha	36	42.28	3.58				
	120+40 kg/ha	36	42.41	3.59				
	160 kg/ha	36	41.71	3.67				

9. Table Comparison of the Means of Thousand Kernel Weight Parameters Measured in the Sample of All Genotypes Based on Categorical Variables, 2016,2017 Hatvan and 2019 Gödöllő crop years.

As seen in Table 9, the outcomes reveal that there is no significant difference in statistical level in thousand kernel weight based on treatment ($F(5-210) = 1.154$, $p > .05$), however, there is a significant difference in statistical level in thousand kernel weight based on year ($F(2-213) = 30.280$, $p < .001$) and site ($t(214) = 2.752$, $p < .01$), genotypes ($F(4-211) = 28.322$, $p < .001$) in the sample of all genotypes. Accordingly, the mean values of thousand kernel weight in 2016 tend to be higher than in 2017 and 2019; Hatvan tends to be higher than Gödöllő; Karéj tends to be higher than Nádor, which tends to be lower than Alföld.

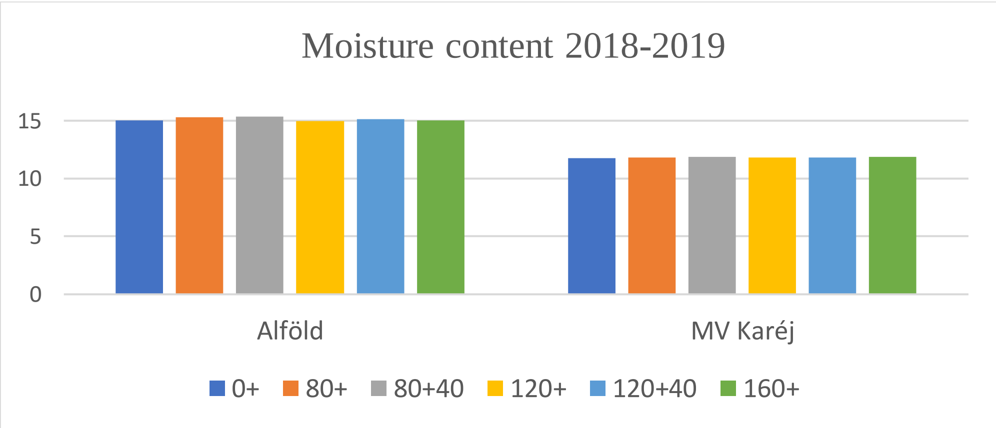
4.3. The grain moisture

Figures 9-10 and Table 10 as well as Table 31-32-32 and Figure 32 (Appendix 1) give information on N application effects on grain moisture content in the studied winter wheat varieties. Figure 19 Shows the experimental site #1's results for 2015-2016 and 2016-2017 crop seasons: the moisture content values slightly increased in some of the tested varieties by increasing the level of divided N application, but the changes found were not significant. However, the highest value was recorded on the untreated plot of MV Toldi with 17.70%, and the lowest result on the MV Nádor 80+40 kg/ha^{-1} N applied plot with 5.30% humidity.



9. Figure Impact of N topdressing applications on moisture content of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary)

Figure 10 shows the experimental site #2's results for the 2018-2019 crop season. Grain moisture content values changes found were not significant, however, and the highest value was recorded on 120+40 kg/ ha^{-1} N applied plot of MV Karéj with 12.70% and the lowest result on Alföld 80 kg/ ha^{-1} N applied plot with 9.00% humidity content.



10. Figure Impact of N topdressing applications on moisture content of wheat varieties. 2018-2019 (Gödöllő, Hungary)

Comparing the two sites, site #2 had higher grain moisture content for both varieties, Alföld had 86.33% and MV Karéj 18.30% more moisture content at site #2 than site #1; however, results showed significant differences between year, site, and genotype via the one-way ANOVA test of moisture content. But that moisture content ($F_{(5.102)}$ = .253, $p > .05$) did not have significant effect due to different dose and application type of N applications, as is shown on Table 36-54.

The significance level of the difference based on year, site, genotypes and treatment in terms of moisture content measured in the sample of all genotypes was examined through ANOVA and outcomes were reflected in Table 10.

Moisture Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	90	8.19	1.66	59.097	2-213	.000	3 > 2 > 1
	2017	90	9.77	0.61				
	2019	36	10.57	1.32				
Site	Hatvan	180	8.98	1.48	-6.009	214	.000	2 > 1
	Gödöllő	36	10.57	1.32				
Genotypes	Alföld	54	8.56	1.50	46.976	4-211	.000	2 > 1
	Karéj	54	10.55	1.02				
	Nádor	36	8.37	1.52				
	Toborzó	36	8.01	0.79				
	Toldi	36	10.42	0.23				
Treatment	0 kg/ha	36	9.18	1.52	.063	5-210	.997	
	80 kg/ha	36	9.26	1.46				
	80+40 kg/ha	36	9.16	1.62				
	120 kg/ha	36	9.24	1.58				
	120+40 kg/ha	36	9.33	1.64				
	160 kg/ha	36	9.30	1.67				

10. Table Comparison of the Means of Moisture Content Parameters Measured in the Sample of All Genotypes Based on Categorical Variables, 2016 and 2017 Hatvan and 2019 Gödöllő crop years.

As seen in Table 10, the outcomes reveal that there is no significant difference in statistical level in moisture content based on treatment (F(5-210) = .063, p > .05); however, there is a significant difference in statistical level in moisture content based on year (F(2-213) = 59.097, p < .001), site (t(214) = -6.009, p < .001) and genotypes (F(4-211) = 46.976, p < .001) in the sample of all genotypes. Accordingly, the mean values of moisture content in 2018-2019 tend to be higher than in 2016-2017, which tends to be higher than in 2015-2016; Gödöllő tends to be higher than Hatvan, and Karéj tends to be higher than Alföld.

4.4. The grain protein

Table 11-16 and Figure 11-12 as well as Table 34-35 and Figure 33-34-35 (Appendix 1) show the grain protein values in site #1 in 2015-2016, 2016-2017 and site #2 in 2018-2019 crop years. Protein amounts changed from 6.86% to 17.33 %.

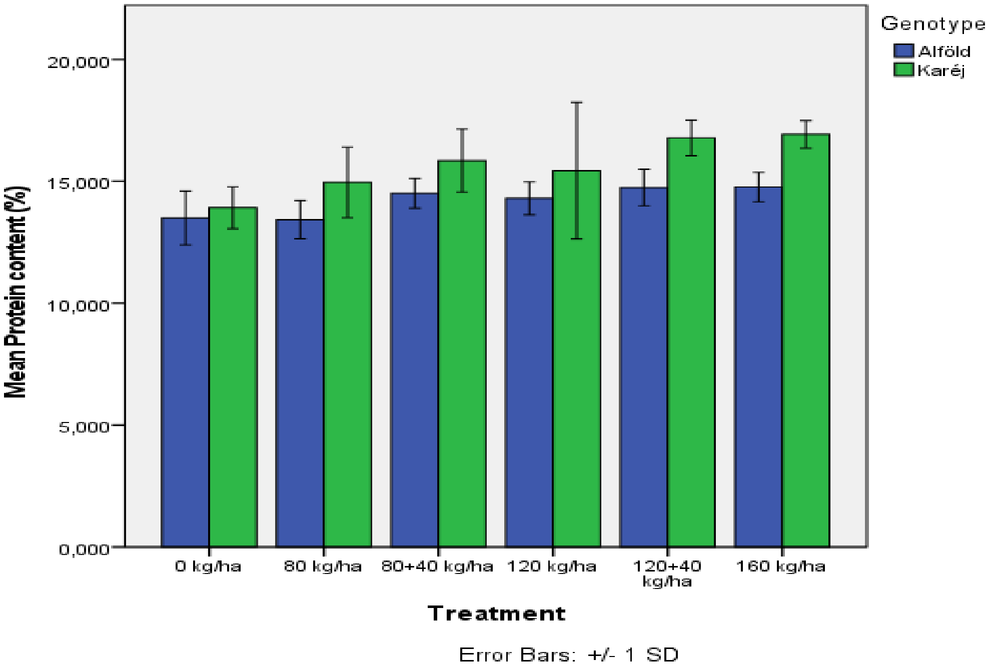
Protein content % 2015-2016 and 2016–2017					
N	**Alföld**	**MV Nádor**	**MV Karéj**	**MV Toborzó**	**MV Toldi**
0	13,36	11,56	11,15	11,94	12,17
80	14,24	12,48	12,55	12,91	13,40
80+40	15,19	12,96	13,35	13,49	13,56
120	15,50	13,28	13,40	13,68	13,71
120+40	15,43	13,61	14,10	14,27	14,18
160	15,89	13,96	14,35	14,45	14,36

11. Table Impact of N topdressing applications on protein content of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary)

Protein content % 2018–2019		
N	**Alföld**	**MV Karéj**
0	13,60	13,80
80	13,00	15,20

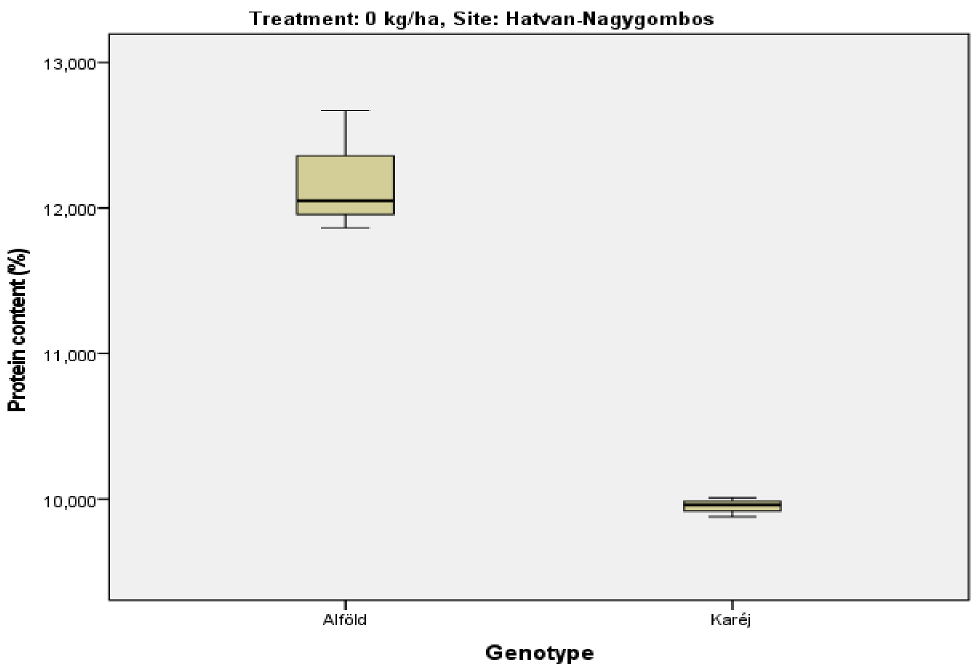
80+40	13,40	15,90
120	13,30	15,50
120+40	14,10	17,20
160	13,80	16,90

12. Table Impact of N topdressing applications on protein content of wheat varieties. 2018–2019 (Gödöllő, Hungary)



11. Figure Impact of N topdressing applications on protein content of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary) and 2018-2019 (Gödöllő, Hungary) combined

Based on the results of the experiment, we can conclude that increasing levels of N topdressing had a significant effect on grain protein content in all studied winter wheat varieties, either in split or undivided dose applications. The results obtained are in harmony with Dubetz et al., (1979), Pollhamer (1981), Vida et al., (1996), Varga and Svecnjak (2006), Öztürk and Gökkuş (2008), and Pepó (2010) studies. There were varietal differences, too, as untreated plots had remarkable differences between varieties such as 2016-2017 crop seasons of untreated Alföld and MV Karéj’s plots showing 32.63% differences shown on Figure 12 boxplot. A special increase in dose applications had a remarkable effect in the experimental year 2017. The highest 17.33% grain protein content was observed on the Alföld plot with split 120+40 kg ha^{-1} N application at site one 2015-2016 crop season and the lowest, 6.86 %, was obtained on Karéj untreated plot at site #1's 2016-2017 crop season. Split dose application did not have a significant effect compared to the same total amount of undivided application; however, sites had significant effect under identical agronomical treatments. Alföld had up to 10.30% differences between the two sites regarding grain protein content, and MV Karéj plots had 19.80% greater results in the general average of grain protein content of the tested MV Karéj plots. The MV Karéj have shown greater results on site #2 compared to site #1, except for the 80 and 120 kg ha^{-1} N single dose application according to One Way ANOVA statistics.



12. Figure Impact of N topdressing applications on protein content of wheat varieties untreated plots. 2015-2016 and 2016–2017 (Nagygombos, Hungary)

As seen in Table 36-54 (Appendix 1) the outcomes reveal that there is a significant difference in the statistical levels of grain protein content between trial years ($F_{(2.105)}$ = 8.829, $p < .001$), site ($t_{(106)}$ = -2.885, $p < .01$), genotype (t(87.225) = 2.094, $p < .05$) and the treatment ($F_{(5.102)}$ = 10.238, $p < .001$).

The significance level of the difference based on year, site, genotypes, and treatment by means of protein content measured in the sample of all genotypes was examined through ANOVA and outcomes were reflected in Table 13.

Protein Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	90	14.12	1.12	25.938	2-213	.000	3 > 1 > 2
	2017	90	13.08	1.60				
	2019	36	14.93	1.48				
Site	Hatvan	180	13.60	1.47	-4.946	214	.000	2 > 1
	Gödöllő	36	14.93	1.48				
Genotypes	Alföld	54	14.63	1.17	8.426	4-211	.000	1 > 2 > 3
	Karéj	54	13.99	1.94				
	Nador	36	12.95	1.01				
	Toborzo	36	13.46	1.62				
	Toldi	36	13.60	1.13				
Treatment	0 kg/ha	36	12.24	1.57	18.050	5-210	.000	2, 3, 4, 5, 6 > 1; 4, 5, 6 > 2; 5, 6 > 3; 6 > 4
	80 kg/ha	36	13.33	1.22				
	80+40 kg/ha	36	13.93	1.43				
	120 kg/ha	36	14.07	1.28				
	120+40 kg/ha	36	14.56	1.23				
	160 kg/ha	36	14.80	1.08				

13. Table Comparison of the Means of Protein Content Parameters Measured in the Sample of All Genotypes Based on Categorical Variables, 2016,2017 Hatvan and 2019 Gödöllő crop years.

As seen in Table 13, outcomes revealed that there is a significant difference in statistical level in protein content based on year (F(2-213) = 25.938, p < .001), site (t(214) = -4.946, p < .001), genotypes (F(4-211) = 8.426, p < .001) and treatment (F(5-210) = 18.050, p < .001) in the sample of all genotypes. Accordingly, the mean values of protein content in 2018-2019 tend to be higher than in 2015-2016 tend to be higher than in 2016-2017; Gödöllő tends to be higher than in Hatvan; Alföld tends to be higher than in Karéj, which tends to be higher than in Nádor. 2, 3, 4, 5 and 6 tend to be higher than in 1; 4, 5 and 6 tend to be higher than in 2; 5 and 6 tend to be higher than in 3; and 6 tends to be higher than in 4.

The significance level of the difference, based on genotypes and treatment by means of protein content measured in the sample of all genotypes in 2015-2016, was examined through ANOVA and outcomes were reflected in Table 14.

Protein Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Genotypes	Alföld	18	15.14	1.02	13.004	4-85	.000	1 > 2, 3, 5; 3, 4 > 2; 4 > 3, 5
	Karéj	18	13.93	1.06				
	Nádor	18	13.24	0.96				
	Toborzó	18	14.64	0.76				
	Toldi	18	13.64	0.62				
Treatment	0 kg/ha	15	12.92	0.83	11.433	5-84	.000	3, 4, 5, 6 > 1, 2; 5 > 4
	80 kg/ha	15	13.48	0.90				
	80+40 kg/ha	15	14.44	1.06				
	120 kg/ha	15	14.20	0.75				
	120+40 kg/ha	15	14.91	0.94				
	160 kg/ha	15	14.76	0.80				

14. Table Comparison of the Means of Protein Content Parameters Measured in the Sample of All Genotypes in 2016, Based on Categorical Variables, Hatvan site.

As seen in Table 14, according to the outcomes it is found out that there is a significant difference in statistical level in protein content based on genotypes (F(4-85) = 13.004, p < .001) and treatment (F(5-84) = 11.433, p < .001) in the sample of all genotypes in 2015-2016. Accordingly, the mean values of protein content in Alföld tend to be higher than in Karéj, Nádor and Toldi, Nádor and Toborzó tend to be higher than in Karéj, Toborzó tends to be higher than in Nádor and Toldi; 3, 4, 5 and 6 tend to be higher than in 1 and 2; and 5 tends to be higher than in 4.

The significance level of the difference, based on genotypes and treatment in terms of protein content measured in the sample of Alföld and Karéj genotypes in Gödöllő in 2018-2019, was examined through Independent Samples t-Test and outcomes were reflected in Table 15.

Protein Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Genotypes	Alföld	18	14.21	0.86	-3.285	34	.002	2 > 1
	Karéj	18	15.65	1.64				
Treatment	0 kg/ha	6	13.71	0.92	2.370	5-30	.063	
	80 kg/ha	6	14.20	1.34				
	80+40 kg/ha	6	15.18	1.17				
	120 kg/ha	6	14.88	1.93				
	120+40 kg/ha	6	15.77	1.30				
	160 kg/ha	6	15.85	1.29				

15. Table Comparison of the Means of Protein Content Parameters Measured in the Sample of Alföld and Karéj Genotypes in Gödöllő in 2019, Based on Categorical Variables, Gödöllő site.

As seen in Table 15, the outcomes revealed that there is no significant difference in statistical level in protein content based on treatment (F(5-30) = 2.370, p > .05), however, there is a significant difference in statistical level in protein content based on genotypes (t(34) = -3.285, p < .01) in the sample of Alföld and Karéj genotypes in Gödöllő in 2018-2019. Accordingly, the mean values of protein content in Karéj tend to be higher than in Alföld.

The significance level of the difference, based on year, site and treatment in terms of protein content measured in the sample of Karéj genotype, was examined through ANOVA and outcomes were reflected in Table 16.

Protein Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	18	13.93	1.06	23.524	2-51	.000	3 > 1 > 2
	2017	18	12.39	1.51				
	2019	18	15.65	1.64				
Site	Hatvan	36	13.16	1.50	-5.561	52	.000	2 > 1
	Gödöllő	18	15.65	1.64				
Treatment	0 kg/ha	9	12.09	1.91	4.060	5-48	.004	3, 4, 5, 6 > 1; 5, 6 > 2
	80 kg/ha	9	13.35	1.66				
	80+40 kg/ha	9	14.17	1.80				
	120 kg/ha	9	14.10	1.84				
	120+40 kg/ha	9	15.01	1.58				
	160 kg/ha	9	15.21	1.43				

16. Table Comparison of the Means of Protein Content Parameters Measured in the Sample of Karej Genotype Based on Categorical Variables

As seen in Table 16, outcomes revealed that there is a significant difference in statistical level in protein content based on year ($F(2-51) = 23.524$, $p < .001$), site ($t(52) = -5.561$, $p < .001$) and treatment ($F(5-48) = 4.060$, $p < .01$) in the sample of Karéj genotype. Accordingly, the mean values of protein content in 2018-2019 is higher than 2015-2016, and 2015-2016 is higher than 2016-2017; Gödöllő tends to be higher than in Hatvan; 3, 4, 5 and 6 tend to be higher than in 1; and 5 and 6 tend to be higher than in 2.

4.5. The gluten content

Gluten content %

N	Alföld	MV Nádor	MV Karéj	MV Toborzó	MV Toldi
0	27,41	24,98	21,20	25,11	24,31
80	31,84	27,89	25,75	28,01	28,18
80+40	34,48	29,71	28,40	30,34	28,81
120	35,16	30,33	28,65	31,27	28,06
120+40	35,28	30,58	30,35	31,99	30,44
160	36,37	32,36	31,65	33,31	31,45

17. Table Impact of N topdressing applications on gluten content of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary)

Gluten content %		
N	**Alföld**	**MV Karéj**
0	25,50	28,60
80	23,80	32,70
80+40	23,50	34,90
120	24,30	34,20
120+40	26,50	39,40
160	25,80	38,10

18. Table Impact of N topdressing applications on gluten content of wheat varieties. 2018–2019 (Gödöllő, Hungary)

Grain gluten amounts changed from 10.00 % to 41.10 %. The highest value was observed on the MV Karéj plot with split 120+40 kg ha^{-1} N application as 41.10% and the lowest, 10.00 %, had been obtained on MV Karéj untreated plot. Grain gluten content was significantly affected by increasing doses of N applications as well with increased split dose applications. Similar examples have been reported by several authors (Győri, 2006; Kismányoky and Tóth, 2010; Rakszegi et al., 2016). Table 17-18-19-20-21-22 as well as Figure 36-40 (Appendix 1) show strong effect of N application on grain gluten content regardless of crop year, variety, or split/undivided application. Alföld had up to 34.22% differences between two sites in terms of grain gluten content, and MV Karéj plots had 25.23% higher results in the general average of protein content of the tested MV Karéj plots between two experimental sites. In addition, split dose application did not have significant effect on grain gluten content compared to the same amount of undivided application.

The significance level of the difference based on year, site, genotypes and treatment, in terms of gluten content measured in the sample of all genotypes, was examined through ANOVA and outcomes were reflected in Table 19.

Gluten Content (%)		N	M	SD	F/t	df	p	Difference
Year	2016	90	30.73	3.66	24.209	2-213	.000	3 > 1 > 2
	2017	90	28.85	4.65				
	2019	36	34.52	3.90				
Site	Hatvan	180	29.79	4.28	-6.141	214	.000	2 > 1
	Gödöllő	36	34.52	3.90				
Genotypes	Alföld	54	34.12	3.42	14.093	4-211	.000	1 > 2, 3
	Karéj	54	29.62	5.23				
	Nádor	36	29.30	3.01				
	Toborzó	36	30.01	4.43				
	Toldi	36	28.55	3.62				
Treatment	0 kg/ha	36	25.70	5.06	21.138	5-210	.000	2, 3, 4, 5, 6 > 1; 3, 4, 5, 6 > 2; 5, 6 > 3; 6 > 4
	80 kg/ha	36	29.00	3.38				
	80+40 kg/ha	36	31.01	3.62				
	120 kg/ha	36	31.26	3.40				
	120+40 kg/ha	36	32.78	3.84				
	160 kg/ha	36	33.72	2.93				

19. Table Comparison of the Means of Gluten Content Parameters Measured in the Sample of All Genotypes Based on Categorical Variables

As seen in Table 19, outcomes revealed that there is a significant difference in statistical level in gluten content based on year (F(2-213) = 24.209, p < .001), site (t(214) = -6.141, p < .001), genotypes (F(4-211) = 14.093, p < .001) and treatment (F(5-210) = 21.138, p < .001) in the sample of all genotypes. Accordingly, the mean values of gluten content in 2018-2019 tend to be higher than in 2015-2016, which tend to be higher than in 2017. Gödöllő tends to be higher than Hatvan; Alföld tends to be higher than in Karéj and Nádor; 2, 3, 4, 5 and 6 tend to be higher than in 1; 3, 4, 5 and 6 tend to be higher than in 2; 5 and 6 tend to be higher than in 3, and 6 tends to be higher than in 4.

The significance level of the difference based on genotypes and treatment, in terms of gluten content measured in the sample of all genotypes in 2016, was examined through ANOVA and outcomes were reflected in Table 20.

Gluten Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Genotypes	Alföld	18	34.24	3.15	17.043	4-85	.000	1 > 2, 3, 5; 4 > 2; 4 > 3; 3, 4 > 5
	Karéj	18	28.71	3.29				
	Nádor	18	30.23	2.78				
	Toborzó	18	32.71	2.50				
	Toldi	18	27.75	2.04				
Treatment	0 kg/ha	15	26.60	2.78	11.632	5-84	.000	3, 4, 5, 6 > 1, 2
	80 kg/ha	15	28.75	3.01				
	80+40 kg/ha	15	31.99	3.14				
	120 kg/ha	15	31.16	2.57				
	120+40 kg/ha	15	32.94	3.04				
	160 kg/ha	15	32.94	2.80				

20. Table Comparison of the Means of Gluten Content Parameters Measured in the Sample of All Genotypes in 2016 Based on Categorical Variables

As seen in Table 20, outcomes revealed that there is a significant difference in statistical level in gluten content based on genotypes (F(4-85) = 17.043, p < .001) and treatment (F(5-84) = 11.632, p < .001) in the sample of all genotypes in 2016. Accordingly, the mean values of gluten content in Alföld tend to be higher than in Karéj, Nádor and Toldi, Toborzó tends to be higher than in Karéj, Toborzó tends to be higher than in Nádor, and Nádor and Toborzó tend to be higher than in Toldi. 3, 4, 5 and 6 tend to be higher than in 1 and 2.

The significance level of the difference based on year and treatment, in terms of gluten content measured in the sample of Toldi genotype, was examined through Independent Samples t-Test and outcomes were reflected in Table 21.

Gluten Content (%)		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	18	27.75	2.04	-1.345	34	.188	
	2017	18	29.36	4.64				
Treatment	0 kg/ha	6	24.32	3.67	3.928	5-30	.007	3, 5, 6 > 1
	80 kg/ha	6	28.21	3.26				
	80+40 kg/ha	6	28.83	2.54				
	120 kg/ha	6	28.08	3.27				
	120+40 kg/ha	6	30.45	2.54				
	160 kg/ha	6	31.44	2.80				

21. Table Comparison of the Means of Gluten Content Parameters Measured in the Sample of Toldi Genotype Based on Categorical Variables

As seen in Table 21, outcomes revealed that there is no significant difference in statistical level in gluten content based on year (t(34) = -1.345, p > .05), however, there is a significant difference in statistical level in gluten content based on treatment (F(5-30) = 3.928, p < .01) in the sample of Toldi genotype. Accordingly, the mean values of gluten content in 3, 5 and 6 tend to be higher than in 1.

The significance level of the difference based on genotypes and treatment, in terms of gluten content measured in the sample of Alföld and Karéj genotypes in Gödöllő in 2018-2019, was examined through Independent Samples t-Test and outcomes were reflected in Table 22.

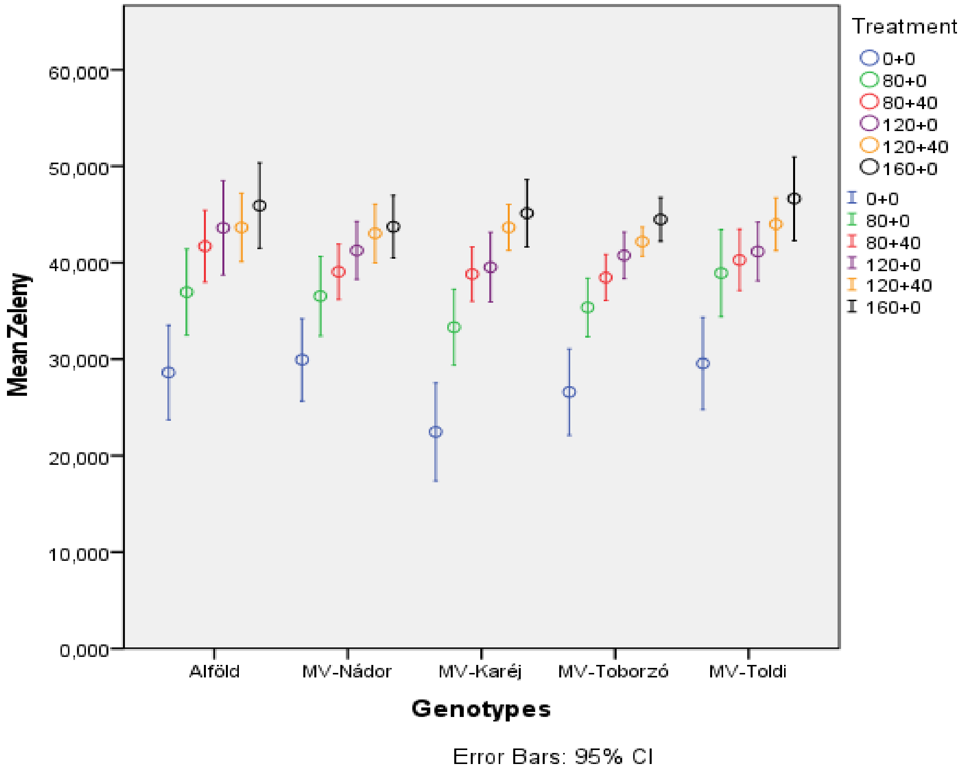
Gluten Content (%)	**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**

Genotypes	Alföld	18	35.53	2.37	1.589	34	.121	
	Karéj	18	33.51	4.85				
Treatment	0 kg/ha	6	31.25	5.57	3.884	5-30	.008	5, 6 > 1, 2, 3; 5 > 4
	80 kg/ha	6	32.27	3.22				
	80+40 kg/ha	6	34.34	1.90				
	120 kg/ha	6	34.12	3.29				
	120+40 kg/ha	6	37.95	2.11				
	160 kg/ha	6	37.18	2.07				

22. Table Comparison of the Means of Gluten Content Parameters Measured in the Sample of Alföld and Karéj Genotypes in Gödöllő in 2019 Based on Categorical Variables

As seen in Table 22, according to the outcomes it is found out that there is no significant difference in statistical level in gluten content based on genotypes ($t(34) = 1.589$, $p > .05$); however, there is a significant difference in statistical level in gluten content based on treatment ($F(5\text{-}30) = 3.884$, $p < .01$) in the sample of Alföld and Karéj genotypes in Gödöllő in 2018-2019. Accordingly, the mean values of gluten content in 5 and 6 tend to be higher than in 1, 2 and 3; 5 tends to be higher than in 4.

4.6. The Zeleny number (ml)



13. Figure Impact of N topdressing applications on Zeleny Nr. of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary) 1

Zeleny Nr/mL					
N	**Alföld**	**MV Nádor**	**MV Karéj**	**MV Toborzó**	**MV Toldi**
0	28,64	29,93	23,60	26,60	29,56
80	36,95	36,54	33,30	35,39	35,13
80+40	41,71	39,06	38,80	38,45	35,69
120	43,64	41,29	39,55	40,79	36,44
120+40	43,64	43,01	43,70	42,17	38,28
160	45,90	43,75	45,10	44,50	41,14

23. Table Impact of N topdressing applications on Zeleny Nr. of wheat varieties. 2015-2016 and 2016–2017 (Nagygombos, Hungary) 2

Zeleny Nr/mL		
N	**Alföld**	**MV Karéj**
0	38,50	41,10
80	37,60	50,80
80+40	35,60	55,40
120	35,90	51,90
120+40	42,70	60,70
160	41,30	58,90

24. Table Impact of N topdressing applications on Zeleny Nr. of wheat varieties. 2015-2016 and 2018–2019 (Gödöllő, Hungary)

The significance level of the difference based on year in terms of parameters was examined through ANOVA and outcomes were reflected in Figure 13 and Table 23-28 as well as Table 36-54 (Appendix 1)

As seen in Table 36-54 (Appendix 1), outcomes revealed that there is a significant difference in statistical level in Zeleny number ($F_{(2.105)}$ = 18.886, $p < .001$) based on year, (t(103.445) = 3.234, $p < .01$) based on site and ($F_{(5.102)}$ = 13.148, $p < .001$) based on treatment. However, no significance ($t_{(106)}$ = 1.635, $p > .05$) based on genotypes.

The significance level of the difference based on year, site, genotypes and treatment, in terms of Zeleny number measured in the sample of all genotypes, was examined through ANOVA and outcomes were reflected in Table 25.

Zeleny Number		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	90	35.05	6.04	31.764	2-213	.000	2, 3 > 1
	2017	90	42.68	8.80				
	2019	36	45.88	10.12				
Site	Hatvan	180	38.87	8.44	-4.391	214	.000	2 > 1
	Gödöllő	36	45.88	10.12				
Genotypes	Alföld	54	39.59	8.59	1.672		.158	

	Karéj	54	42.55	11.45				
	Nádor	36	38.93	7.62		4-211		
	Toborzó	36	37.98	7.41				
	Toldi	36	40.10	8.39				
	0 kg/ha	36	29.59	8.82				
	80 kg/ha	36	37.56	7.49				
	80+40 kg/ha	36	40.65	6.78				
Treatment	120 kg/ha	36	41.71	6.91	23.141	5-210	.000	2, 3, 4, 5, 6 > 1; 4, 5, 6 > 2; 5, 6 > 3; 6 > 4
	120+40 kg/ha	36	44.71	6.58				
	160 kg/ha	36	46.00	7.58				

25. Table Comparison of the Means of Zeleny Nr. Parameters Measured in the Sample of All Genotypes Based on Categorical Variables

As seen in Table 25, outcomes revealed that there is no significant difference in the statistical level in Zeleny number based on genotypes (F(4-211) = 1.672, p > .05); however, there is a significant difference in statistical level in Zeleny number based on year (F(2-213) = 31.764, p < .001), site (t(214) = -4.391, p < .001) and treatment (F(5-210) = 23.141, p < .001) in the sample of all genotypes. Accordingly, the mean values of Zeleny number in 2016-2017 and 2018-2019 tend to be higher than in 2015-2016; Gödöllő tends to be higher than in Hatvan; 2, 3, 4, 5 and 6 tend to be higher than in 1; 4, 5 and 6 tend to be higher than in 2; 5 and 6 tend to be higher than in 3; and 6 tends to be higher than in 4.

The significance level of the difference based on genotypes and treatment, in terms of Zeleny number measured in the sample of Alföld and Karéj genotypes in Gödöllő in 2018-2019, was examined through Independent Samples t-Test and outcomes were reflected in Table 26.

Zeleny Number		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Genotypes	Alföld	18	38.61	6.26		34	.000	2 > 1

	Karéj	18	53.14	7.75	-6.188			
Treatment	0 kg/ha	6	39.78	8.35	1.148	5-30	.357	
	80 kg/ha	6	44.23	8.03				
	80+40 kg/ha	6	45.52	11.59				
	120 kg/ha	6	43.88	9.99				
	120+40 kg/ha	6	51.72	10.56				
	160 kg/ha	6	50.12	11.06				

26. Table Comparison of the Means of Zeleny Nr. Parameters Measured in the Sample of Alföld and Karéj Genotypes in Gödöllő in 2019 Based on Categorical Variables

As seen in Table 26, outcomes revealed that there is no significant difference in statistical level in Zeleny number based on treatment (F(5-30) = 1.148, p > .05), however, there is a significant difference in statistical level in Zeleny number based on genotypes (t(34) = -6.188, p < .001) in the sample of Alföld and Karej genotypes in Gödöllő in 2018-2019. Accordingly, the mean values of zeleny number in Karéj tend to be higher than in Alföld.

The significance level of the difference based on genotypes and treatment, in terms of Zeleny number measured in the sample of Alföld and Karéj genotypes in 2015-2016, was examined through Independent Samples t-Test and outcomes were reflected in Table 27.

Zeleny Number		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Genotypes	Alföld	18	33.24	6.54	-.754	34	.456	2 > 1
	Karéj	18	34.99	7.40				
Treatment	0 kg/ha	6	22.97	3.05	18.143	5-30	.000	2, 3, 4, 5, 6 > 1; 3, 4, 5, 6 > 2; 5 > 4
	80 kg/ha	6	30.02	4.54				

	80+40 kg/ha	6	37.01	4.94				
	120 kg/ha	6	35.54	2.89				
	120+40 kg/ha	6	40.06	3.49				
	160 kg/ha	6	39.08	3.01				

27. Table Comparison of the Means of Zeleny Nr. Parameters Measured in the Sample of Alföld and Karéj Genotypes in 2016 Based on Categorical Variables

As seen in Table 27, outcomes revealed that there is no significant difference in statistical level in Zeleny number based on genotypes ($t(34) = -.754$, $p > .05$); however, there is a significant difference in statistical level in Zeleny number based on treatment ($F(5-30) = 18.143$, $p < .001$) in the sample of Alföld and Karéj genotypes in 2016. Accordingly, the mean values of Zeleny number in Karéj tend to be higher than in Alföld; 2, 3, 4, 5 and 6 tend to be higher than in 1; 3, 4, 5 and 6 tend to be higher than in 2; and 5 tends to be higher than in 4.

The significance level of the difference based on year, site and treatment, in terms of Zeleny number measured in the sample of Karéj genotype, was examined through ANOVA and outcomes were reflected in Table 28.

Zeleny Number		**N**	**M**	**SD**	**F/t**	**df**	**p**	**Difference**
Year	2016	18	34.99	7.40	21.924	2-51	.000	3 > 1, 2
	2017	18	39.51	10.25				
	2019	18	53.14	7.75				
Site	Hatvan	36	37.25	9.10	-6.338	52	.000	2 > 1
	Gödöllő	18	53.14	7.75				
Treatment	0 kg/ha	9	29.05	11.20	5.969	5-48	.000	3, 4, 5, 6 > 1; 5, 6 > 2
	80 kg/ha	9	39.16	10.25				
	80+40 kg/ha	9	44.36	9.23				
	120 kg/ha	9	43.65	7.79				

	120+40 kg/ha	9	49.36	9.09				
	160 kg/ha	9	49.72	8.75				

28. Table Comparison of the Means of Zeleny Nr. Parameters Measured in the Sample of Karéj Genotype Based on Categorical Variables

As seen in Table 28, outcomes revealed that there is significant difference in statistical level in Zeleny number based on year ($F(2-51) = 21.924$, $p < .001$), site ($t(52) = -6.338$, $p < .001$) and treatment ($F(5-48) = 5.969$, $p < .001$) in the sample of Karéj genotype. Accordingly, the mean values of Zeleny number in 2019 tend to be higher than in 2015-2016 and 2016-2017; Gödöllő tends to be higher than in Hatvan; 3, 4, 5 and 6 tend to be higher than in 1; and 5 and 6 tend to be higher than in 2.

5. CONCLUSION AND RECOMMENDATIONS

- Test weight measurements showed no significant differences by different dose and divided amounts of nitrogen fertilizer applications. However, year, site and genotype showed significant differences on test weight results of tested winter wheat species. Alföld and Karéj species had greater results both on sites and years.

- Thousand kernel weight measurements showed no significant differences by different dose and divided amount of nitrogen fertilizer applications. However, year, site and genotype showed significant differences on thousand kernel weight results of tested winter wheat species. Hatvan site had greater results compared to Gödöllő.

- The grain moisture measurements showed no significant differences by different dose and divided amounts of nitrogen fertilizer applications. However, year, site and genotype showed significant differences on grain moisture results of tested winter wheat species. Alföld and Karéj species had greater results both on sites and years. The Gödöllő site had greater results compared to Hatvan.

- The grain protein measurements showed significant effect on all studied years, sites, genotypes and treatment parameters. 2018-2019 was the leading year and the Gödöllő site had higher figures than Hatvan. The Alföld variety showed the best performance while Karéj was the second good performer among the five studied winter wheat varieties. Apart from this, the general results wherein all the years, sites and varieties were measured, showed the increased level of Nitrogen fertilizer supply caused an increase in the grain protein content (where no species, year sites separated). However, division of the given amounts of the nitrogen fertilizer did not have significant effect on tested winter wheat varieties. On the other hand, those at the Hatvan site's 2015-2016-year trials regarding all varieties and 2018-2019-year 80+40 kg/ha divided application, compared to 120 kg/ha un-divided applications, as well as the Karéj's 80+40 kg/ha compared to 120 kg/ha applications, showed that while increasing doses of the nitrogen fertilizer supply shows significant effect, divided doses of the nitrogen fertilizer showed greater effect compared to same amounts un-divided applications. Therefore, 80+40 kg/ha N application is recommended.

- The grain gluten measurements showed significant effect on all studied year, site, genotype and treatment parameters. 2018-2019 was the leading crop year as well as the Gödöllő site had greater figures than Hatvan. Alföld variety showed the best performance among the five studied winter wheat varieties. Apart from this, the general results wherein all the years, sites and varieties that were measured, showed that the increased level of Nitrogen fertilizer supply caused an increase in the grain protein content. However, division of the given amounts of the nitrogen fertilizer did not have a significant effect on tested winter wheat varieties. On the other hand, those at the Hatvan site's 2015-2016- crop year trials and Toldi varieties, and Hatvan's site trials results of 80+40 kg/ha divided application compared to 120 kg/ha un-divided applications, showed that while increasing doses of the nitrogen fertilizer supply shows significant effect, divided doses of the nitrogen fertilizer showed greater effect compared to the same amounts in undivided applications.

- The Zeleny number measurements showed significant effect on all studied years, sites, genotypes and treatment parameters. 2018-2019 was the leading year, and the Gödöllő site had higher figures than Hatvan. The Karéj variety showed the best performance among the five studied winter wheat varieties. Apart from that, the general results wherein all the years, sites and varieties that were measured, showed that the increased level of Nitrogen fertilizer supply caused an increase to the Zeleny number; however, division of the given amounts of the nitrogen fertilizer did not have significant effect on the tested winter wheat varieties. On the other hand, those in the Hatvan site 2015-2016-year trials, the Gödöllő site 2018-2019-year trials' results, and the Karéj varieties measurement of 80+40 kg/ha divided application compared to 120 kg/ha un-divided applications, and the 120+40 kg/ha divided applications compared to 160 kg/ha un-divided applications showed that, while increasing doses of the nitrogen fertilizer supply shows significant effect, divided doses of the nitrogen fertilizer showed greater effect compared to the same amounts in un-divided applications.

6. NEW SCIENTIFIC RESULTS

1- Measurements of this experiment proved that increasing amounts of Nitrogen fertilizer application raised the protein content of the tested winter varieties; however, 80+40 kg/ha Nitrogen fertilization was even more remarkable and recommended.

2- The Gödöllő site and Alföld variety showed the best results comparing the sites and the tested winter wheat varieties, in regard to the grain gluten content. While the grain gluten content increased with higher amounts of Nitrogen fertilizer applications, increasing the level of the Nitrogen application did not affect the result significantly.

3- By analyzing the Zeleny number of the chosen winter wheat varieties, results showed that the Karéj variety was significantly affected by split-dose application of Nitrogen fertilizer; however, all the varieties of Zeleny numbers rose with the increasing amount of N application.

4- All the tested winter wheat varieties showed significant differences, comparing all the measurement parameters (Zeleny number, Grain protein content, Grain gluten content, Test weight, Thousand kernel weight and Grain moisture) by site, genotype, and year.

7. PUBLICATIONS

1. Eser A. (2017): “Storage proteins in wheat (*Triticum aestivum L.*) and impact of mycotoxins affecting quality and quantity, with focus on nitrogen supply.*” Collumela Journal of Agricultural and Environmental Sciences.* 299. DOI: 10.18380/SZIE.COLUM.2017.4.1.suppl.

2. Eser A. – Kassai M.K. – Tarnawa Á. – Nyárai H.F. – Horváth Cs. – Jolánkai M. (2017): „Impact of nitrogen topdressing on the quality and quantity of wheat yield varieties.” *Georgikon for Agriculture* 21. 1. 109-113 pp.
3. Eser A. – Kassai M.K. – Tarnawa Á. – Nárai H.F. – Jolánkai M. (2017): „Impact of crop year and nitrogen topdressing on the quantity and quality of wheat yield.” *Columella 4.1. Suppl.* 157-162 pp.
4. Eser A. (2018): "Impact of nitrogen topdressing on the quality and quantity parameters of yield and grain protein of wheat (*Triticum aestivum L.*)." *17th Alps Adria Scientific Workshop, Hnanice, Czech Republic.* 144-145 pp. ISBN 978-963-269-734-5
5. Eser A., Kato H., Kempf L., Nyarai F., Kunos V., Szentpetery Z. (2019): "A world alimentation chance estimate based on protein production of crop species." *Columella - Journal of Agricultural and Environmental Sciences Vol. 6, No. 1* (2019) DOI: 10.18380/SZIE.COLUM.2019.6.35
6. Eser A., Kató H., Kempf L., Jolánkai M. (2019): "Water footprint of yield protein content of twelve field crop species on a Hungarian crop site." *Agrokémia és Talajtan – Agrochemistry and Soil Science.* 1-8. DOI: 10 1556/0088.2019.00041
7. Eser A. (2019): "Impact of nitrogen topdressing on the quality and quantity parameters of yield and grain protein of wheat (*Triticum aestivum L.*)." (2019) *Abstract book of the 18th Alps-Adria Scientific Workshop.* Online ISBN 978-963-269-818-2. DOI: 10.34116/NTI.2019.AA.18. 52-53 pp.
8. Eser, A., Kassai, K.M., Kato, H., Kunos, V., Tarnava, A., & Jolánkai, M. (2020). "Impact of nitrogen topdressing on the quality parameters

of winter wheat (*Triticum aestivum L.*) yield." *Acta Alimentaria Acta Alimentaria*, 49(3), 244-253. https://doi.org/10.1556/066.2020.49.3.2

9. Eser A., Kato H., Czerödi-Kempf L., Hollo-Cseh R. (2020): "Effect of the crop year's weather on the quality and quantity of winter wheat (*Triticum aestivum L.*)." *19th Alps-Adria Scientific Workshop Online* ISBN 978-963-269-896-0 DOI: 10.34116/NTI.2020.AA. 30.
10. Kassai M.K., Tarnawa Á., Nyárai H.F., Eser A., Kempf L., Jolánkai M. (2017): "A csapadék és a hőmérséklet évjárati hatása őszi búza fajták fehérjeprodukciójára." *Növénytermelés*. 66. 3. 1-9 pp.
11. Kassai M.K., Tarnawa Á., Nyárai H.F., Szentpétery Zs., Eser A., Kató H., Jolánkai, M. (2019): "Quality and quantity of winter wheat varieties in 22 years' time range." In: *Book of Proceedings. 2nd Conference on Long Term Field Experiments*. 20-21. November 2019. Nyíregyháza. Ed: Makádi M. Nyíregyháza, 28-31 pp.
12. Kassai M.K., Tarnawa Á., Nyárai H.F., Szentpétery Zs., Eser A., Kató H., Jolánkai, M. (2020): "Quality and quantity of winter wheat varieties in 22 years' time range." *Collumela Journal of Agricultural and Environmental Sciences.* DOI: 10.18380/SZIE.COLUM.2020.7.1.5, 5-9 pp.
13. Kató H., Eser A., Holló-Cseh R., Kassaı M.K., Tarnawa Á. (2020): "Induced climate impacts on mycotoxins contamination in maize." *19th Alps-Adria Scientific Workshop Online* ISBN 978-963-269-896-0 DOI: 10.34116/NTI.2020.AA. 33 pp.
14. Jolánkai M., Kassai M.K., Eser A., Kempf L., Tarnawa Á. (2018): "Water footprint of protein yield of field crop species based on evapotranspiration patterns." *Review on Agriculture and Rural Development.* 7. 1-2. 11-15 pp.

15. Jolánkai M., Tarnawa Á., Kassai M.K., Szentpétery Zs., Eser A., Kató H. (2019): "Crop year effects on the quantity and quality of winter wheat varieties." In: *Transport of water, chemicals and energy in the soil-plant-atmosphere system.* Ed.: A. Celková. UH-SAV, Bratislava. 87-91 pp.
16. Jolánkai M., Tarnawa Á., Kassai M.K., Szentpétery Zs., Eser A., Kató H. (2020): "Crop year effects on the quality and quantity of winter wheat varieties." *Acta Horticulturae et Regiotecturae – Special Issue.* 20–22 pp. DOI: 10.2478/ahr-2020-0017
17. Jolánkai M., Tarnawa A., Kassai M.K., Eser A., Kende Z. (2021): Water Footprint of the Protein Formation of Six of Field Crop Species. Environ Anal Eco stud. 8(3). EAES. 000686. 2021. DOI: 10.31031/EAES.2021.08.000686, 884-885 pp.
18. Tarnawa Á., Kassai M.K., Eser A., Kempf L., Jolánkai M. (2017): "Precíziós módszerek alkalmazása a szántóföldi növénytermesztésben." In: *Precíziós gazdálkodás.* Ed: Milics G. Opal Média és Kommunikáció Kiadó, Budapest. 82-84 pp
19. Kunos, V., Cséplő, M., Seress, D., Eser, A., Kende, Z., Uhrin, A., Bányai, J., Bakonyi, J., Pál, M., Mészáros, K. "The Stimulation of Superoxide Dismutase Enzyme Activity and Its Relation with the Pyrenophora teres f. teres Infection in Different Barley Genotypes." *Sustainability 2022*, 14, 2597. https://doi.org/10.3390/su14052597
20. Khaeim H., Kende Z.*, Balla I., Csaba Gyuricza, Eser A., Tarnawa A. (2022): "The Effect of Temperature and Water Stresses on Seed Germination and Seedling Growth of Wheat (*Triticum aestivum L.*)." *MDPI Sustainability*, Sustainability 2022, 14(7), 3887; https://doi.org/10.3390/su14073887