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FERTILISATION MANAGEMENT OF WHEAT CONTAMINATED WITH *FUSARIUM GRAMINEARUM* AT ALBOTA AGRICULTURAL DEVELOPMENT AND RESEARCH STATION, ARGES COUNTY, ROMANIA

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Abstract

As it is well known, Romania is an important cultivator and producer of wheat in the European Union. Due to the pedo-climatic conditions that our country has, wheat is found in all development regions, and especially in the South-Muntenia Region. Here, in 2020, 602,794 ha were cultivated, representing 28% of Romania's total area cultivated with wheat. The production obtained was 1,753,248 tons, and accounted for 27% of Romania's total wheat production. Unfortunately, this crop faces diseases and pests that can affect plant nutrition and development, and ultimately influences indicators such as the average production and total production. Contamination of cereals with toxic fungal metabolites is one of the main problems of contemporary agriculture. Fusarium species are the most dangerous pathogens of cereals and have a high level of toxicity. These metabolites are the main cause of the development of cereal fusarium (FHB). Under the existing natural conditions at Albota-Pitesti Agricultural Research and Development Station (ARDS), Arges County the paper presents several studies on the mineral nutrition of winter wheat subject to the risk of contamination with Fusarium toxins. It should be noted that the types of soil on which the experiments were performed were Vertic Luvisols. Five winter wheat varieties were selected for testing: Delabrad, Dropia, Faur, Glosa and Gruia. The phenophases in which the mineral nutrition of the plants was characterized with macro and micronutrients, were those of the ear emergence-flowering.

Key words**:** *fertilisation, Fusarium toxins, Romania, wheat area and production*

INTRODUCTION

The main metabolites of microscopic fungi are mycotoxins. Cereals, cereal products, and food are contaminated by them [3], [4], [5].
In global agriculture, one of the current problems is the contamination of cereals with toxic fungal metabolites (pathogens and saprotrophs) [11].
The pathogens of cereals, which have a high level of toxicity and a high degree of danger are the species of *Fusarium*. Fumonisin B1 and deoxynivalenol, secondary metabolites of these fungi, are the most widespread mycotoxins in Europe and worldwide. The presence of these metabolites in grains is the main cause of development of Fusarium head blight [7], [10], [12], [13] [17], [18], [19].
Named in the interwar period "grânarul Europei/the granary of Europe", Romania was also in 2020 a popular wheat grower. Thus, according to Eurostat, Romania ranked 4th in terms of the area cultivated with this cereal and 6th in the category of total wheat

production. Unfortunately, the average production placed our country towards the end of the ranking [8]. It is known that this indicator, mentioned above, is directly influenced by the applied cultivation technologies, by the pedo-climatic conditions and by the presence of diseases or pests, among which *Fusarium graminearum* stands out. This pathogen causes the appearance of the well-known and destructive disease called ear fusarium wilt, which is manifested by: inducing the sterility of the inflorescences, which means reducing the number of grins in the wheat ear, poor filling and thus reducing the size of the grains [1] (Fig. 1).

Photo 1. Attack of *Fusarium graminearum*
Source: [1].

Of course, all this leads to a decrease in production and crop quality [6].
The experiments presented in this paper were made at ADRS Pitesti-Albota (Agricultural Development Research Station Pitesti-Albota). Among the research areas of this institution we mention: integrated management of field crops protection, study of biology and damage caused by diseases and pests to field crops, new methods of control and prevention for them [20].
ADRS Pitești-Albota is located in the South-Muntenia Region, in Argeș County (Map 1). Although the South-Muntenia Region was the main wheat grower and producer in the country, Argeș County did not stand out by obtaining significant quantities of cereals.

Map 1. The position of ARDS Pitești, Albota in Romania
Source: [14].

Thus, at the level of 2020 it owned only 8% of the total wheat production obtained in the Region.

MATERIALS AND METHODS

In the experimental plots from ADRS Pitești, Albota, five varieties of wheat susceptible to the attack of *Fusarium graminearum* were tested. Varieties were tested on fertilized plots with the next doses (kg active ingredients / ha): $N_0P_0K_0$ and $N_{90}P_{80}K_0$. The wheat varieties were: Delabrad, Dropia, Faur, Glosa and Gruia.
From the arable layer of these experimental plots, soil samples were collected and analyzed and at the same time samples were extracted from the plants in the stages of the ear emergence-flowering.
The following analyzes were performed from the soil samples: total nitrogen (Nt), available phosphorus (P_{AL}), available potassium (K_{AL}), soil reaction (pH) and total humus (Ht). The soil type in the experiment was Vertic Luvisols.
The dry matter of the aerial parts of the plants was subjected to the following analyzes: determination of the content of micronutrients (Mn, Fe, Zn, Cu) and macronutrients (Mg, N, P, K). All analyzes were performed according to the RISSA methodology and the results obtained were interpreted in comparison with

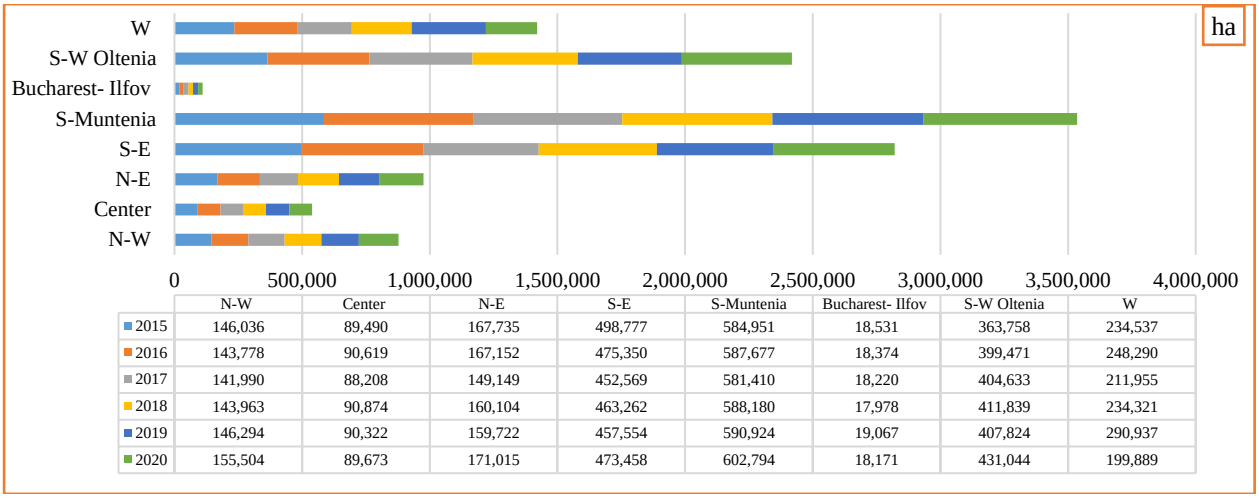
some optimal limits in the literature [2], [15], [16].

For the statistical analysis presented in the paper, the data extracted from the Eurostat and NIS sites were used and the analyzed indicators were the following: the total cultivated area and the total wheat production in Romania, for the 8 Regions and for the South-Muntenia Region, in the period 2015-2020.

RESULTS AND DISCUSSIONS

The data provided by Eurostat shows that in 2020 Romania was ranked on the fourth place in the top wheat-growing countries in the European Union, after France, Germany and Poland. Also in the same year, it ranked sixth in total wheat production, after countries such as: France, Germany, Poland, Spain and Italy. Thus, Romania owned 10.97% of the cultivated area with wheat and 5.1% of the total wheat production achieved in the European Union [8].

Figure 1 shows the areas cultivated with wheat, in Romania, by Development Regions. It is observed that in the South-Muntenia Region were found the largest areas in each year of the analyzed period, 2015-2020. Other important cultivating regions were: South-East and South-West Oltenia.



	N-W	Center	N-E	S-E	S-Muntenia	Bucharest- Ilfov	S-W Oltenia	W
2015	146,036	89,490	167,735	498,777	584,951	18,531	363,758	234,537
2016	143,778	90,619	167,152	475,350	587,677	18,374	399,471	248,290
2017	141,990	88,208	149,149	452,569	581,410	18,220	404,633	211,955
2018	143,963	90,874	160,104	463,262	588,180	17,978	411,839	234,321
2019	146,294	90,322	159,722	457,554	590,924	19,067	407,824	290,937
2020	155,504	89,673	171,015	473,458	602,794	18,171	431,044	199,889

Fig. 1. Dynamics of wheat cultivated areas in Romania, in the period 2015-2020
Source: [9].

Analyzing the situation in the main wheat-growing regions, we can conclude that the areas destined for this crop increased for South-Muntenia by 103.05% and for South-West Oltenia by 118.50%, and for the South-East Region decreased by 5.08%.

In 2020, the percentage of the most important wheat-growing regions was as follows: South-Muntenia Region - 28%, South-East Region - 22% and South-West Oltenia Region - 20% (Figure 2). The other Regions together accounted for 30% of the total area sown with wheat in our country.

In the South-Muntenia Region, the main cultivator, the counties that made the biggest contribution to obtaining the first place in the ranking were Teleorman - 28% and Călărași - 21%. The percentage obtained by Argeș County, where the lands of ADRS Pitești-Albota are located, was among the lowest in the Region, of 8%.

The total wheat production harvested in the 8 Development Regions, in the period 2015-2020, is presented in Figure 3. In first place was the South Muntenia Region, followed by South-West Oltenia, South-East and West It can be seen that the total wheat production increased in the analyzed period in the South-West Oltenia Region by 136.36% and decreased in the South-Muntenia Region by 25.82%, in the South-East Region by 36.02% and by 18.38% in the West Region.

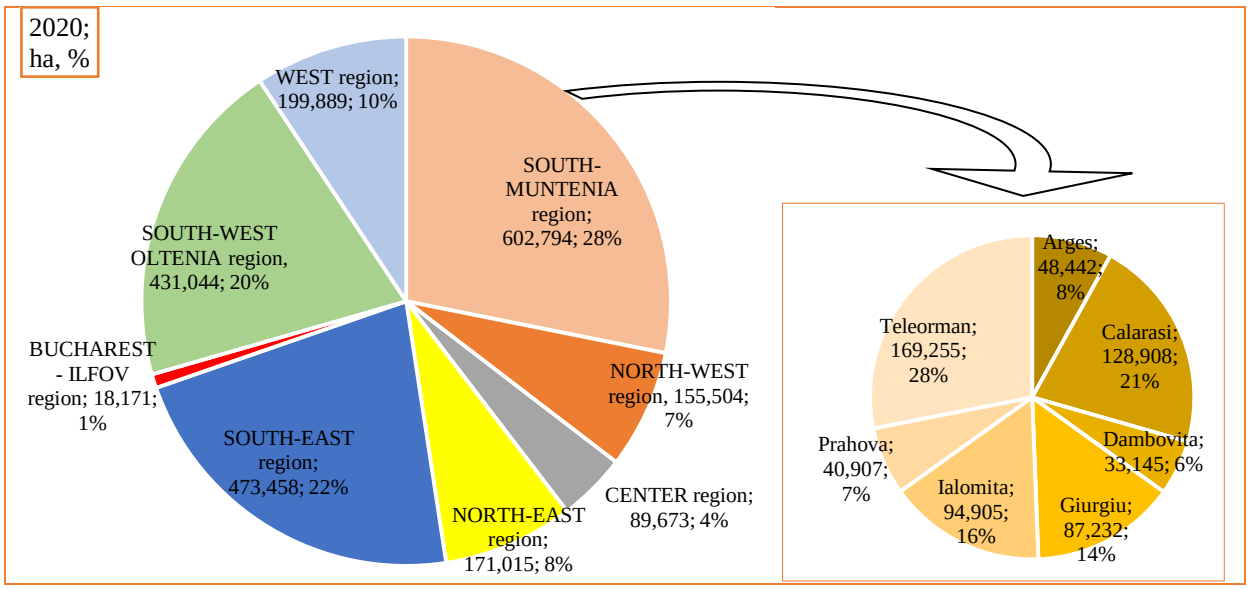
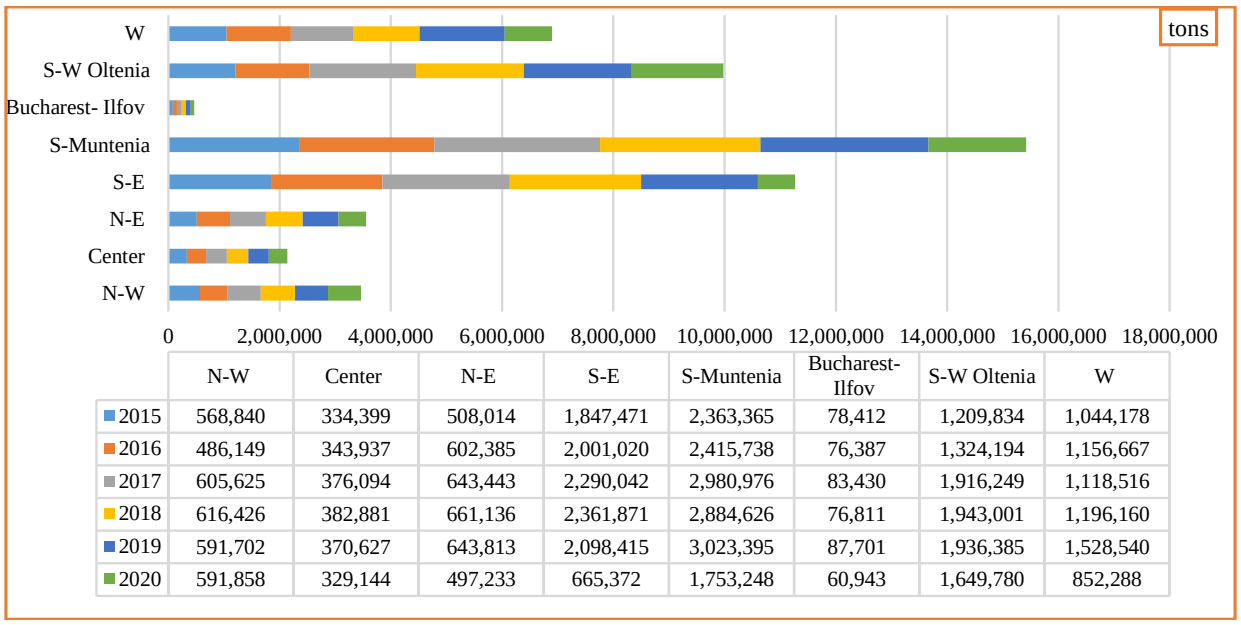


Fig. 2. Areas cultivated with wheat in Romania, by Regions and component counties, in 2020
Source: [9].



	N-W	Center	N-E	S-E	S-Muntenia	Bucharest-Ilfov	S-W Oltenia	W
2015	568,840	334,399	508,014	1,847,471	2,363,365	78,412	1,209,834	1,044,178
2016	486,149	343,937	602,385	2,001,020	2,415,738	76,387	1,324,194	1,156,667
2017	605,625	376,094	643,443	2,290,042	2,980,976	83,430	1,916,249	1,118,516
2018	616,426	382,881	661,136	2,361,871	2,884,626	76,811	1,943,001	1,196,160
2019	591,702	370,627	643,813	2,098,415	3,023,395	87,701	1,936,385	1,528,540
2020	591,858	329,144	497,233	665,372	1,753,248	60,943	1,649,780	852,288

Fig. 3. The dynamics of the total wheat production obtained in Romania, in the period 2015-2020
Source: [9].

In 2020, the percentage of the largest wheat-producing regions was the following: South-Muntenia Region - 27% and South-West Oltenia Region - 26% (Figure 4). The other Regions together accounted for 47% of the total wheat production obtained in our country.

In the South-Muntenia Region, the main producer, the counties that made the biggest contribution to obtaining the first place in the top were Teleorman - 41% and Giurgiu - 19%. The percentage obtained by Argeș County, was among the lowest in the Region, of 8%.

Regarding the average wheat production / ha, Romania does not register special yields. Thus, in 2020, our country ranked last in the European Union, with 2.96 tons / ha of wheat [8]. One of the important factors influencing yield is *Fusarium graminearum*, the pathogen that causes fusariosis.

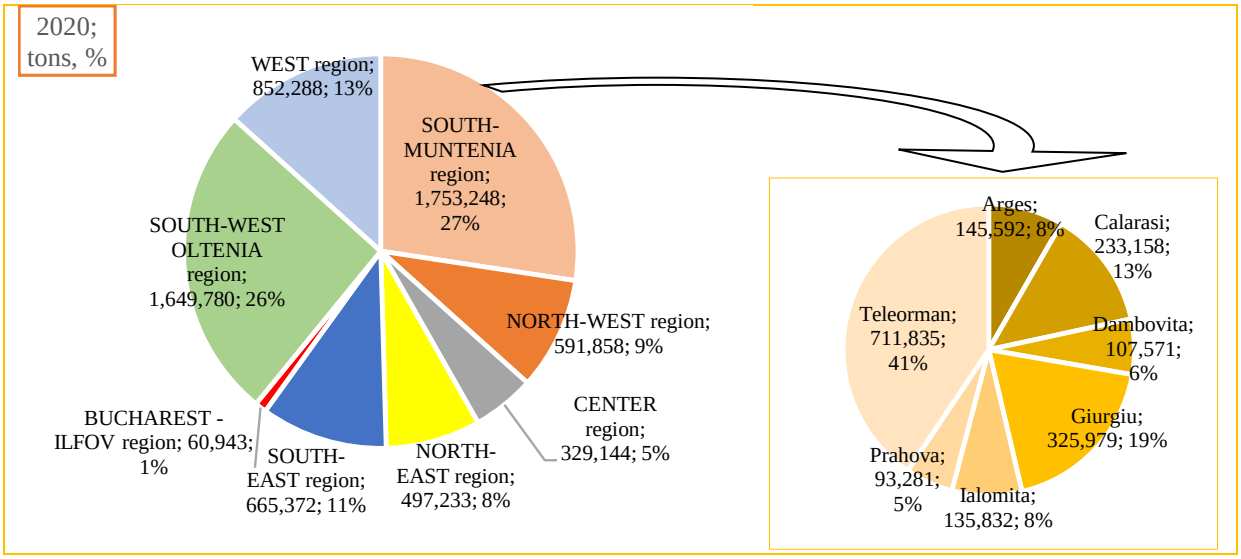


Fig. 4. The total wheat production obtained in Romania, by component Regions and counties, in 2020
Source: [9].

The following are aspects related to soil characterization from ARDS Pitești, Albota and characterization of the mineral nutrition status of wheat plants from the five varieties sensitive to the attack of *Fusarium graminearum*, in order to determine the factors that favor its appearance:

Characterization of the soil in the experiment

The characterization of the soil from ADRS Albota is presented in Table 1.

Table 1. The main agrochemical properties of soil from ADRS Albota

Soil fertilisation	Humus, %	Nt, %	pH $_{H2O}$	P_{AL}	K_{AL}
$N_0P_0K_0$	2.24	0.26	4.89	33.18	166.66
N_{90} $P_{80}K_0$	2.17	0.39	4.73	44.97	120.00

Source: own determinations.

The level of humus supply is low and the nitrogen supply is medium.

The mobile phosphorus content was high and the mobile potassium content was moderately-low.

The state of mineral nutrition of the plants in the experiment

The content of N (Figure 5) was within the limits of the optimal range.

Higher values of this nutrient has recorded on the parcel fertilised with $N_{90}P_{80}K_0$, as the effect of the high nitrogen rates applied in the soil.

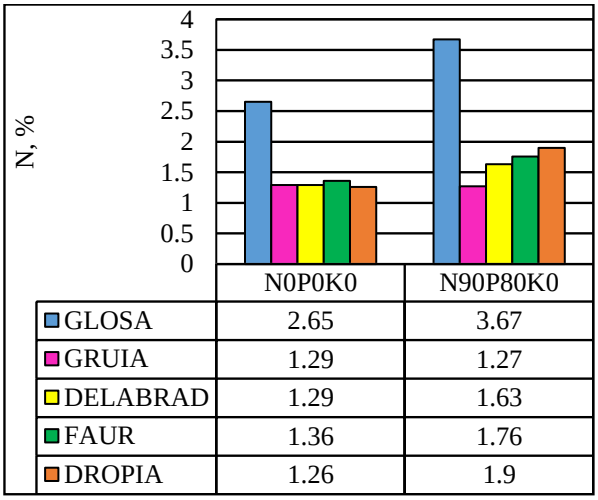
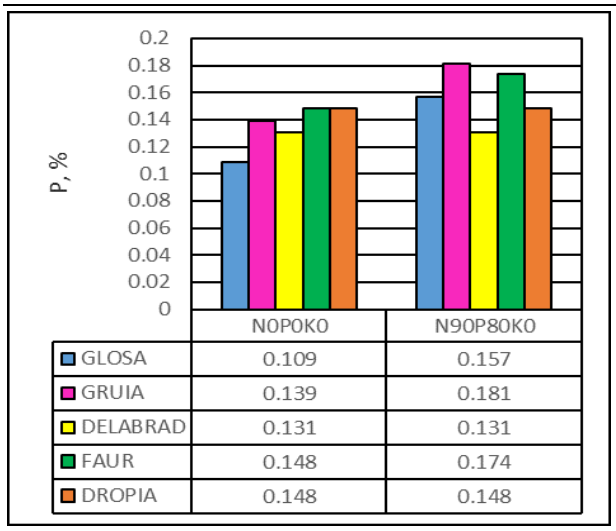


Fig. 5. The content of nitrogen in the aerial parts of winter wheat (ear emergence-flowering stage), ARDS Pitești, Albota
Source: own determinations.

Of the five wheat varieties analyzed, the highest percentage of N in the aerial parts of the plants was recorded in the Glosa variety - 3.67%.

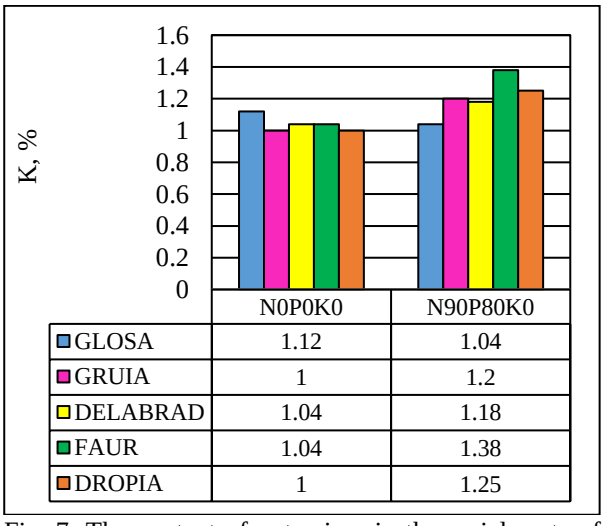
The contents of phosphorus, potassium and magnesium (Figures 6, 7 and 8) were below the limit of the optimal range, their accessibility to plants were reduced by low pH conditions, the acid reaction being one of the factors that favor the attack of *Fusarium graminearum* on wheat.



	N0P0K0	N90P80K0
GLOSA	0.109	0.157
GRUIA	0.139	0.181
DELABRAD	0.131	0.131
FAUR	0.148	0.174
DROPIA	0.148	0.148

Fig. 6. The content of phosphorus in the aerial parts of winter wheat (ear emergence-flowering stage), ARDS Pitești, Albota
Source: own determinations.

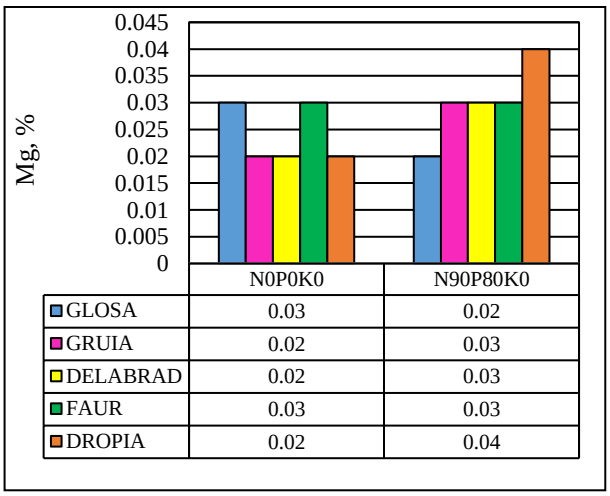
In general, the five varieties in the experiments responded well to fertilization with $N_{90}P_{80}K_0$.
The highest content in P was noted in Gruia - 0.181% (Figure 7).
In Delabrad and Dropia varieties no difference was observed between the 2 fertilization variants.
With the exception of the Glosa variety, the other varieties recorded higher values of K content also in the 2nd fertilization variant. At Faur we recorded the highest percentage of K - 1.38% (Figure 8).



	N0P0K0	N90P80K0
GLOSA	1.12	1.04
GRUIA	1	1.2
DELABRAD	1.04	1.18
FAUR	1.04	1.38
DROPIA	1	1.25

Fig. 7. The content of potassium in the aerial parts of winter wheat (ear emergence-flowering stage), ADRS Pitești, Albota
Source: own determinations.

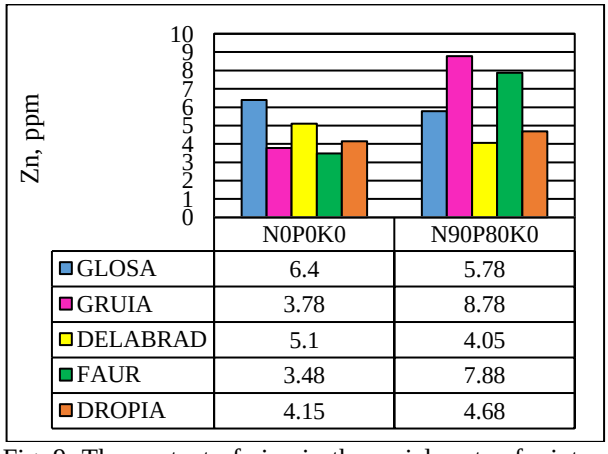
The Mg content did not differ much between the 2 fertilization variants (Figure 10).



	N0P0K0	N90P80K0
GLOSA	0.03	0.02
GRUIA	0.02	0.03
DELABRAD	0.02	0.03
FAUR	0.03	0.03
DROPIA	0.02	0.04

Fig. 8. The content of magnesium in the aerial parts of winter wheat (ear emergence-flowering stage), ARDS Pitești, Albota
Source: own determinations.

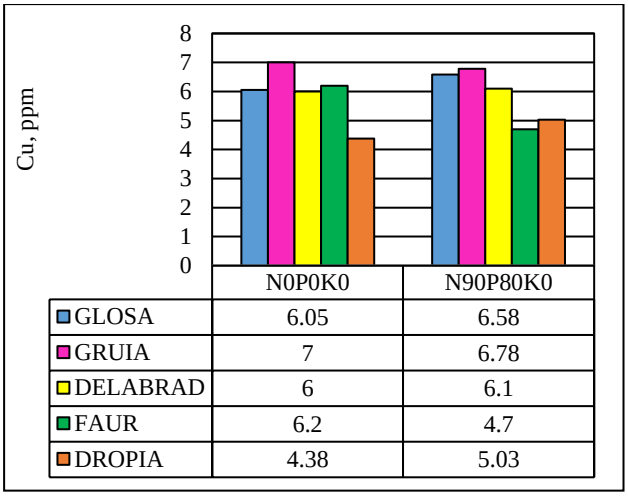
However, with the exception of Glosa and Faur varieties, the other varieties recorded slightly higher values of Mg content in the fertilization variant with $N_{90}P_{80}K_0$. In Dropia we recorded the highest percentage of Mg - 0.04%.
The Zn content (Figure 9) was below the optimum limit, which shows that the absorption of Zn in the plant is largely genetically controlled.
Supplementing plant nutrition with zinc is an important agricultural means to reduce the incidence of *Fusarium graminearum* attack on winter wheat crops.



	N0P0K0	N90P80K0
GLOSA	6.4	5.78
GRUIA	3.78	8.78
DELABRAD	5.1	4.05
FAUR	3.48	7.88
DROPIA	4.15	4.68

Fig. 9. The content of zinc in the aerial parts of winter wheat (ear emergence-flowering stage), ARDS Pitești, Albota
Source: own determinations.

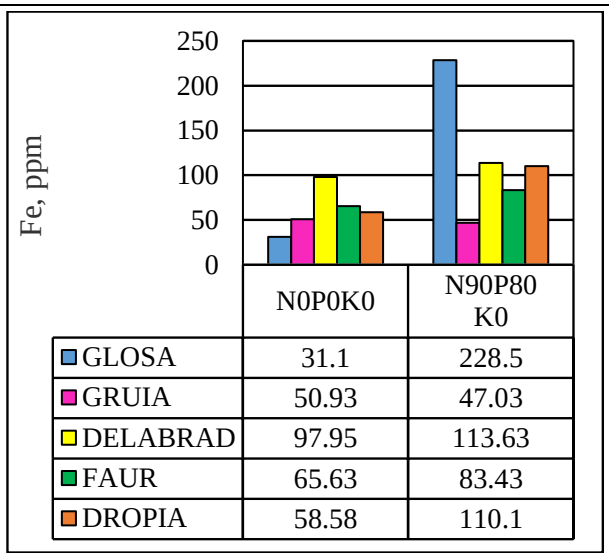
Glosa and Delabrad had more Zn (in the aerial parts of the plants) in the variant with $N_0P_0K_0$, and the other 3 varieties in the 2nd variant fertilization. The highest concentration of Zn was observed in Gruia - 8.78 ppm (Figure 9).
The contents of Cu, Fe and Mn (Figures 10, 11 and 12) were within the limits of the optimal range.
High values of these nutrients to the upper optimum limit have recorded, especially due to the acid reaction of the soil.
The Cu content accumulated after the 2 fertilization variants is shown in Figure 10.
It is observed that Gruia and Faur varieties reacted better to the variant with $N_0P_0K_0$, because they concentrated higher amounts of Cu, and the other varieties registered higher values for the fertilization variant with $N_{90}P_{80}K_0$.
The Glosa variety recorded the highest concentration of Cu - 6.58 ppm after fertilization with $N_{90}P_{80}K_0$.



	N0P0K0	N90P80K0
GLOSA	6.05	6.58
GRUIA	7	6.78
DELABRAD	6	6.1
FAUR	6.2	4.7
DROPIA	4.38	5.03

Fig. 10. Copper content determined in winter wheat - the aerial parts (emergence-flowering of the ear stage), ADRS Pitești, Albota
Source: own determinations.

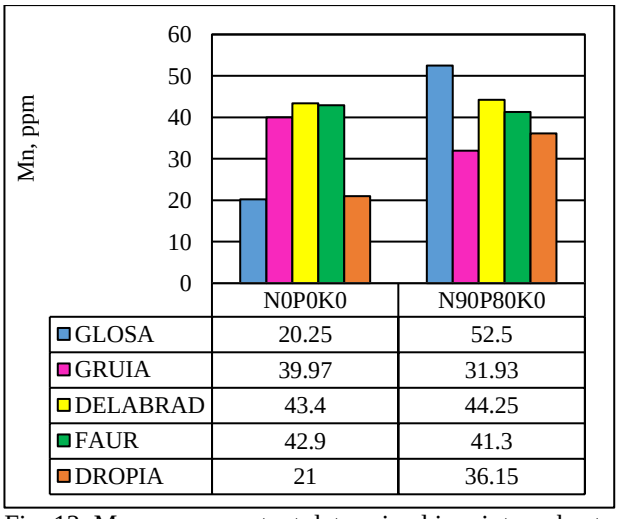
Figure 11 shows the iron content of winter wheat plants. With the exception of the Gruia variety, the five experimental varieties responded well to fertilization with $N_{90}P_{80}K_0$. The highest concentration of Fe was found in the Delabrad variety - 113.63 ppm.



	N0P0K0	N90P80 K0
GLOSA	31.1	228.5
GRUIA	50.93	47.03
DELABRAD	97.95	113.63
FAUR	65.63	83.43
DROPIA	58.58	110.1

Fig. 11. Iron content determined in winter wheat - the aerial parts (ear emergence-flowering stage), ADRS Pitești, Albota
Source: own determinations.

The Mn content accumulated after the 2 fertilization variants is shown in Figure 12. From this it is observed that the Delabrad and Faur varieties concentrated higher amounts of Mn in the variant with $N_0P_0K_0$, and the other varieties registered higher values in the variant with $N_{90}P_{80}K_0$. At Glosa we recorded the highest concentration of Mn - 52.5 ppm.



	N0P0K0	N90P80K0
GLOSA	20.25	52.5
GRUIA	39.97	31.93
DELABRAD	43.4	44.25
FAUR	42.9	41.3
DROPIA	21	36.15

Fig. 12. Manganese content determined in winter wheat - the aerial parts (emergence-flowering of the ear stage), ADRS Pitești, Albota
Source: own determinations.

Figures 13, 14 and 15 show the correlations created between the content of N and those of P, K, Mn, Fe, Zn and Cu, existing in the dry matter of plants.

Figure 13 shows that the potassium content of the plants increases with the growth of the nitrogen content, up to the optimum limit of 2.8% N, in the dry matter of the plants.

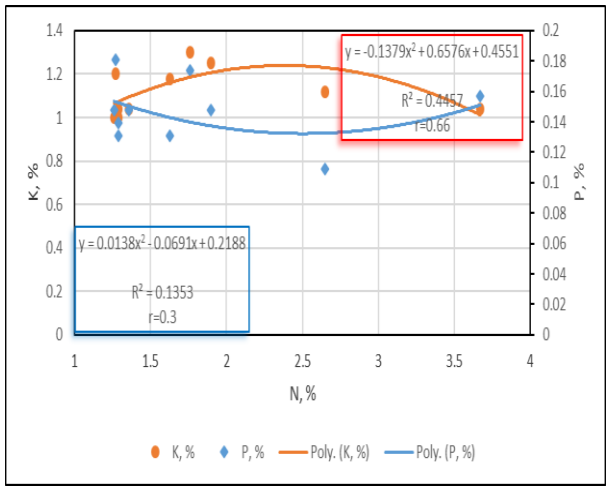


Fig. 13. Correlation between the N content and those of P and K, in winter wheat - aerial parts (ear emergence-flowering stage), ARDS Pitești, Albota
Source: own determinations.

When the optimum value is reached, the potassium content decreases as the nitrogen content increases.
The iron and manganese content of the plants increases as the nitrogen content increases (Figure 14).
The data obtained shows that unilateral fertilisation, with high rates of nitrogen, through changes induced in plant mineral nutrition, could increase the incidence of *Fusarium graminearum* attack on wheat on soil with acid reaction.

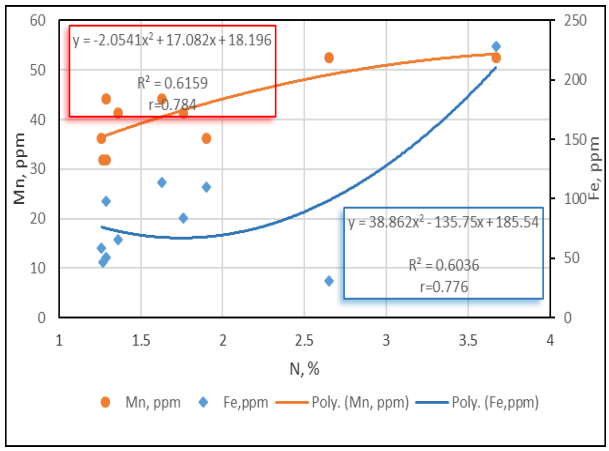


Fig. 14. Correlation between the N content and those of Mn and Fe, in winter wheat - aerial parts (emergence-flowering of the ear stage), ARDS Pitești, Albota
Source: own determinations.

Analyzing Figure 15 we find that the zinc content of plant dry matter increases with increasing nitrogen content to 2.5% N and is almost constant in the content range of 2.5 - 3.5% N.

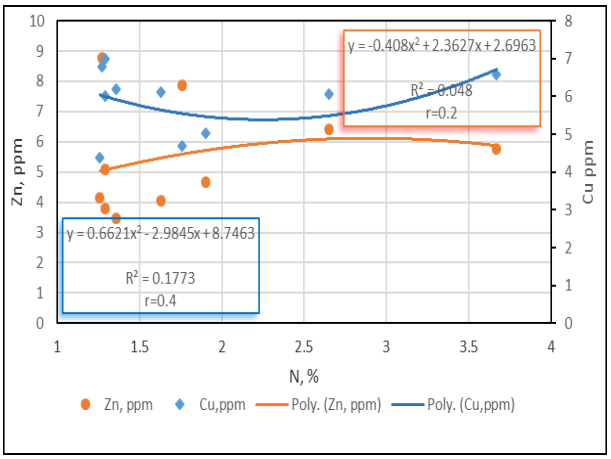


Fig. 15. Correlation between the N content and those of Zn and Cu, in winter wheat - aerial parts (ear emergence-flowering stage), ADRS Pitești, Albota
Source: own determinations.

The copper content of the dry matter of the plants decreases with the growth of the nitrogen content to 2.5% of N, and after this value, it shows an increasing trend with increasing N content of plants.
Excessive fertilization with high doses of nitrogen can cause imbalances in plant nutrition with P, K and Mg, which will lead to a low content of these macronutrients. All this will growth the attack of *Fusarium graminearum*.
By balancing plant nutrition and increasing plant resistance to disease, the application of potassium fertilizers is an agricultural measure designed to reduce the incidence of *Fusarium graminearum* attack in the study area.
Agrochemicals that improve plant nutrition can be important methods to prevent and control the attack of *Fusarium graminearum*, especially because they can reduce the genetic sensitivity of some winter wheat varieties to the attack of *Fusarium graminearum*.

CONCLUSIONS

The analyzes made on soil and wheat plants, at ADRS Pitești, Albota showed that:

- The soil shows an acid reaction with pH values between 4.73 - 4.89;
- The nutrient content in winter wheat plant were within the optimum range for N, Fe, Cu, Mn and were below the optimum range for P, K, Mg and Zn.

The experiments performed on the five wheat varieties sensitive to *Fusarium*, with 2 fertilization variants, under the conditions mentioned above, highlighted the following aspects:

- in certain situations, an element that can trigger the attack of *Fusarium graminearum* is the acid reaction of the soil;
- The appearance of *Fusarium graminearum* can be favored by the low content of P, K and Mg in plants, caused by excess nitrogen.
- in the case of wheat grown on acidic soil, unilateral fertilization with high doses of nitrogen could increase the incidence of *Fusarium graminearum* attack due to changes in plant mineral nutrition.

Consequently, in the studied area, the application of potassium fertilizers and the supplementation of plant nutrition with Mg and Zn are agricultural methods to reduce the incidence of *Fusarium graminearum* attack.

By better managing the problems caused by pathogens, a better average yield / ha can be achieved.

ACKNOWLEDGEMENTS

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