PhD. thesis

EFFECT OF SULPHUR FERTILIZATION ON THE QUALITY AND QUANTITY OF WINTER WHEAT

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1. Introduction and goal set

As air pollution regulations are becoming stricter, the sulphur deposition in the atmosphere decreases and the usage of superphosphate decreases as well, the sources for the automatic sulphur fertilization of the land are no longer available. Literature on the role of sulphur in agriculture is expanding and emphasizes growing sulphur deficiency.

In the Hungarian agriculture winter wheat (Triticum aestivum L) production has always been significant. The production area has been ranging around 1.1 – 1.2 million ha on the average of many years. The average yields varied between 2.6-5.2 t/ha (2006: 4.13 t/ha; 2007: 3.59 t/ha; 2008: 5.02 t/ha), according to the crop year, the national winter wheat yield varied between 3-6 t/ha. Although the national wheat supply has never been short, besides varying crop yields we have to face quality problems as well.

Today, thanks to genetics and the development of cultivation methods, wheat production improved and Hungary joined the most developed countries in terms of quality, quantity and economics. Quality production of winter wheat is one of the key factors of maintaining market position and it become even more emphasized after our EU accession.

The role of sulphur and the importance of sulphur fertilization in the production of the major cereal crops, wheat and corn, and in the high sulphur demanding oil crops has been examining worldwide. Sulphur deficiency causes decreased N utilization and yield loss and decreases the baking value of the flour of cereal crops. In order to achieve good quality and high yields sulphur fertilization might be necessary. As POTAPOV and FEJÉR stated back in 1955, the scientific goal of clarifying the role of sulphur and sulphur compounds is necessary for high quality and quantity crop production. In a farm experiment we analysed the effect of sulphur fertilization on the N and S content of different winter wheat plant parts on the baking quality and tried to find how the measured element concentrations reflect the nutritional status of the plant. We try to find how the N/S ratio changes in the different plant parts according to the sulphur supply and how these data can be used for diagnostic purposes in agricultural consultancy. We try to contribute to the specification of practical sulphur fertilization methods in order to improve quality and quantity in wheat production.

1. Material and methods

1.1. Small plot experiments in Látókép

Some of the experiments were carried out in the University of Debrecen Centre of Agricultural Sciences and Engineering Látókép Research Site between 2001-2002, in a field trial set by Prof. Dr. László Ruzsányi in 1984; the other part of my experiment was based on the sulphur fertilization experiment set up by myself in the crop year of 2001/2002.

The soil of the research site is calcareous chernozem soil formed on loess. The pH value is near neutral, the KCl pH in the cultivated layer ranges between 5.5 and 6.5, the lime content ranges between 10-13 %, the kA number is 43. The humus content ranges between 2.5-3.0 %, the humus layer is 70-80 cm deep. The Al-soluble P_2O_5- (130-150 $mgkg^{-1}$) content is medium and the Al-soluble K_2O- (240-260 $mgkg^{-1}$) content is good. The Al-soluble sulphur content ranges between 6.0-6.2 mg/kg. As regards water management, the research site is classified in category IV, which refers to medium water absorbing capacity and good water holding capacity.

In the field trial our experiment was carried out in triculture (corn-pea-winter wheat) with ploughing cultivation with and without irrigation. The plot size was 46 m^2. 2 x 30 ml irrigation water was applied. In both years MV Pálma variety was planted. 34% ammonium-nitrate, 18% superphosphate and 60% chloride of potash was used. The phosphorus and potassium fertilizers were applied in autumn previous to the deepest cultivation method, while 50-50 % of the nitrogen was applied in autumn and in spring. Herbicides and fungicides were used according to the circumstances. The application of insecticides was only necessary in certain years. In the sulphur fertilization experiment the NPK was supplied in different forms of fertilizers. We analysed the effect of sulphur in different forms of fertilizers as complementary element on the quality and quantity of winter wheat. Furthermore, in two cases in spring specifically sulphur foliar treatment was applied. The table well reflects that on plot 1 (control) no fertilizers were applied, and on plot 2 no sulphur-containing fertilizers were applied. Similar to plot 2, on plot 3 and 4 mono-ammonium-phosphate (MAP) was applied; sulphur was supplied in the form of foliar fertilizer in spring. On plots 7 and 8 Biofert, a by-product of lysine production complemented with MAP and sulphur was used. In treatments 5 and 6 superphosphate was used. The variety was again Mv Pálma. We used 4 replications; the size of the plots was 24 m^2 and they were randomly selected. Table 1 and 2 summarize the treatments used in the experiment.

Table 1: Fertilization treatments in Ruzsányi's winter wheat NPK fertilization Debrecen-Látókép (2001*;* 2002)

Treatment	N	P_2O_5	K_2O
	kg/ha		
1	0	0	0
2	50	35	40
3	100	70	80
4	150	105	120
5	200	140	160

Table 2: Fertilization treatments in the small plot sulphur fertilization experiment Debrecen-Látókép (2001/2002)

Treatment	N	P_2O_5	K_2O	SO_4 (g/ha)	Fertilizers
	kg/ha				
1	**0**	**0**	**0**	0	-
2	**100**	**70**	**80**	-	MAP
3	**100**	**70**	**80**	500	MAP; FitoHorm32S
4	**100**	**70**	**80**	1000	MAP, FitoHorm32S
5	**100**	**70**	**80**	-	superphosphate
6	100	140	80	-	superphosphate
7	**100**	**70**	**80**	-	Biofert; MAP
8	150	70	80	-	Biofert; MAP

1.2. On-farm experiment

The experiment was set up in the autumn of 2001 on the B-2-4-6 field of the Agricultural Cooperation in Felsőzsolca. The total area of the experiment was 2.88 ha. The experiment was repeated in 2002 autumn on the B-8-9-11 field with the same total area.

The type of the experiment was meadow soil, specifically unstable meadow. The water management of these types of soils is usually favourable and in case the soil water is not too close to the surface the wet period in spring is not long. Soil water has a beneficial effect for plants in the summer period. Since the great compactness and the specific water management practices make cultivation difficult, soil quality should be taken into consideration in order to the better utilization of the elements. The chemical analysis of the soil has been conducted in both crop years; the following data on the cultivated layer have been gathered: humus – 2.77 %, $CaCO_3$ – 2.62 %, kA number 55, $pH_{(KCL)}$ 6.13, Al-soluble P_2O_5 – 145 mg/kg, Al-K_2O – 235 mg/kg. According to the methods and limit values by MÉM NAK (1979) these values suggest that the soil has medium humus, good phosphorus and weak potassium content. Soil water is in 4 m depth and the area is not susceptible to draught. The sulphur content of the soil is KCl=21, 56; LE=20.40.

The agrotechnical factors were according to farm practice. In the starting year of the experiment no P and K fertilizers were applied, 50 % N was applied in autumn before ploughing the other half was applied in spring in the form of 34% ammonium nitrate. The amount of N fertilization was equal to 200 kg active agent component. The used variety was GK Élet in both years, which is an early ssp. muticum variety that can achieve record yields, good-excellent flour quality (B2-A1), and is widely used. In intensive production circumstances it has high yields and excellent quality (good fertilization effect).

Sowing time was 3 October 2001 and 5 October 2002. The germ per ha was 4.86 and the sowing depth was 6 cm. In both years cultivation was done by discs and in the same way. Besides the basic fertilizers used in common farm practice, the crop stands in the research have been supplied with FitoHorm 32 S solution. The sulphate-sulphur content of the sulphur fertilizer was 30 m/m, density 1.2 g/cm^3, accordingly, the active agent content was 360 g sulphate/l. Furthermore, it contains 35 g/l potassium-oxide and 100 g/l nitrogen. The date of applications was 10 April 2002 and 16 April 2003. I used the producer's suggestions of FitoHorm 32 S solution to determine the treatments. The treatments were conducted in small, medium and big doses in two replications. The size of the plots was 200 m x 18 m (0.36 ha) and they were randomly selected, going by the width of the spraying machine that provided the foliar treatment.

Table 3 and 4 show the fertilization treatments and the applied quantities in active agent component.

Table 3: Standard treatments in the experiment, Felsőzsolca (2002, 2003)

TREATMENT	FERTILIZER	APPLIED FERTILIZER QUANTITY		
		l/ha	l/plot	
			Felsőzsolca 2001/2002	Felsőzsolca 2002/2003
1. treatment (control)	-	0	0	0
2. treatment	FitoHorm 32 S sulphur solution (foliar fertilizer)	2	0,72	0,72
3. treatment	FitoHorm 32 S sulphur solution (foliar fertilizer)	4	1,44	1,44
4. treatment	FitoHorm 32 S sulphur solution (foliar fertilizer)	6	2,16	2,16

Table 4: Active agent component supplied in the treatments, Felsőzsolca (2002, 2003)

RESEARCH SITES	SULPHATE SUPPLIED IN ACTIVE AGENT COMPONENT							
	1.treatment (control)		2.treatment		3.treatment		4.treatment	
	g/ha	g/plot	g/ha	g/plot	g/ha	g/plot	g/ha	g/plot
2001/2002	0	0	500	180	1000	360	1500	540
2002/2003	0	0	500	180	1000	360	1500	540

2.3.Weather conditions

2.3.1. Látókép

The growing season of 2000/2001 was characterized by dry autumn and mild winter months with average precipitation. The average spring was followed by hot and dry May, which distorted the plant stands in their growing. The precipitation in June (160 mm) slightly compensated the effects of May.

In 2001/2002 the growing of the plants was satisfactory thanks to the favourable autumn weather and the water deposit from the former year ensured right conditions for the initial growing. However, cold winter, mild spring and the hot weather from May together with draught resulted in unfavourable growing conditions.

2.3.2. Felsőzsolca

In the growing season of 2001/2002 the whole country suffered from draught. In the sowing period the temperature was higher than average and the precipitation was favourable, therefore the right conditions for the satisfactory growing of the stands were provided at the beginning. Unfortunately, the amount of precipitation was very low in winter. As a result of the spring weather that was dry also by the end of May significant water deficiency cumulated. The low precipitation was accompanied by 2.2-3 ºC higher than average summer months.

The weather conditions of the growing season of 2002/2003 were extremely unfavourable for winter wheat production as well. The beginning of the growing season was characterized by high amount of precipitation in autumn and in winter. However, spring and summer were dry and was even more exaggerated by the effect of the former dry year. The overwintering of winter wheat was rendered more difficult by the changeable winter months that were colder than the many year average. The biggest heat was recorded in this growing season in May and July, which, accompanied by draught interfered balanced growing.

2.4.Describing the plant sampling method

The plant samples were gathered in the critical growing stages (stooling, stalking, heading and flowering, maturing). The whole plant above the soil and the individual parts (leaf, stem, ear) have been analysed during the growing. Fresh and air dried weight of the green plant samples and the N and S content after proper preparation were measured. As regards the grains, the baking quality of the flour made of them was examined.

2.5.Describing the laboratory analysis

The laboratory analysis was carried out in the accredited laboratory of the University of Debrecen, Centre of Agricultural Sciences and Engineering, Faculty of Agriculture, Institute of Food Science, Quality Assurance and Microbiology according to the applying updated MSZ, MSZ-ISO standards and AACC methods. The preparation of the green plant samples was according to the specifications of the MSZ 6884-1. After removing the contamination with tap water the fresh samples were weighed than dried in 60 ºC drying chamber until air dry. Then the air dry samples were ground by a grinder with filter 1 mm diameter. The homogenized samples were used for the following analysis.

2.5.1. Determining the element content with ICP-OES

We used OPTIMA 3300 DV inductively coupled plasma optical emission spectrometer (ICP-OES) by Perkin Elmer Ltd. (KOVÁCS ET AL., 1996, 1998). For the determination of the total element content wet charring of the samples was carried out by HNO3-H2O2 by LABOR MIM OE718/A electric block charring machine. The weight of the appropriately prepared (dried, ground) samples were 1.0 g (±0.01 g), the grain samples were 2.0 g (±0.01 g). The element content data refer to dry matter values.

2.5.2. Determining the flour quality

Flour was ground according to the MSZ 6367/9:1989 by LABOR MIM AQC-109 lab mill. In order to determine baking quality, we used the following examinations and methods: crude protein content, MSZ 6367/11-84; wet gluten content and gluten deformation, MSZ-ISO-5531:1993; farinograph water absorption, MSZ-ISO-5530-3:1994 and MSZ ISO 5530-3/1995; Hagberg's falling number, MSZ ISO 3093:1995.

2.6.The statistical data processing method

To describe the general data set, the basic statistical methods in descriptive statistics (extremes, average, deviation, relative deviation) were used. The result of the deviation analysis clearly determines the possibilities of further statistical processing. Variance analysis was used to find whether the different qualitative and quantitative factors have significant effect on the subgroups of the sample set, i.e. whether the different factors influence the qualitative parameters. By calculating the $SD_{5\%}$ the margin of error above which the correlation of the factors is valid was determined.

SPSS 12.0 software was used for data processing (KECSKEMÉTI ÉS IZSÓ, 1996). The diagrams describing the averages and the deviances were prepared in Microsoft Excel 2003.

3. Results

3.1.NPK long term field trial

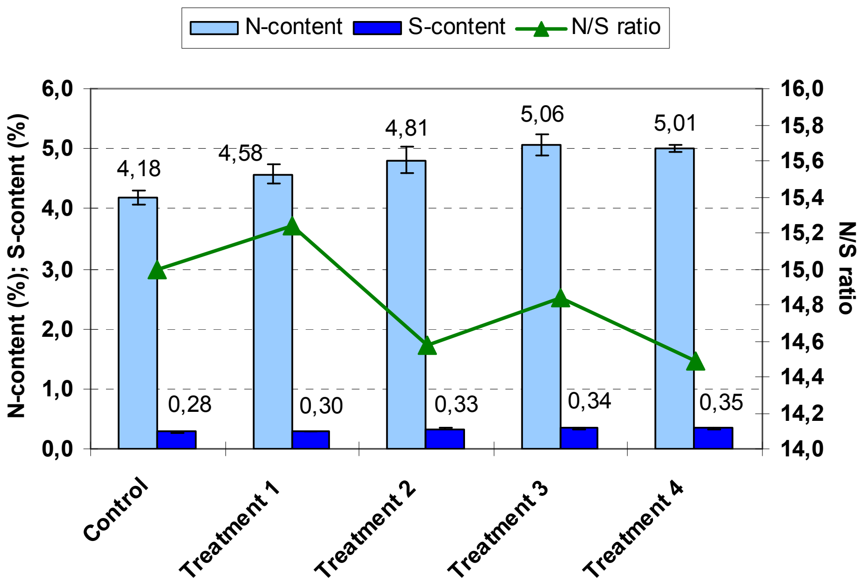
We found that the effect of increasing fertilizer doses on the nitrogen and sulphur content of wheat in the stooling stage is strongly influenced by the crop year. The nitrogen content of wheat samples from the control plots was 4.18% on the average of the 4 replications, which is the lowest of the treatments (*Figure 1*). As regards nitrogen content, the highest levels were found in treatment 3, where the nitrogen content of the samples exceeded 5% (5.06%). Similarly, sulphur content was lowest in plots where no fertilizers were applied (0.28%), while the highest sulphur content was measured in treatment 4 (0.35%). The nitrogen content increased at greater extent than the sulphur content, thus the change of the two parameters resulted that the examined N/S ratio increased. In 2002, statistically proved conclusions similar to the upper could not be drawn.

Comparing the different fertilizer doses, at the heading and flowering stage in irrigated circumstances greater change in the nitrogen content was experienced in the first year of the experiment. The lowest nitrogen content (2.22%) was measured at samples from the control plots. The nitrogen content of treatment 3 was 13% higher (2.84%). In 2002, the concentration and the ratio of the examined elements were higher than the earlier year both with or without irrigation (N=3.95% and 4.27%; S=0.35-0,38%; N/S=11.16).

In 2001, in the heading and flowering stage the increasing NPK doses influenced the nitrogen and sulphur content both with or without irrigation, and the change was statistically proved (P=0.1%, P=5%). The sulphur content was peaked at treatment 3 (0.29%, 0.23%) in both research years and both with or without irrigation, i.e. the sulphur content of the plant samples was highest at 150 kg/ha N, 105 kg/ha P and 120 kg/ha K fertilizer doses.

As regards the data lines of treatments without irrigation in both years, I found that the fertilization increased the sulphur content at higher rate than in case of nitrogen content. Compared to the control (1.13%), the nitrogen content increased by 24%; while compared to the 0.12% concentration of the untreated samples the sulphur content increased by 42%. As the increase of the sulphur content was faster, the N/S ration of the plant tissues decreased from 9.99 to 8.16.

Figure 1. The effect of fertilization treatments on the nitrogen and sulphur content on the N/S ratio (Debrecen- Látókép; 2001)



—control **N0** —1. treatment **N50** —2. treatment **N100** —3. treatment **N150** —4. treatment **N200**

As regards the effect of irrigation on the element content (*Figure 2, 3, 4, 5*) in the stalking stage, the change of the nitrogen content was statistically not proved in either year. Except from the results of the 2nd fertilizer treatment in 2001, the sulphur content was highest on the non-irrigated plots in each case (0.34%). Accordingly, the N/S ratio of the irrigated plots was higher when higher fertilizer doses (10.56 and 11.40) were applied in 2001, while in 2002 it was higher in each treatment (11.6 and 12.47).

As regards the results of the two years in the heading and flowering stage, the nitrogen content was higher in most of the cases on the irrigated plots (maximum in 3. treatment 150/105/120 NPK). As a result of the increasing fertilizer doses the increase of the sulphur content is also presented by the graph. In 2001 the sulphur content was higher on the non-irrigated plots (0.29%), while in 2002 the sulphur content of the irrigated plots was higher (0.26%).

In the maturing stage the increasing fertilizer doses resulted in the linear change of the nitrogen content, except from the data of the irrigated treatments in the year of 2001. As regards the extreme values, the fertilizer effect was higher in 2001 on the irrigated plots (1.39%), while in 2002 it was higher on the non-irrigated plots. In both years, the nitrogen content in the samples from the irrigated plots proved to be higher compared to the samples from the non-irrigated plots. Sulphur content was linearly increased as a result of increasing fertilizer doses. In both years the sulphur content of the non-irrigated plots proved to be higher. The increasing NPK doses resulted in decreasing N/S ratio in both irrigation methods in 2001, while in 2002 it was higher in each treatments. No tendency was found in the second research year among the data of the irrigated plots.

Figure 2: The effect of fertilizer treatments on the sulphur content of wheat samples gathered in different growth stages on non-irrigated plots
Ruzsányi L. NPK-treatment (Debrecen-Látókép, 2001; 2002)

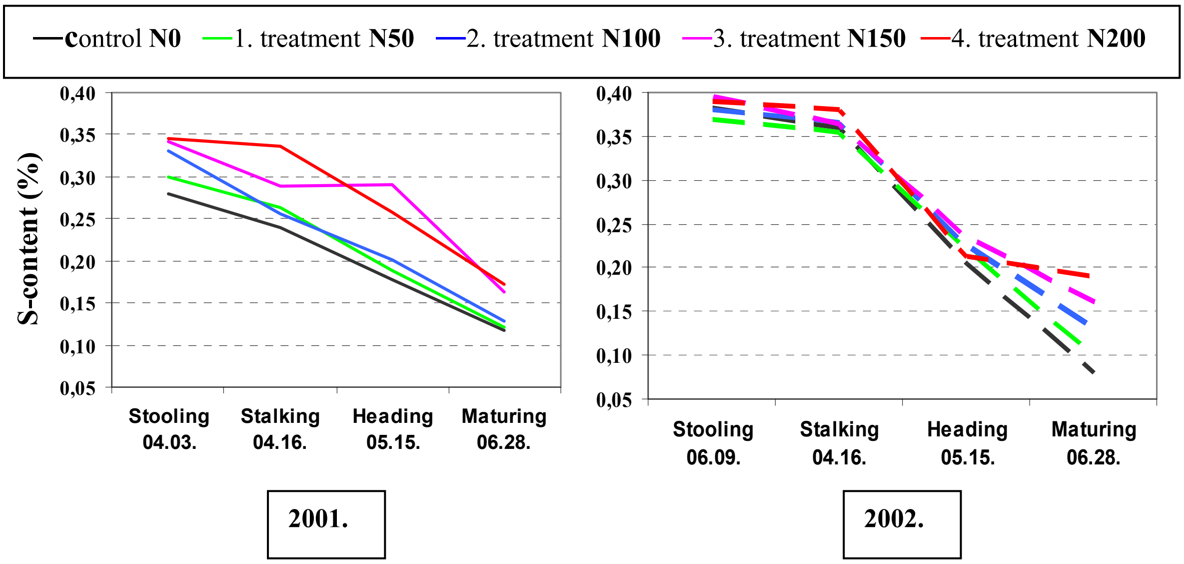


Figure 3: The effect of fertilizer treatments on the sulphur content of wheat samples gathered in different growth stages on irrigated plots
Ruzsányi L. NPK-treatment (Debrecen-Látókép, 2001; 2002)

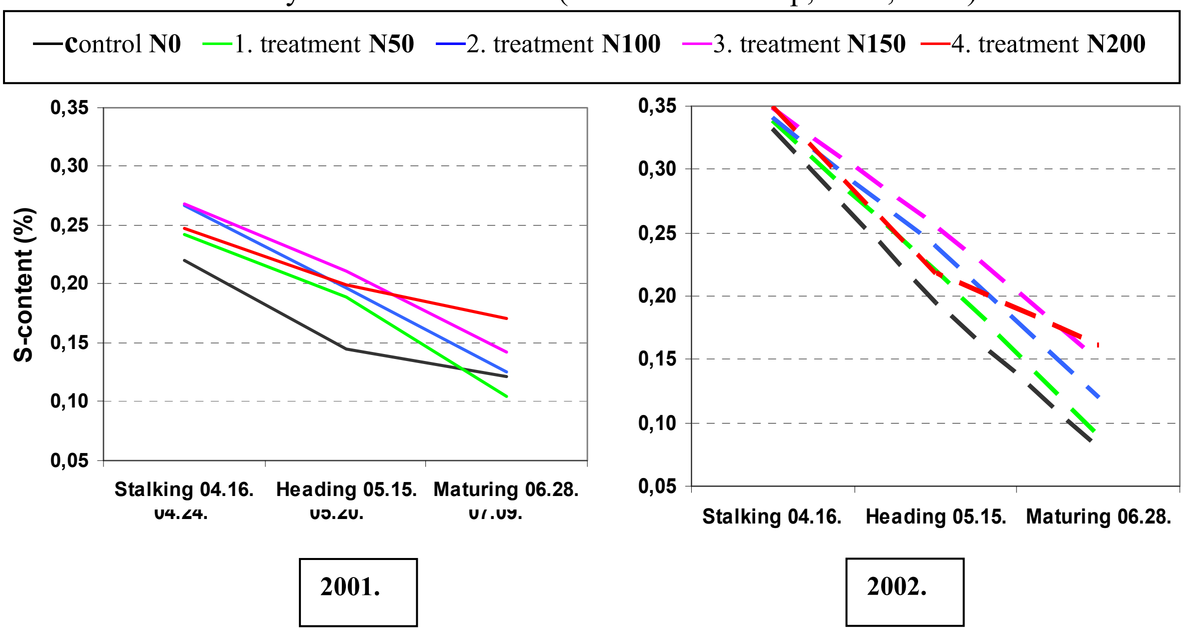


Figure 4: The effect of fertilizer treatments on the N/S ratio of wheat samples gathered in different growth stages on non-irrigated plots
Ruzsányi L. NPK-treatment (Debrecen-Látókép, 2001; 2002)

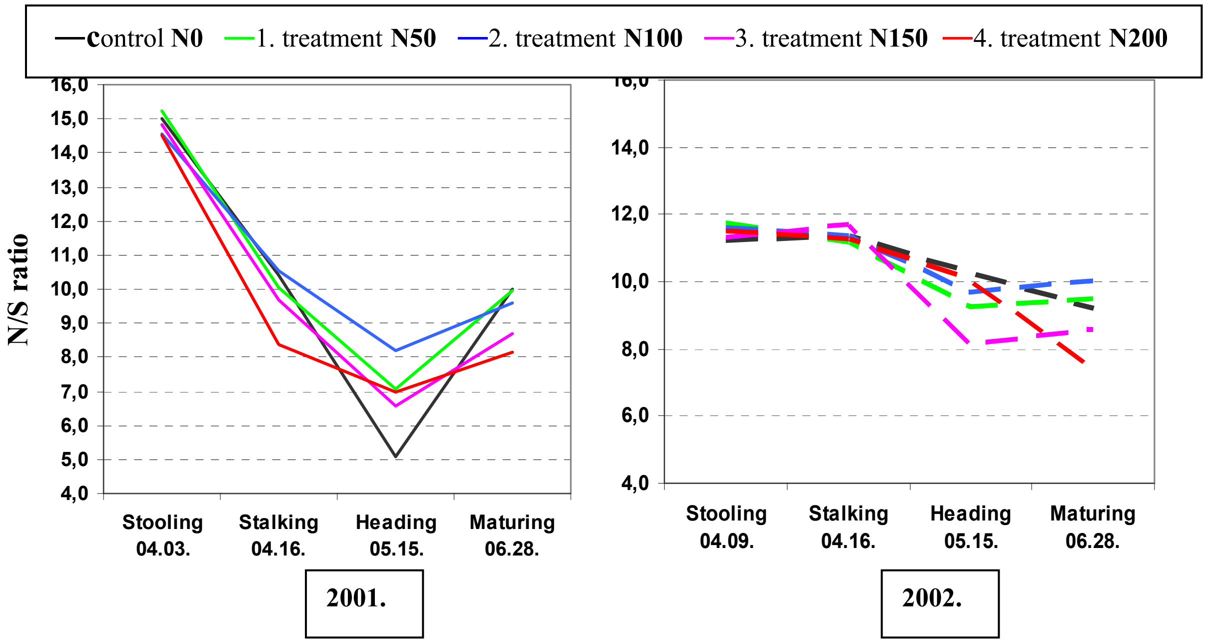
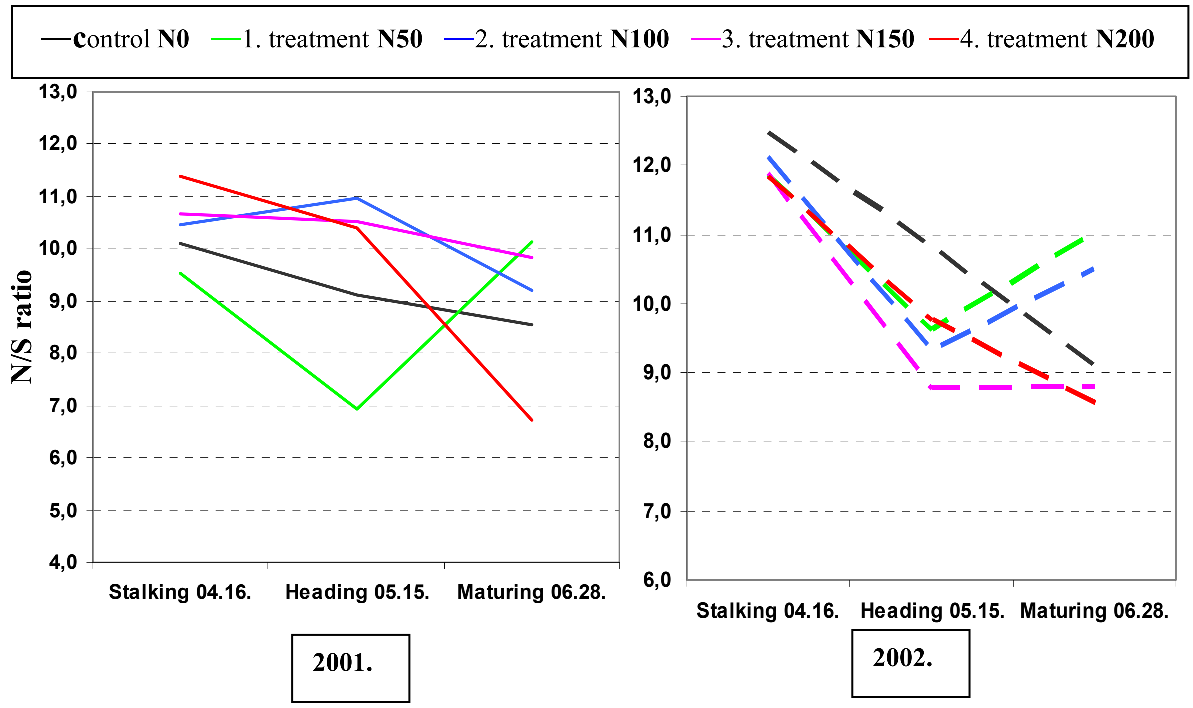


Figure 5: The effect of fertilizer treatments on the N/S ratio of wheat samples gathered in different growth stages on irrigated plots
Ruzsányi L. NPK-treatment (Debrecen-Látókép, 2001; 2002)



3.2.Small plot sulphur fertilization experiment

The application of different doses of FitoHorm 32 liquid fertilizer had no statistically proved influence on the change of the sulphur content in either growth stage. Similarly, clear increase or decrease in the sulphur content was not found in any of the growth stages. Out of the examined growth stages, the application of the product had significant effect on the nitrogen content of wheat in the heading and flowering stage (P=5%). The change in the N/S ratio caused by the application of FitoHorm 32 S was statistically proved in the stalking and heading and flowering stages (P=0.01; P=05%) (*Table 5*).

Table 5. The effect of sulphur fertilization on the mean and deviation values of the nitrogen and sulphur content and the N/S ratio of wheat
*S*ulphur fertilization experiment *(Debrecen-Látókép, 2002)*

Growth stage	Treatment: NPK (100/70/80) + FitoHorm 32 S	**N (%)**		**S (%)**		**N/S**	
Stooling	0 l/ha FitoHorm 32 S	**4,46**	0,09	**0,31**	0,01	**14,24**	0,05
	2 l/ha FitoHorm 32 S	**4,39**	0,19	**0,31**	0,02	**13,55**	0,66
	4 l/ha FitoHorm 32 S	**4,21**	0,10	**0,30**	0,01	**13,86**	0,61
	SD 5%	***0,21***		***0,03***		***0,92***	
Stalking	0 l/ha FitoHorm 32 S	**3,66**	0,10	**0,35**	0,01	**10,68**	0,19
	2 l/ha FitoHorm 32 S	**3,56**	0,03	**0,33**	0,02	**10,33**	0,11
	4 l/ha FitoHorm 32 S	**3,73**	0,11	**0,36**	0,03	**9,72**	0,03
	SD 5%	***0,14***		***0,03***		***0,21****	
Heading and flowering	0 l/ha FitoHorm 32 S	**1,94**	0,02	**0,20**	0,01	**9,61**	0,51
	2 l/ha FitoHorm 32 S	**1,91**	0,01	**0,19**	0,02	**10,84**	0,16
	4 l/ha FitoHorm 32 S	**1,79**	0,10	**0,21**	0,03	**8,19**	1,38
	SD 5%	***0,10****		***0,03***		***1,37****	
Maturing	0 l/ha FitoHorm 32 S	**1,30**	0,06	**0,15**	0,02	**9,24**	1,23
	2 l/ha FitoHorm 32 S	**1,27**	0,00	**0,15**	0,01	**8,54**	0,12
	4 l/ha FitoHorm 32 S	**1,31**	0,08	**0,14**	0,01	**9,26**	0,21
	SD 5%	***0,11***		***0,02***		***1,36***	

*Significance levels: *P=5%, **P=1%, ***P=0,1%;*

As regards the certain plant parts, the application of different doses of FitoHorm 32 S had no statistically proved influence on the nitrogen and sulphur content and N/S ratio of wheat stem samples.

Examining the leaf samples we found that the application of FitoHorm 32 S had statistically proved influence (P=1%) on the nitrogen content in the last sampling phase (from 0.64% to 0.80%) and on the sulphur content in the heading and flowering stage (from 0.32% to 0.43%). Out of the qualitative parameters the influence of the application of different doses of FitoHorm 32 S on the wet gluten content was statistically proved at P=0.01 %, i.e. compared to the control treatment (30.7%) the application of 2 litre/ha FitoHorm 32 S increased the wet gluten content by 2% (32.7%), while the application of 4 litre/ha FitoHorm 32 S increased it by 3.8% (to 34.5%). As regards the rheological experiments (farinograph), the dough formation time was significantly influenced by sulphur fertilization (P=1%). The dough stability time also increased as a result of increasing doses of the fertilizer, the diagram width decreased. I found that the application of sulphur fertilization had statistically proved influence on the departure time of the farinograph curve (P=5%). Similarly, significant effect was proved for baking values of wheat (P=1%). The baking value of the wheat samples from the control plots where no FitoHorm 32 S was applied was 61. The application of 2 and 4 l/ha FitoHorm 32 S increased this value to 62 and 78, respectively. FitoHorm 32 S had no statistically proved effect on the crop yield.

The application of superphosphate, which has been the most commonly used phosphorus fertilizer for decades, in two doses had no significant effect on the sulphur content in either of the growth stages. The application of superphosphate in double doses had statistically proved influence on the nitrogen content in the stooling and maturing stages. The application of double dose superphosphate resulted in decreased N/S ratio in the growth stages, although the effect was only significant in the maturing stage (P=1%)(from 9.68 to 7.87%).

As regards the element content of winter wheat samples, I found that a unique tendency similar in each examined growth stage can be drawn only in the case of sulphur content; on plots treated with higher doses of phosphorus fertilizers the sulphur content was higher. As regards the N/S ratio, there was statistically proved difference (P=1%) in the heading and flowering stage. According to my calculations, the application of double dose phosphorus active agent component had no statistically proved influence on the nitrogen and sulphur content of leaf samples in either growth stage. The phosphorus fertilizers applied in two different doses significantly increased the gluten index (P=5%), i.e. the increase of the superphosphate dose strengthened the gluten structure. As regards the rheological characteristics I found that the increase of the superphosphate dose influenced the baking quality at P=5% significance level. In the first treatment the baking quality was equal to 66 FE, which decreased to 60 FE in the second treatment.

Similar to the findings about FitoHorm 32 S, even double dose application of superphosphate had no significant effect on the water absorbance. Besides applying 100 kg/ha nitrogen active agent component and 80kg/ha potassium active agent component, the application of 70 kg/ha and 140 kg/ha phosphorus active agent in the form of superphosphate in the first and second treatment respectively significantly influenced the crop yield.

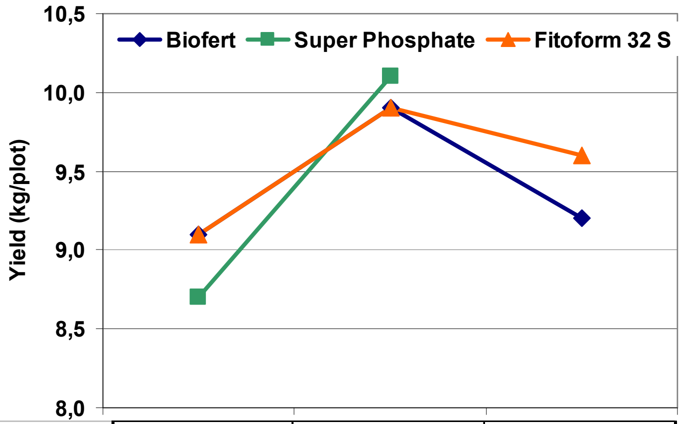
The third product of which effect was examined in the Látókép small plot experiment was Biofert, a by-product of lysine production. I found that the application of different doses of

Biofert had no statistically proved influence on the nitrogen content and N/S ratio in either growth stage. As regards the sulphur content results I found that only in the stalking stage caused the application of Biofert significant difference in the sulphur content of the samples from different treatments.

The analysis of the wheat stem revealed that only in the whole growth stage had Biofert statistically proved effect on the parameters (N=0.96%; S=0.14%; N/S=6.74). As regards the leaf stems, Biofert increased the nitrogen content in the heading and flowering stage but the difference between the measuring values was not significant. However, the effect of Biofert was statistically proved in the whole growth stage, where the increasing doses of the product decreased the nitrogen content of leafs (from 1.19% to 0.81%). As regards the sulphur content, I would emphasize the samples from the heading and flowering stage, where Biofert had statistically proved influence (P=5%) on the examined element. The lowest sulphur content (30%) was measured at leaf samples from the second stage, the highest sulphur content (0.35%) was measured at samples from the first treatment. As regards the N/S ratio, the application of Biofert had no statistically proved difference between the treatments in the different growth stages.

We found statistically proved difference between the sulphur content of the ear samples gathered in the heading and flowering stage (P=0.1%). The highest sulphur content was measured at samples from the highest Biofert dose treatment (0.21%). The nitrogen content of samples gathered in the heading and flowering stage decreased and had a tendency. As regards the baking quality parameters, the application of Biofert decreased the wet gluten quantity. Compared to the control results, I found that the gluten index decreased (from 33.6 % to 30.9%) but the results were not statistically proved. The dough formation period decreased but it was not significant. The product had statistically proved influence (P=1%) on the dough deformation time and the baking value. According to my calculations, the drop of the baking value of the sample (from 75 to 63) was caused by the decrease in the degree of dough deformation, thus the sample ranked a lower baking quality category. Biofert had no statistically proved influence on product yields. The highest crop yield per ha was measured in the 5 l/ha dose treatment. Table 6 summarizes the effect of each sulphur fertilizer used in the experiment on the crop yield.

Figure 6: The effect of increasing doses of Biofert, superphosphate and FitoHorm 32 S on crop yield; Sulphur fertilization experiment (Debrecen-Látókép, 2002)



	Control	Treatment 1	Treatment 2
Biofert	0 l/ha	5 l/ha	7,5 l/ha
Super Phosphate	100/70/80 NPK	100/140/80 NPK	_
Fitohorm 32 S	0 l/ha	2 l/ha	4 l/ha

3.3 On-farm experiment

In the stooling stage in 2002, the increasing sulphur fertilizer doses had no statistically proved effect on any of the examined wheat part parameters (N, S, N/S). In 2003, on plots where fertilizer was used the nitrogen and sulphur content was higher in each case and the differences were statistically proved (P=1%).

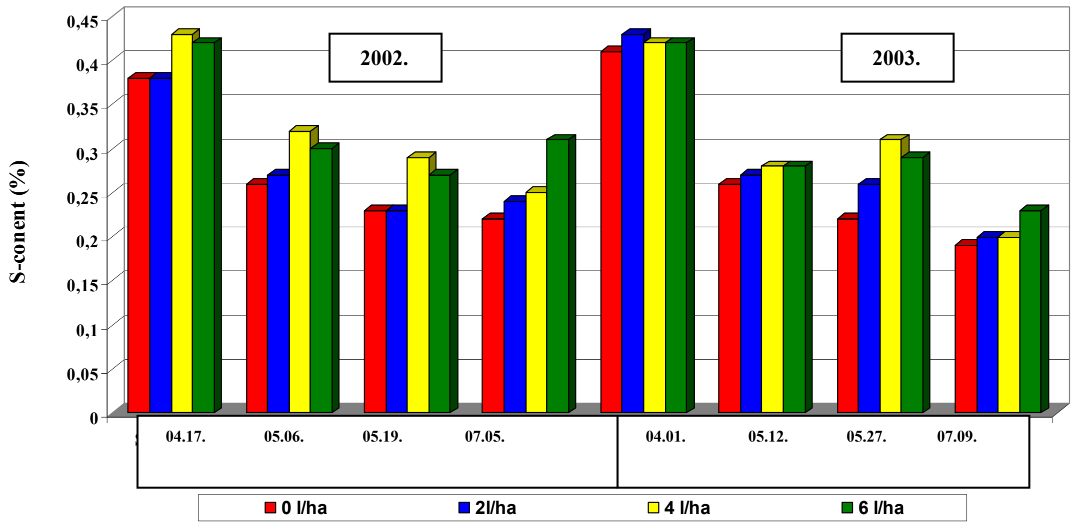
In 2002 in the stalking stage the increasing doses of FitoHorm 32 S increased the concentration of both examined elements. The maximum nitrogen content (2.80%) was measured when 6 l/ha foliar fertilizer was applied. The maximum average sulphur content (0.32%) was measured when 4 l/ha foliar fertilizer was applied. According to the one factor variance analysis the product had significant influence on all three examined parameters (P=0.1%). In 2003, as regards the data gathered in the second research year only on the N/S ratio had the product significant influence (P=5%). The maximum nitrogen (3.01%) and sulphur content (0.28) was measured in treatments when 4 l/ha and 6 l/ha doses had been applied. The N/S ratio was also highest in those treatments when 4 l ha sulphur had been applied (max. 10.76%).

In 2002 in the heading and flowering stage the increasing doses of FitoHorm 32 S increased the nitrogen content. The 1.90 % nitrogen content measured in the control treatment increased to 2.19 % as the result of applying 4 l/ha foliar fertilizer. The tendency of the sulphur data in the same year can also be characterized by an optimum-curve with the maximum at 0.29% in the second treatment. Next year, both the nitrogen and sulphur values reached their minimum in the control treatment and reached their maximum in the second treatment.

In 2002, the changes in the sulphur content of the whole plant samples were statistically proved (P=5%9 in the whole growth stage. The FitoHorm treatments had no statistically proved effect on either the nitrogen or the sulphur content in the second treatment. The treatments increased the N/S ratio (P=5%).

The complex analysis of the whole plant samples gathered in the whole growth stage in both years (*Figure 7*) revealed that 4 l/ha Fitororm 32 S in the stooling, stalking and heading and flowering stages and 6 l/ha FitoHorm 32 S in the whole growth stage resulted the highest sulphur content.

Figure 7: The sulphur content of the whole wheat plant as an effect of FitoHorm 32 S treatments (Felsőzsolca; 2002, 2003)



In 2002 in the stalking stage the sulphur fertilization statistically proved the concentration and the ratio of both elements. The increase in the nitrogen content was linear as result of the treatment, the smallest nitrogen content (1.58%) was measured at samples from the control treatment, while the highest nitrogen content (1.79%) was measured at samples from the third treatment. The increase of the sulphur content was achieved the highest sulphur content (0.20%) when 4 l/ha foliar fertilizer was applied. In the second year the foliar treatment had no significant influence on the nitrogen and sulphur content or the N/S ratio of the stem according to the variance analysis. The increase of the nitrogen and sulphur content was linear. The average sulphur content in the control and third treatment was 0.19 % and 0.21 %, respectively. When analysing the nitrogen and sulphur content according to the crop year we found that the values were higher at stem samples gathered in the year of 2003. The variance analysis of the samples gathered in the heading and flowering stage in 2002 showed that the application of increasing amounts of FitoHorm 32 S had no statistically proved influenced on any of the examined parameters. The nitrogen content increaed and reached its peak in the 4 l/ha foliar fertilizer treatment (1.47%). The next year the increase of the nitrogen content was statistically proved (P=0.1%), the sulphur content increased. In 2003 no tendency was found in the change of the N/S ratio of the stem, however, statistically proved difference (P=5%) was found between the mean values of the plots where different treatments have been conducted.

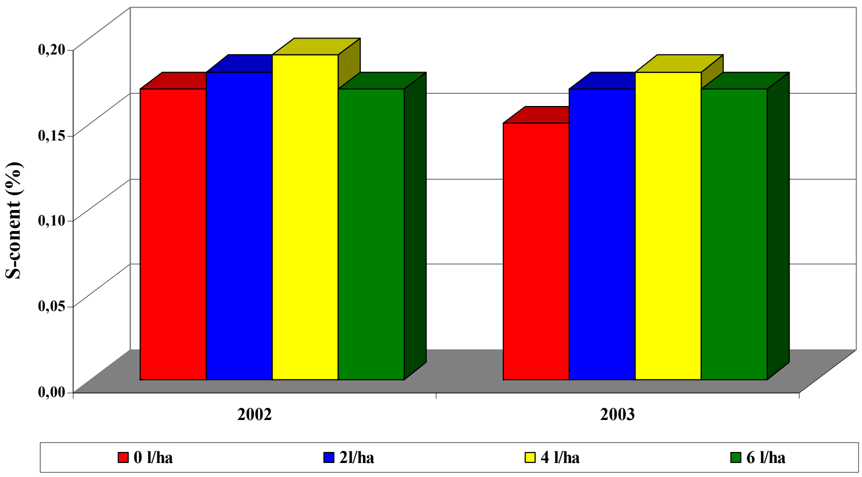
Examining the tendency of the year effect I found that as regards the sulphur content, the mean values of the treatments were higher in 2003, while as regards the nitrogen content the values in 2002 were higher, except from the third treatment. In 2002 in the maturing stage only the sulphur content of the stem showed clear linear increase (P=5%). However, when examining the N/S ratio in the second research year, significant difference was found between the mean values of the single fertilizer doses (P=0.1%). The nitrogen content data were higher in 2003 and the sulphur content was higher in 2002. Accordingly, the values representing narrower N/S ratio can be found in the first year, while those representing wider N/S ratio can be found in the second year.

In the first research year, FitoHorm 32 S foliar treatments had statistically proved influence on the nitrogen content of samples gathered in the stalking stage (P=5%). The sulphur content increased (by 0.53% in the second treatment), the difference between the mean values was statistically proved. Linear increase was found in the nitrogen content in the samples gathered the following year, as regards the sulphur content (P=0.1%) the minimum value of the data set was in the first treatment while the maximum was in the second treatment at 6 l /ha sulphur dose. Comparing the results according to the crop year we found that the nitrogen and sulphur content of the samples gathered in 2002 was in each case higher than those gathered in 2003.

When analysing the nitrogen and sulphur content of leaf samples gathered in the heading and flowering stage we found statistically proved increase in the element contents in both cases in the first year as a result of increasing doses of FitoHorm 32 S (P=1%). The increase of the concentrations shows linear trend until the second treatment (from 2.74% to 3.63 %), then the intensity declines. In 2003 the leaf analysis revealed that the nitrogen content linearly increased. The lowest sulphur content was measured in the control treatments (2.06%) and the highest concentrations were found at samples treated with 4 l/ha doses (3.09%). The N/S ratio was lowest in the control parcels (6.17%), the highest ratio was found in the third treatment (6.87%).

In the maturing stage the foliar treatments had statistically proved influence on the nitrogen content of the leaf samples (from 2.40 % to 2.77%) and increased the sulphur content (from 0.43% to 0.65%). Similar to the first year, in the second year the nitrogen content showed linear increase as a result of increasing doses of foliar fertilization and the sulphur concentration reached its maximum (0.29%) in the second treatment. In each treatment the nitrogen content of the leaf was higher in the first year, as regards the sulphur content the differences seem even higher. In the ears, the application of different doses of FitoHorm 32 S resulted statistically proved differences between the mean N values in the treatments (P=1%), and the tendency of the increase was linear (*Figure 8.*). Accordingly, the lowest nitrogen content was measured in case of the ear samples from untreated plots (2.06%), while the highest nitrogen content was found at the third treatment (2.32%). The application of different doses of Fitohorm 32S caused statistically proved difference between the mean N content values in wheat ear samples in the treatments and the increase is linear (*Figure 8.*). The change in the N/S ratio was not statistically proved in either of the research years.

Figure 8: The nitrogen content in the wheat ear in the whole growth phase
(Felsőzsolca, 2002, 2003)



In the first research year the application of different doses of FitoHorm 32 S had significant influence (P=1%) on the baking value. On each of the sulphur-treated plots the baking quality clearly improved (*Figure 10.*) Examining the laboratory samples I found that as a result of the treatment the samples rated A1 quality class from the feed grade. The application of FitoHorm 32 S also had statistically proved influence on the wet gluten content (A1 quality). The tendency of the examined parameter can be presented, thus the wet gluten content (48.4%) reached its maximum on plots treated with 4 l/ha dose (*Figure 10*).

Figure 10: Baking quality and wet gluten content as a result of FitoHorm 32 S treatments (Felsőzsolca ; 2002, 2003)

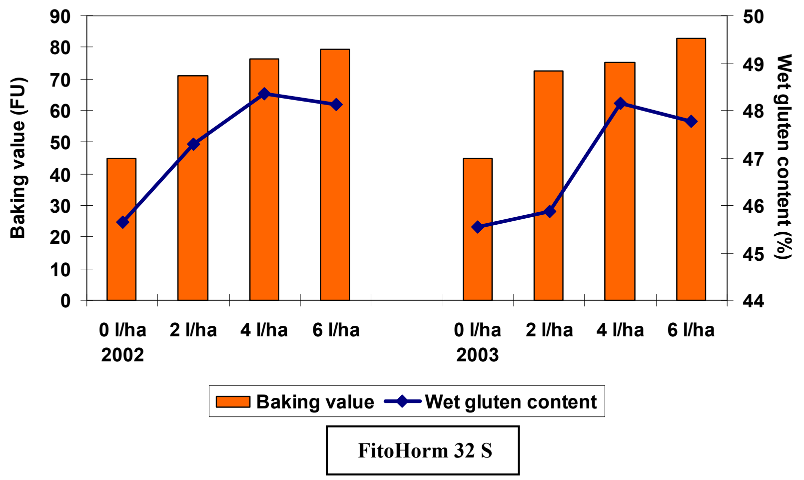
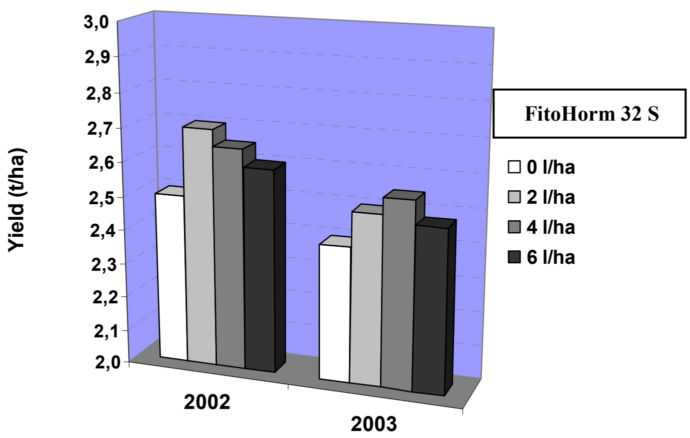


Figure 11: The effect of sulphur fertilization on the crop yield of winter wheat (Felsőzsolca, 2002; 2003)



4. New scientific results

1. The sulphur content and N/S ratio of the whole wheat plant without the root was as follows:

in the stooling stage S=0.30-0.38% N/S=11.73-14.47

in the stalking stage S=0.24-0.36% N/S=8.38-12.10

in the heading stage S=0.19-0.29% N/S=8.19-10.97

in the maturing stage S=0.13-0.15% N/S=7.84-9.54

The same data on unstable meadow soil in Felsőzsolca was as follows:

in the stooling stage S=0.38-0.43% N/S=10.53-11.57

in the stalking stage S=0.27-0.32 N/S=9.32-10.76

in the heading stage S=0.23-0.29% N/S=7,00-9.16

in the maturing stage S=0.20-0.31% N/S=7.04-10.18

2. Examining the single plant parts the following sulphur content and N/S data were gathered: in Látókép the sulphur content

of the stem:

in the stalking stage: S=0.19-0.21% N/S=11.73-13.00

in the heading stage S=0.13-0.15% N/S=7.64-9.03

in the maturing stage S=0.13-0.16% N/S=3.50-5.00

the element content of the leaf:

in the stalking stage S=0.36-0.38% N/S=10.60-10.88

in the heading stage S=0.32.0.43% N/S=8.15-8.82

in the maturing stage S=0.14-0.17% N/S=3.88-6.15

the element content of the ear:

in the heading stage S=0.19-0.20% N/S=9.53.10.10

in the maturing stage S=0.15-0.16% N/S=13.22-14.11

In Felsőzsolca the sulphur content of the stem:

in the stalking stage S=0.19-0.21% N/S=8.40-11.00

in the heading stage S=0.19-0.24% N/S=6.24-7.79

in the maturing stage S=0.16-0.27 N/S=4.64-6.70

the sulphur content of the leaf:

in the stalking stage S=0.30-0.53% N/S=7.38-10.50

in the heading stage S=0.39-0.48% N/S=6.20-8.28

in the maturing stage S=0.28-0.65% N/S=4.63-8.66

the sulphur content of the ear:

in the maturing stage S=0.17-0.19%; N/S=11.44-12.74

3. As an effect of systematic irrigation, the sulphur content of the samples decreased in the stalking and heading and flowering stages; according to the crop year the irrigation influenced the sulphur content in the stalking and heading and flowering stages.
4. In the stalking stage both in irrigated and non-irrigated circumstances we found that the sufficient NPK-fertilizer dose can moderate the influence of the crop year on the sulphur content.
5. On calcerous chernozem soil in the Hajdúság loess region the application of FitoHorm 32 S in 4 l/ha dose increased the wet gluten content of wheat samples (P=0.01%) and the baking value (P=0.1%) compared to the control treatment. Accordingly, sulphur fertilization is reasonable to be included in the technology of quality wheat production, contrary to 2.
6. Sulphur fertilization has positive influence both on the crop yield and quality. The effect is even more emphasized in draughty years, thus the application of foliar fertilizers is especially reasonable in those crop years.

5. Practical results

1. We recommend to include sulphur fertilization in the technology of quality wheat production, and to include the estimation of sulphur supply and the implementation of practical sulphur fertilization in agricultural consultancy.

2. According to my findings the application of 4 l/ha FitoHorm 32 S increased the wet gluten content of wheat samples and improved baking quality, rating the samples A1 from B1 category. On the basis of this effect, FitoHorm 32 S sulphur fertilizer should be used in cases where increased superphosphate is applied, thus counterweighing the depressing effect of superphosphate on the crop yield. High crop yield and improved baking quality can be reached if 100/140/80 kg/ha NPK active agent 4 l/ha FitoHorm 32 S foliar fertilizer is applied together.

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