PHD Thesis

# THE EFFECT OF NITROGEN AND SULFUR FERTILIZATION ON THE YIELD AND QUALITY PARAMETERS OF WINTER WHEAT

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# 1. INTRODUCTION AND OBJECTIVES OF THE DOCTORAL DISSERTATION

A healthy lifestyle, proper nutrition, different diets and their complementary elements are becoming more and more important today. Proper nutrition is based on the production and use of the right raw material. These high-quality foods can be produced with the appropriate processing technology and the previous healthy herbage, in a pre-designed way, with nutrient supply and cultivation technology that meets the needs of the plant (JOLÁNKAI, 2004).

Wheat is the most important cereal crop in Hungary (mainly winter wheat), since the bread produced from it is a staple food. From the bread, our body can take vital chemical elements, most of the vitamins and essential nutrients. According to BICSKEI (2010), the use of wheat is mostly in the form of a meal. Mostly bakery products are made mostly bread, but many other uses include the use of baking, pastry and confectionery. Wheat is also used for animal nutrition for feed purposes as well. Good quality abrasive fodder, but its by-products are also useful in animal husbandry. One of the most important processing technology, the grinding produces bran, which is rich in fiber. Wheat straw is an excellent bedding, possibly a feed additive and a feed additive, but its industrial use is not negligible (straw cellulose, energetics, etc.).

Worldwide, wheat is harvested around 600 million tonnes a year, among the three largest crops grown. Winter wheat is a predominant part of the crops produced in Hungary and has an area of between 1.0-1.2 million hectares. It is the most important bakery plant in Hungary. Wheat is one of the most important commodities in international trade (SHEWRY, 2009; PEPÓ, 2007; HORTOBÁGYI, 1980; GYŐRI and GYŐRINÉ, 1998).

Quality is a complex concept, from the point of view of everybody, from the breeder to the consumer, including the growers and the primary grain processing industry (milling industry) and the industry of the largest flour, the baking industry. Based on the quality definition, the product always needs to be met with expected standards. Winter wheat is our cereal that can be classified by most tools and methods. The standards and methods are updated from year to year and are expanded according to market demands, and the scope of qualification opportunities and needs is expanded. In addition, the standardization of documents drafting classifications between countries allows for simplification of trade opportunities. The continuous change in the Hungarian standard for winter wheat (MSZ 6383:2012) also confirms this, as following our accession to the European Union, the standard required further modifications and enlargement. Thanks to the unified rating, market opportunities opened up a new space for Hungarian wheat. (MÓRÉ and DIÓSI, 2014; DIÓSI et., al., 2015; DIÓSI, 2016).

In addition to the quantitative production of wheat, the quality of the quality indicators is gaining more and more attention. These indicators are influenced by a number of factors, most important of which include soil cultivation, nutrient supply (volume and application) and plant protection.

The sum of the biotic (genetics, agrotechnics) and abiotic (sunlight, precipitation, temperature) factors present in cultivation affects the quality of the product during harvesting. It is important to observe the appropriate work operations and to choose the right time and maintain the quality parameters during harvesting during storage. The correct choice of agrochemicals involves a set of factors influencing the quality of the growers. One of the most important of these is fertilizer applied at the right time, in form and quantity, since this affects most of the nutritional parameters (protein content, gluten parameters, rheological parameters) (DIÓSI, 2016).

There are many publications, scientific works and experiments on the influence of harvest, the quantitative and qualitative effects of nitrogen fertilizer, the importance of irrigation and plant protection, but there is little work on the quality impact of nitrogen fertilizer distribution and sulfur treatment. My research attempted to examine this area better. My aim was to investigate how the distribution of nitrogen fertilizer (application in a single run, in two spring times, the time of steam elongation and divided in early spring and the time of tuning of ear, divided in early spring) affects yield averages and the development of important quality parameters. Besides the two (one medium and one) dose of fertilization I also evaluated the effect of sulfur fertilization. The experiments were carried out under voluntary a condition, which hopefully allows us to produce useful results in addition to the farm sizes used in practice.

## 2. METHODS OF RESEARCH

During my research, I conducted arable and laboratory tests of winter wheat varieties with different application times and different nitrogen and sulfur doses. The laboratory tests took place in the laboratories of the Faculty of Agriculture, Food Science and Environmental Management of the University of Debrecen, Institute of Food Science.

### 2.1. Field experiment, settings

The settings are set at a large parcel size under faulty conditions. The arable operations, discarded seed, fertilizer and pesticide used were provided to me by K-N-P Kft. For the experiment, an area of 18.5 hectares of arable land belonging to the Mezőgyán, with a numbered track number of 0388, has been designated. Soil testing was carried out on 06/06/2013 at the Laboratory of ALFÖLDVÍZ Zrt. In Békéscsaba, accredited by NAT in NAT-1-0951 / 2012 accredited testing laboratory.

The set experiment was carried out on 18,5 ha soil, thus allowing the field to be set in nearly 10 hectares. On the other side of the area, corn was grown, and next year winter wheat is replaced by maize, so corn is grown every year with the same soil preparation, sowing parameters and cultivation conditions. In the third year the area was rebuilt, so winter wheat returned to the area in a 2-year rotation. The area of approximately 10 hectares was divided into 42 parcels, and the various experimental settings were made on parcels of 100 m long and 18 m wide, ie 0.18 hectares. The 42 segregated areas had a triple repetition of 14 settings, resulting in a total of 1 set of over 0.5 ha.

To set up the experiment, we chose 2 winter wheat varieties. One of the varieties used is Mv Suba, while the other is GK Kalász. Altogether two varieties were set, since many varieties would have meant that the area would have been fragmented. We selected the catalogs of breed catalogs published by breeding institutes GK winter Offer (2013) and the Martonvásár Fajtakatalógus 2013-2014 (2013). During the search or selection, important factors were that crops with the same cultivation, with growth intensity and similarly resistant to plant protection, tolerance.

During the research we examined the qualitative and quantitative parameters of the two winter wheat varieties, during which the variables in the cultivation differed beyond the abiotic factors, the amount of fertilizer used and the application dates.

The amount of nitrogen fertilizer used was determined at 3 doses. Nitrogen fertilizer was not released during abs. contr.. In another two settings, 90 kg/ha of nitrogen is the active ingredient in Hungary, which is commonly used in winter wheat production and a high nitrogen content of 150 kg/ha has been released. In both cases, ammonium nitrate (34%) was used as a granulate. As an autumn basic fertilizer, soil fertilization was carried out with nitrogen, phosphorus and potassium complex fertilizer (NPK 15:15:15) prior to sowing. Proposed in the settings, it was dispensed with 1/3 of the amount of nitrogen to be released.

Nitrogen application was carried out in addition to the basic fertilization in autumn at 3 other times: - Early spring application in a single run, only 2/3 of fertilizer (ammonium nitrate 34%) calculated for the remaining nitrogen active ingredient

- Early spring divided in early spr. and the time of steam elong. - 1/3 - 1/3 ratio of the remaining nitrogen fertilizer (ammonium nitrate 34%)

- Early spring divided in early spr. and time of tun. of ear- the ratio of fertilizer (ammonium nitrate 34%) to the remaining nitrogen active component divided by 1/3 - 1/3.

In addition to the use of nitrogen in liquid form, sulfur was blown prior to harvesting as the last session after flowering. With the 42 parcels set, half of the working width was 9 meters per plot with FitoHorm Turbo Potassium ($SO_3$ 57%) Fertilizer Formulation (FITOHORM TERMÉKKATALÓGUS, 2014).

In the area the fore crop was corn, after the harvest, the remains were cleared from the area after being baling. After smoothing the bales, the soil was broken into a double-sided reel with a 7,2 meter working with RÁBA STEIGER. As a base fertilizer 15:15:15 NPK fertilizer was delivered with Bogballe fertilizer spreading machine in 18 m working width. The spread of the complex fertilizer was sown 2 days before sowing and was rotated in the soil with a disc. Semi-seeded seeds were seeded in the prepared soil using an IH6200 seed drill. The area's absolute control plots were only provided with the required plant protection treatment, and fertilizer treatment did not affect these areas.

As a first treatment, in early spring, depending on the settings, there were parcels that supplemented the nitrogen dose of the main fertilizer with the total amount of suckling during the entire season, so they received the full nitrogen dose early in the spring. The parcels of the other 2 settings received only 1/3 of the corresponding nitrogen dose. In Figure 2, the redlabeled parcels obtained the total nitrogen dose calculated for growing time (primary fertilizer excess) in early spring. Control is visible in gray color, which is untreated for fertilization. The second treatment took place at the end of the bushing, but before stalking. I marked the green areas at the end of the bushing. The third treatment was carried out at the end of the stem, but before the flowering was completed, also with the addition of ammonium nitrate. In Figure 1, yellow parcels indicate the early spring and the time of tuning of ear.

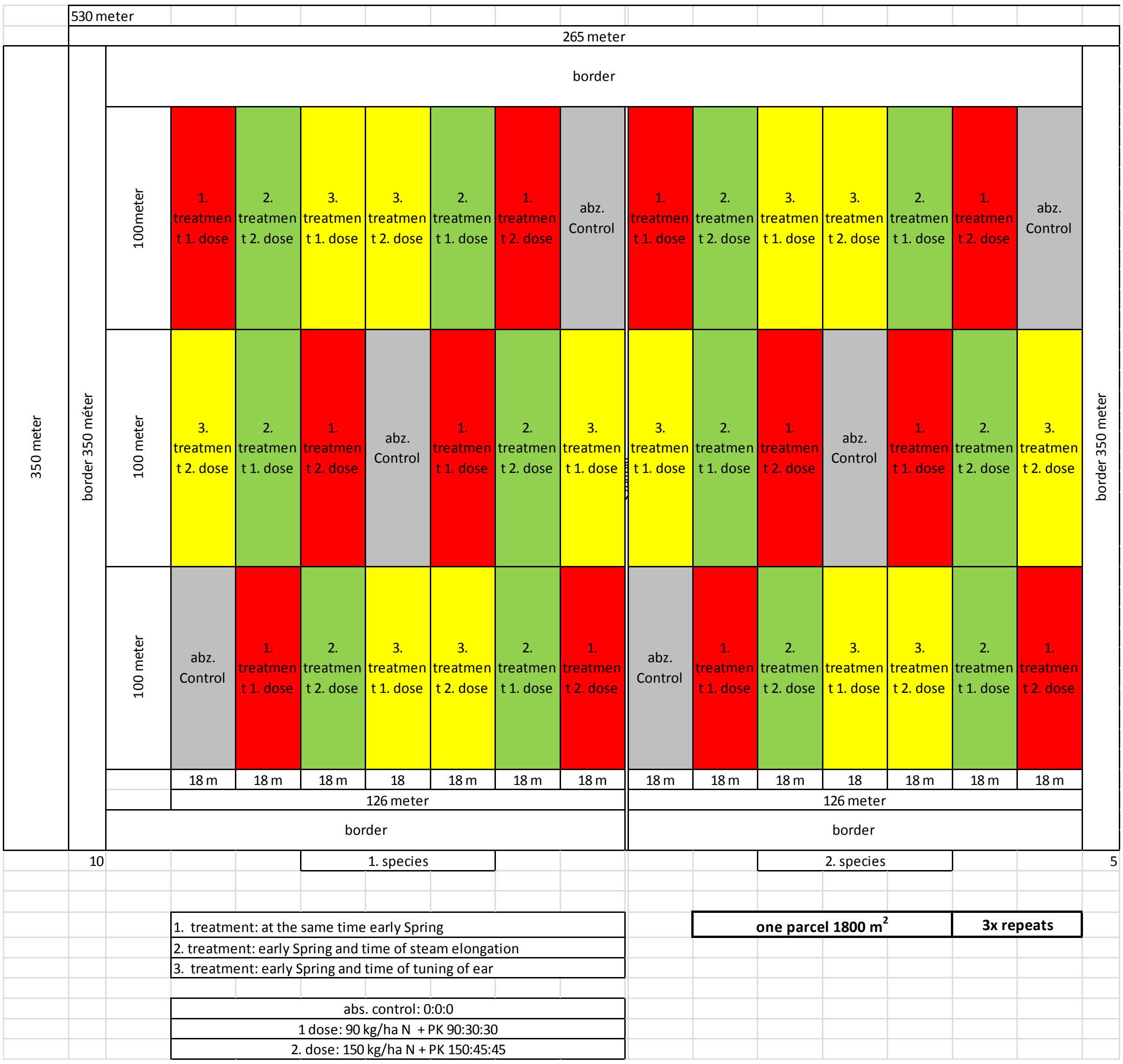


**Figure 1.** – Division of the territory, parcel layout and marking with different colors (Sarkadkeresztúr, 2013-2016)

The liquid sulfur ($SO_3$ 57%) was applied at 4 l/ha. The preparation used (FitoHorm Turbo Potassium) was recommended by FitoHorm Kft. for significant sulfur and low nitrogen content. Sulfurization was performed on all parcels set at a width of 9 meters. The treatment was done after flowering in the period of fruit set. As a result, the triple repetition of the 14 settings doubled, so we could collect different samples from 84 parcels in all three pilot years (Figure 2).

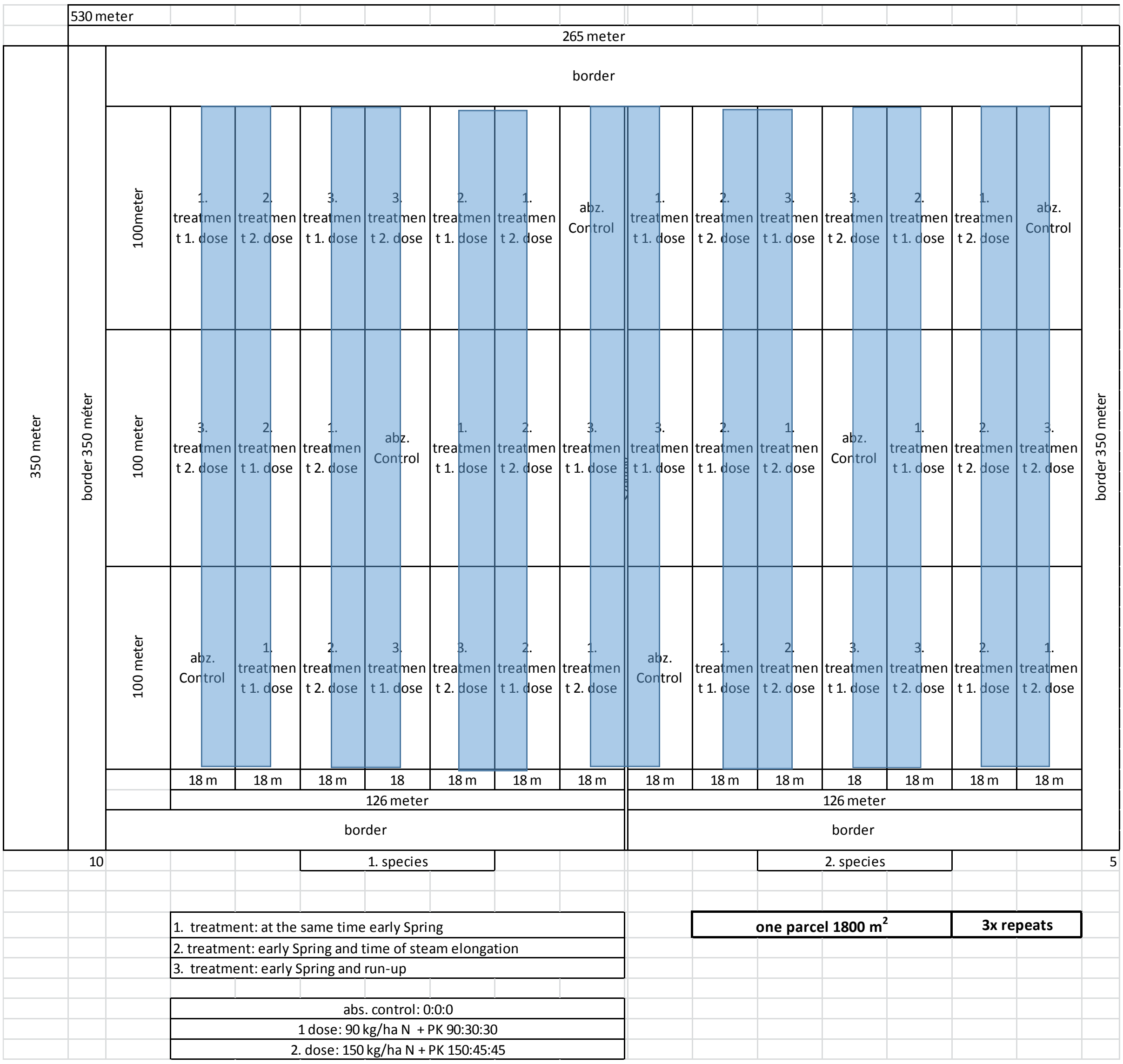

**Figure 2.** – Treatment of parcels with sulfur (Sarkadkeresztúr, 2013-2016)

The date of harvesting was based on the moisture content of the samples, from storage point of view the moisture content of the harvest between 10 and 14% was ideal, with harvesting in mind. The collection of samples was carried out at the same time as the parcels were unloaded from the conveyor wagons. In addition, the wheels of the transport wagon on the sides of the digitally operated slipper scale used to determine the mass of the harvested sample, thus calculating the average size of the area for each of the three material years. Table 1 summarizes the dates of all arable operations that have been made during the three pilot years (divided by years).

**Table 1** – The date of all arable operations (three years)

| **work/sezon** | **2013/2014** | **2014/2015** | **2015/2016** |
|---|---|---|---|
| *complex fertilizer application* | 02. 12. 2013. | 27. 10. 2014. | 21. 10. 2015. |
| *sowing* | 03. 12. 2013. | 28. 10. 2014. | 22. 10. 2015. |
| *1. fertilizer treatment* | 06. 03. 2014. | 10. 03. 2015. | 04. 03. 2016. |
| *2. fertilizer treatment* | 08. 04. 2014. | 30. 04. 2015. | 30. 04. 2016. |
| *3. fertilizer treatment* | 26. 05. 2014. | 24. 05. 2015. | 26. 05. 2016. |
| *weed control (Desormon 0,8 l/ha)* | 05. 04. 2014. | 10. 04. 2015. | 03. 04. 2016. |
| *sulfur treatment* | 30. 05. 2014. | 29. 05. 2015. | 30. 05. 2016. |
| *harvest* | 05-06. 07. 2014. | 10. 07. 2016. | 14. 07. 2016. |

**Sample collection times, sampling**

My measurements were performed in 3 repetitions, randomly placed repetitions, each of the samples of each field parcel. Thus, 28 adjustments in three replicas each year make 84 parcels per harvest, with a sample of 168 for 3 years.

## 2.2. Field and laboratory tests, methods

Among grain parameters, tests should be mentioned, carried out, in which the whole grains were used and measured. Laboratory tests were carried out at the laboratories of the Department of Food Science at the Faculty of Agriculture, Food Science and Environmental Management at the University of Debrecen, in accordance with the standards, Table 2.). After finishing the wheat grains, the grinding was done with the Metefém FQC-109 type lab according to standard MSZ 6367/9: 1989, followed by a 250 µm sieve of flour from the bran.

**Table 2.** Seed and flour parameters, used tools and deviced

| | Parameter | Device/tool | Methode/Standard |
|---|---|---|---|
| **grain parameters** | average yield of treatments,<br>rapid moisture | Pfeuffer He Lite | |
| | thousands grain weight | x g/1000 db | |
| | hectolitre weight | hectolitre mass measuring | MSZ 6383:2012 |
| **flour parameters** | Hagberg falling number | Perten falling number | MSZ ISO 3093:1995 |
| | Rheological parameters (water absorption capacity, stability time, baking value) | Valorigraph | MSZ ISO 5530-3:1995;<br>MSZ 6369-6:1988;<br>MSZ 6383:2012 |
| | protein content<br>(seed and flour) | Tecator 1007 destructive blocks and Tecator 1026 destillation apparatus | Kjeldahl methodes<br>MSZ 6830-4:1981 |
| | wet gluten content,<br>gluten index,<br>gluten expansively | PERTEN Glutomatic 2200 gluten wash and centrifugEl | MSZ ISO 5531:1993;<br>MSZ 6369/5-1987;<br>MSZ EN ISO 21415-1:2007 |
| | sulfur content<br>(grain and flour) | OPTIMA 3300 DV type ICP-OES, Perkin-Elmer Ltd., Echelle system, flush with argon gas | KOVÁCS ET AL. 1996<br>MSZ-08-1783-38:1985 |

### 2.2.3. Statistical data analysis

The results obtained during the measurements give repetitions a set of data in which the basic statistical methods of descriptive statistics can be applied. Analysis can be used to characterize the relative effect of different quantitative and qualitative factors. In the paper, the relationship between the three independent variables (application time, fertilizer dose and sulfur used or sulfur emission) and the results of the different parameters studied were determined. The calculation of the SLD5% (Least Significant Difference) is justified by the interaction of factors whose values are above the defined error threshold (SVÁB, 1981, HRUZSVAI, 2013).

Based on the description of the SVAV (1973), the effect of the different treatments was evaluated in the statistical analysis by examining the evolution of the dependent variables. Examination of the differences between the means of the singly involves the evaluation of the differences between the control and treated plots between any two combinations and the examination of the main effects (NPK doses, sulfur treatment and nitrogen treatment times) and their interactions:

- NPK doses: 90 kg/ha N + PK, 150 kg/ha N + PK
- sulfur treatment: + S, ø S
- Times of the nitrogen treatment: in one pass in early spring, divided in early spring and the time of steam elongation, divided in early spring and the time of tuning of ear.

## 3. SUMMARY

Numerous scientific articles can be found about the variety use, calculation of adequate nitrogen dose and usage of other fertilizers what can help landowners optimize their production. The purpose of this research was to study the effectiveness of different application times with higher and lower NPK fertilizer doses on the quality and quantity features of the winter wheat grain and flour. Furthermore, the sulfur is reported as a significant factor of flour quality, so the modifying effect of sulfur leaf treatment was also evaluated. The experiments were set up in a field experiment with about 0.18 ha parcel size, therefore almost real production circumstances were provided for the tests.

In case of the sulfur treated GK Kalász winter wheat the highest yields were experienced in that fertilizer sharing when the spring dose were applied in early spring and the time of steam elongation in the case of 90 kg/ha N+PK dose, while 150 kg/ha N+PK dose resulted highest yields when it was divided in the same time in the three experimental year. In case of the Mv Suba the positive effect of the higher dose and the sulfur treatment was found when the fertilizer was shared in early spring and the time of steam elongation. In the case of the same variety in parcels treated with a lower dose NPK or untreated with sulfur in one pass in early spring gave higher yield. In contrast to MV Suba, GK Kalász reached higher yield values in the case of absolute control settings but the Mv Suba reached higher average yields with the application of different settings and treatments.

The sulfur content of GK Kalász winter wheat grain and flour showed the highest values when the 90 kg/ha N+PK dose was divided in early spring and the time of steam elong., in contrast to other divisions and in one pass in early spring. Independently to sulfur treatment, the parcels fertilized with 150 kg/ha N+PK dose showed higher sulfur content applied in one pass in early spring. In the case of Mv Suba winter wheat grain and flour, none of the doses or the pass out times had not been influenced the sulfur content, furthermore, the positive effects of sulfur treatment also had not been proved since the high standard deviation in the results can be seen in the comparisons by years between the different settings.

The protein content of GK Kalász grain and flour produced without sulfur with 90 kg/ha N+PK dose was the highest when the nitrogen was divided in early spring and the time of tuning of ear. The parcels treated with sulfur with the same dose divided in early spring and the time of steam elong. reached higher values in the three experimental years. In the case of the parcels not treated with sulfur, the 150 kg/ha N+PK dose applied in one pass in early spring resulted the highest values. In the case of the parcels treated with the same amount of sulfur and lower dose of nitrogen, the sharing in early spring and the time of steam elong. resulted higher values in all the three experimental years.

In the three experimental years the falling number fluctuated independently from the different settings in case of the GK Kalász and Mv Suba. The rainier year took effect on this parameter thus the samples from 2015 showed higher enzyme activit values regardless of the type, dose, sulfur treatment or application time.

In the case of the baking value the same conclusion can be drawn regardless of variety. Compared to the absolute control, every setting had positive effect. The parcels with 90 kg/ha N+PK dose applied dividedly in early spring and the time of steam elongation treated with sulfur and the parcels not treated with sulfur reached the highest values during the three experimental years. From the parcels with 150 kg/ha N+PK dose applied in one pass regardless sulfur treatment reached the highest baking values in the three experimental years.

The analysis of wet gluten content confirms that regardless the variety the higher NPK dose produced higher wet gluten content as well as both the 90 kg/ha N+PK and the 150 kg/ha N+PK parcels treated with sulfur showed smaller variance over the higher values between the passing times with parcels not treated with sulfur with the same NPK dose. During the species winter wheat flour gluten spreading measures the absolute control reached the highest values. In regards of the doses the 150 kg/ha N+PK dose samples reached smaller results in contrast to the 90 kg/ha N+PK dose parcels in the three experimental years. Furthermore, the sulfur treatment has positive effects and smaller gluten spread can be seen.

Nowadays the good agricultural practice is more and more important, including the right nutriment supply. Nitrogen is the most widely used element and many kinds of application are known, and the correct dose is important as well as the determination of the correct fertilizer form. The determining these factors requires a complex approach as the ever-expanding fertilizer market tries to meet the needs of farmers with many mixing options and active ingredients. As there are currently no two farms or company, there are many environmental influencing effects (different soil and water management characteristics), factors independent from production (market price), opportunities (machine parks), legistlation (nitrate sensitivity), professionals and farmers have to consider to perform not only a quantity oriented production but the quality have to meet the needs of the market.

## 4. NEW SCIENTIFIC RESULTS OF THE DISSERTATION

1. Based on the results of the pilot experiments, I found that during the cultivation of the winter wheat, in the case of low nitrogen fertilization at 90 kg/ha N + PK fertilizer fertilization, nitrogen fertilization in one pass, high nitrogen dose (150 kg/ha N + PK), The use of a split nitrogen fertilizer at early spring and early start gives rise to high yields.

2. When examining the sulfur content of wheat grain and flour it can be stated that sulfur treatment does not always have a higher sulfur content than samples of sulfur-treated settings and sulfur supply is not always closely related to the sulfur content of grain and flour. As the higher values were obtained in case of nitrogen fertilization in one pass, I found that the plant is more susceptible to sulfur accumulation if there is no continuous nitrogen uptake.

3. I demonstrated that the low nitrogen content of nitrogen divided in early spring and the time of tuning of ear results in higher protein content without sulfur fertilization, but if sulfur fertilization is carried out, nitrogen fertilization divided in early spring and the time of steam elongation results in higher protein content. However, in the case of favorable weather conditions, the use of sulfur fertilizer is justified in order to achieve higher protein content while using a high nitrogen dose in a single run.

4. In the baking value, low spring nitrogen doses, regardless of the treatment of sulfur, resulted high values during the early spring or the early spring and the time of tuning of ear. When using high nitrogen dosages, the samples obtained the highest baking value regardless of the sulfur treatment.

5. The quantitative test of wet gluten confirms that higher fertilizer yield resulted in higher wet gluten content. Regardless of the dose, the sulfur-treated parcels produced even higher values and resulted in less fluctuations between the individual application times compared to the values of the parcels that were not treated with sulfur.

6. Fragmentation of winter wheat flours with N + PK fertilizer treatments at 150 kg/ha resulted in lower results compared to 90 kg/ha N + PK treatments. In addition, samples of sulfur-treated and sulfur-treated parcels of the same doses showed a positive effect on the sulfur treatment, resulting in lower gluten expansive.

## 5. PRACTICAL USE OF RESULTS

1. In the course of farming, consideration should be given to optimizing the amount and date of application of the nitrogen to be released on the basis of the costs and the available results. Higher fertilizer dose (150 kg/ha nitrogen) is recommended in one pass (spring) application, but in the use of lower fertilizer (90 kg/ha nitrogen) in order to improve the quality parameters, distributed nitrogen fertilizer application is both justified for both quantitative and qualitative reasons.
2. Based on the results of the experiment, the results of the experiment show that while the increased nitrogen dose results in higher protein content, the additional sulfur treatment will allow the value to be stabilized, as repetitions of parcels received by the sulfur treatment show less fluctuations than the sulfur-treated parcels.
3. In the case of winter wheat production, the quality of its stabilization is achieved with its sulfur utilization. The advantage of sulfur treatment is that it can be accomplished with plant protection work in one pass, with its impact on production costs moderate compared to the achievable result.

LIST OF ABBREVIATIONS

| | |
|---|---|
| **150 kg/ha N+PK** | 150 kg/ha nitrogen 50 kg/ha phosphorus, potassium 50 kg/ha active ingredient |
| **90 kg/ha N+PK** | 90 kg/ha ha nitrogen 50 kg/ha phosphorus, potassium 50 kg/ha active ingredient |
| **A** | premium farinograph quality category |
| **abs. contr.** | absolute control |
| **B1** | mill (I) farinograph quality category |
| **B2** | mill (II) farinograph quality category |
| **C** | forage farinograph quality category |
| **cc.** | thick |
| **GI %** | gluten index |
| **hrsz.** | topographical numberc |
| **early spr. + time of steam elong.** | early spring and the time of steam elongation |
| **early spr. + time of tun. of ear** | early spring and the time of tuning of ear |
| **KSH** | Hungarian Central Statistical Office |
| **MSZ** | Hungarian Standard |
| **NFCSO** | National Food Chain Safety Office |
| **NPK** | Nitrogen, phosphorus and potassium complex fertilizer 15% N, 15% P, 15% K |
| **VE** | Valorigraph value |

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