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STUDY OF THE INFLUENCE OF YARA MINERAL FERTILIZER RODUCTS ON BIOMASS, PRODUCTIVITY AND QUALITY INDICATORS OF GRAIN FROM COMMON WINTER WHEAT

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Abstract

Three variants of fertilization were carried out at common winter wheat of Avenue variety on a total area of 9 ha. Pre-sowing application was performed with Yara Mila Triple (16% N, 16% P_2O_5, 16% K_2O) and double nitrogen feeding with Yara Vera Amidas (40% N, 14% SO3) and Yara Bela Sulfan (24% N, 15% SO_3, 11% CaO). The pre-sowing study of soil indicators showed that phosphorus can be blocked and more difficult to access for plants due to medium acid reaction of the soil. High levels of potassium have been reported, but additional mineral fertilization is still needed. The values of magnesium are very high, which requires saturating the soil solution with potassium ions until the normal ratio K: Mg of 3: 1 is reached. Very low sulphur content has a direct effect on nitrogen efficiency. The presented biomass maps show its increase after fertilization. Higher productivity, hectolitre weight and protein content in the grains were found for the harvest from field 1 (highest nitrogen fertilizer rate), which confirms the leading role of the macronutrient as a yield factor.

***Key words**: macronutrients, wheat, biomass, productivity.*

INTRODUCTION

Wheat is a main constituent part of the agrarian system of production, which provides the feeding of the world population and the functioning of the chains for production. The high yield potential, the diversity of possibilities for application and the great plasticity of wheat to the climatic and soil conditions carry as a consequence the fact that different technologies for production are practiced on a world scale. In Bulgaria is sown winter wheat, which is a constant constituent part of the grain-production, while in south Europe prevails the durum wheat, which is most frequently cultivated as a spring crop. The winter common wheat is most frequently based on higher investments of production amounts, but in any cases it realizes significantly higher incomes of yield.

As a matter of principle, for obtaining higher yields is required optimum feeding, this can be carried out only by the right reporting of the necessities. For this purpose the most important elements are those, which are expected to be extracted with the yield, as well as the nutrient reserves in the soil and their circle (Nikolova and etc., 2014). In comparison with the rest grain crops wheat is characterized by high requirements to the N quantity. Following namely the context of the production purpose, the nitrogen fertilization with the wheat, as well as its concrete “distribution in portions” is a significant factor for the reaching of the set yield and quality. A big part of the necessary N after blossoming is taken by the plants before blossoming and after this it is reutilized (DuPont&Altenbach, 2003; Xu et al., 2005). It deserves to be drawn attention that during the drought, which becomes more frequent, in the early summer months the fertilization in phase grain filling is with decreased impact. In similar abiotic stressful conditions is reduced namely the productiveness (Porter&Gawith, 1999), which gives us grounds to admit decrease of the usage efficiency of the applied N. The redistributed nitrogen in the plant tissues is an important source of N namely in phase grain filling in connection with the restricted intake of soil N because of the stress of drought (Dalling et al., 1975; Heitholt et al., 1990). The nitrogen feeding is an important factor for the good tillering and the creation of optimum sowing as per thickness (Ur&Vasileva, 2014). The researches show also reduction of the potential yield with high N levels with early application (Gooding&Davies, 1997; Maidl et al., 1998). The division of the fertilization with nitrogen in portions has for purpose to provide the wheat quantitatively with this macroelement according to its necessities in each phase of development, to synchronize the availability of soluble nitrogen in the soil and the necessities of the plant (Sticksel et al., 2000; Golba et al., 2013; Lopez-Bellido et al., 2005), and also to increase the efficiency of nitrogen usage. The feeding with nitrogen significantly influences the absolute content of protein, but the quality of the protein (the formation of gluten) and the sedimentation number are genetically and varietal conditioned (Uhlen et al., 2004). The thickness of the sowing, the number of the grains in the ear and the weight of the grain determine the yield (Desheva&Kachakova, 2013). The grain production is also character-rized by a narrow connection between the phosphorous feeding and the yield. The potassium feeding show restricted efficiency on the yield, but has impact on the qualitative level. Besides, there is determined a positive effect on the yield with the application of sufficient magnesium fertilizer norms. For high yield and especially on poor in sulphur, light soils, the feeding with sulphur is a promising factor for guaranteeing the raw protein content (Järvan et al., 2012). The experiments carried out show positive impact of the sulphur in the generating of proteins in the gluten, which on its behalf, has positive impact on the bread-making qualities of the wheat (Wieser et al., 2004).

The optimum storing with nutrient substances is a constant part of the successful wheat cultivation, based on the right zoning and directed to reaching the yield potential of the variety. Efficiency of fertilization mainly means that the used fertilizer for a given crop improves the yield and quality of the basic production, and also less quantity of nutrient substances are lost from the system soil-plants (Kostadinova, 2011). Yara Mila Triple is a balanced NPK 16/16/16 formula. Thanks to the good results as high yield and quality, the prime cost per decare becomes significantly lower in comparison with the traditional fertilizers. Yara Vera Amidas contains 40% total nitrogen, of which 35% is in amidic form, which has to transform in assimilable form for the plants – from ammonium in nitrate, and 14% sulphur. The granulated form of Yara Vera Amidas allows even distribution on the soil surface and thus the uneven assimilation by the crops is avoided. Yara Bela Sulfan is a complex nitrogen fertilizer for simultaneous application of three important nutrient elements – nitrogen (12% nitrate, 12% ammonium), sulphur (15%) and potassium (11%), which are completely soluble and provide optimum dynamics of the absorption.

The purpose of the study is research on the impact of Yara mineral fertilizer products on the biomass, productivity and qualitative indicators of grain of common winter wheat.

MATERIALS AND METHODS

Three variants of fertilization with common winter wheat variety Avenue are set on total area of 90 da. A pro-sowing bringing in of Yara Mila Triple (16%N, 16%P_2O_5, 16%K_2O) is carried out and double nitrogen feeding with Yara Vera Amidas (40%N, 14%SO_3) and Yara Bela Sulfan (24%N, 15%SO_3, 11%CaO). Variety common winter wheat Avenue is used (selection of company Limagrain). The sowing is done on 11 October 2018 with sowing norm 600 germinating seeds/m^2.

Within the frameworks of the experimental area is carried out a pro-sowing bringing in of Yara Mila Triple (16% N, 16% P_2O_5, 16% K_2O) – 25 kg/decare (4 kg/decare N active substance, a.s.). The distribution of the experimental variants, each of which with area of 30 decare, is as follows:

Variant 1 (Field 1):

First fertilization 09 March 2019: Yara Vera Amidas (40% N) – 20 kg/decare (8 kg/decare N a.s.);

Second fertilization 18 April 2019: Yara Bela Sulfan (24% N) – 25 kg/decare (6 kg/decare N a.s.).

Total active substance nitrogen for the whole period of vegetation: 18 kg/decare N

Variant 2 (Field 2):

First fertilization 09 March 2019: Yara Vera Amidas – 15 kg/decare (6 kg/decare N a.s.);

Second fertilization 18 April 2019: Yara Bela Sulfan – 25 kg/decare (6 kg/decare N a.s.).

Total active substance nitrogen for the whole period of vegetation: 16 kg/decare N

Variant 3 (Field 3):

First fertilization 09 March 2019: Yara Vera Amidas – 14 kg/decare (5.6 kg/decare N a.s.);

Second fertilization 18 April 2019: Yara Bela Sulfan – 20 kg/decare (4.8 kg/decare N a.s.).

Total active substance nitrogen for the whole period of vegetation: 14.4 kg/decare N

The methods for the wide-spectrum analysis of soil samples, taken before sowing, include analysis of P, K, Mg, S, Ca, B, Mo, Mn, Zn, Cu, Fe, Na, pH and exchange cationic capacity of the soil and are presented in Table 1.

Table 1. Standard analytical methods for examination of micro- and macronutrient elements in the soil, pH and exchange cationic capacity of the soil

Element	Digestion Extractor	Analytical Technique
Calcium	1 M ammonium nitrate	Atomic absorption or ICP
Magnesium	1 M ammonium nitrate	Atomic absorption or ICP
Manganese	1 M ammonium acetate with 2 gr/l quinoline	Atomic absorption or ICP
Boron	Hot water (80 °C)	Spectrophotometry of the solution after mixing with azomethine or ICP
Copper	0.05 M EDTA disodium salt	Atomic absorption or ICP
Molybdenum	Ammonium acetate (24,9 gr/l) + oxalic acid (12.6 gr/l)	Atomic absorption with dinitrogen oxide or ICP
Iron	0.05 M EDTA disodium salt	Atomic absorption or ICP
Zinc	0.05 M EDTA disodium salt	Atomic absorption or ICP
Cobalt	0.05 M EDTA disodium salt	Atomic absorption or ICP
Iodine	Hot water (80 ℃)	Ion-selective electrode
Phosphorus	OLSEN (sodium hydrogen-carbonate)	Spectrophotometry of the solution after mixing with ammonium molybdate
Potassium	1 M ammonium nitrate	Atomic emission spectrometry with flame
Sulphur	Calcium tetrahydrogen diortophosphate	Spectrophotometry of deposited barium sulphate solution
pH	Water	pH electrode
Organic matter	WALKEY BLACK METHOD – oxidation of organic matter calcium dichromate+ sulphuric acid; method of DUMAS	Spectrophotometry
Nitrogen	Decomposition to orthophosphorus acid; method of DUMAS	Method of Kjeldahl; CNS analyzer
Cationic exchange	It is washed by 1M ammonium acetate	Atomic absorption or ICP
$CaCO_3$ total	Hydrochloric acid concentrate	Capacity of the released CO_2
$CaCO_3$ active	Ammonium oxalate	Titration with potassium permanganate after adding of 5% sulphuric acid
EC el. conductivity	Water or calcium sulphate	Meter for conductivity
Nitrates	Water or calcium sulphate	Colorimetric analysis

The determining of the grain qualitative indicators includes analysis of: hectoliter weight (kg/hl), content of moisture (%), raw protein (%) and yield wet gluten (%) for each of the set variants. The qualitative indicators of the grain are carried out in Agroecological laboratory of Technical University - Varna. A NIR-analyzer, model: DA7200 NIR is used for the purpose.

A complete monitoring of the field is carried out during the vegetation of the wheat. The platform AtFarm is used for the purpose of a spectral analysis of satellite images in moments, when nitrate feeding is not carried out.

RESULTS AND DISCUSSIONS

The wide-spectrum analysis of the soil samples, taken before sowing, which include analysis of P, K, Mg, S, Ca, B, Mo, Mn, Zn, Cu, Fe, Na, pH, exchange cationic capacity of the soil and content of organic matter is presented in table 2.

Table 2. Values of a wide-spectrum soil analysis

Indicators	Result	Reference value	Inter-pretation	Comments
Calcium (ppm)	4459	1600	Normal	Normal level.
Magnesium (ppm)	371	50	High	(Index 6.0) Above the normal levels.
Manganese (ppm)	110	15	Normal	Normal level. During stress or periods of vigorous growth the spraying with YaraVita Gramitrel may be advisable.
Boron (ppm)	1.50	1.60	Slightly low	Low necessity with this crop.
Copper (ppm)	12.1	4.1	Normal	Normal level. During stress or in periods of vigorous growth the spraying with YaraVita Gramitrel may be advisable.
Molybdenum (ppm)	0.18	0.60	Very low	Low necessity with this crop. The next crop may experience deficiency.
Iron (ppm)	315	50	Normal	Normal level.
Zinc (ppm)	2.0	4.1	Very low	URGENT APPLICATION of 50 - 100 ml/decare YaraVita Zintrac. When the deficiency is very strong, repeat in 10-14 days.
Sulphur (ppm)	3	15	Very low	Review your soil fertilization with a representative of KBC Agro Bulgaria.
Phosphorus (ppm)	21	16	Normal	(Index 2.5) Normal level.
Potassium (ppm)	274	121	High	(Index 3.2) The magnesium assimilability may decrease.
Sodium (ppm)	60	90	Low	This is not a problem for this crop.
pH	5.9	6.5	Low	The acidic soil may decrease the assimilability of N, P, K, Mg, Ca and S. Liming is recommended.
Organic Matter (%)	3.6	2 – 4	Average stock	Normal level.
Exchange cationic capacity (meq/100g)	32.1	15.0	Normal	The cationic exchange capacity of the soil shows good ability for keeping nutrient elements.

The soil reaction is interpreted as medium acid (Table 2). For the development of the wheat this is not a problem, but this presumes that there is a danger the phosphorus to be blocked and to be more difficult for access for the plants. The phosphorus as an example, in triple superphosphate is calcium phosphate, this is a not accessible compound for the plant and barely 15 % of it is in a form, accessible for the crop for the current year. I.e. the literal recalculation of the active substances is not very correct (6.9 to 7.5% is the active form of phosphorus, with normal environment pH above 6.5). When there are unfavourable soil conditions we rely on formulas, in which the phosphorus is in long chains and is easily mobile, in order to be available and free for the plants before it is fixed. The passing of active elements, as they are in mineral fertilizer Yara Mila Triple (NPK 16/16/16) provide a good start for the plants and setting of maximum yield.

Potassium is the other macroelement, which has an important role for the normal crop development. In the sample are reported high levels, but despite this an additional mineral fertilization is necessary. The high levels of magnesium make impression. This element is secondary and the wheat necessities are less, and the levels in the soil are quite high. This requires the soil solution to be saturated with potassium ions. The normal ratio of K:Mg is 3:1, as an example if 240 mg/l soil is the norm for potassium, then 80 mg/l is the norm for the magnesium. This shows that the plants do not assimilate normally the available potassium. If each element is examined individually, the concrete levels shall be reported. Therefore it is more important the nutrient elements to be examined as one complete system. All elements create connections of antagonism or synergism among them. In this connection three out of the chemical elements, which are positively charged, are in high levels – potassium, calcium and magnesium. Thus are created conditions of competition and the plant cannot feed normally. The lack of sulphur and potassium as elements has direct impact on the efficiency of the nitrogen.

The levels of the organic matter (humus) are in normal boundaries.

Sodium shows us the salting degree of the areas, but it is not examined like a nutrient element in this situation.

The zinc levels are very low and the crop would show sensitiveness. The symptoms may be expressed in shortened internodes, small leaves, inter-nerve chlorosis.

We have determined in a parallel study for the same experimental fields, that the content of nitrogen, phosphorus and potassium assimilable forms in the soil after usage of Yara mineral fertilizers is increased in comparison with the control sample before setting of the experiment (Naskova et al., 2021). The trend of increase continues up to phase ear formation, as in phase after harvesting is observed decrease of the reserve, which is an adequate process on basis the wheat botanical characteristics and the vegetation phases. The best results are obtained with the variant fertilization of field 1 regarding ammonium nitrogen, field 3 – nitrate nitrogen, assimilable phosphorus and potassium – field 2.

The impact of the fertilization on the wheat productivity, however, is variable in a long period of time, because of strong yield dependency on the meteorological situation, in particular the precipitations (Toncheva et al., 2010; Koteva, 2012) and the soil fertility (Koteva, 1993). According to Filipov and Vasileva (2005), the wheat yields are influenced most by the nitrogen feeding, followed by the meteorological conditions and the variety. The nitrogen fertilization has a significant impact on the wheat productivity, leads to increase of the yields in comparison with variants without fertilization (Koteva, 2001; Yanchev et al., 2014; Panayotova, 2004). The following of the temperatures, precipitations, winds and snow cover for the present analysis has shown that the precipitations are the limiting factor for the wheat development and they are extremely insufficient as quantity.

The AtFarm platform is used for a complete monitoring of the field during the vegetation in moments when nitric feeding is not carried out. The observations for homogeneity of the field (united passing from phase into phase) are of extreme importance for the yield. All phases from sowing to harvest are followed by the AtFarm platform of Yara and are observed the differences in the development without them being visible at the very field. This allows to be taken into consideration the future feeding or another important activity.

Figures 1-5 are maps of the biomass, shot during the respective period in the active vegetation of the wheat. The rectangle is the whole block of 507 da – at the upper side one next to another as a united, merging line are the three fields x 30 da (or totally this contour is a strip of 90 da and is limited to the right by the forest belt). By the rest part of the rectangle is presented the 417 decare control.

The first nitrogen feeding of the experimental field in village of Gurkovo is carried out on 9 March 2019 with Yara Vera Amidas (40N+14SO_3), and the map of the biomass as of 24 March 2019 visually clearly shows the effect of the carried out activity on the experimental area – the strip of 90 da is coloured in light green to green colour, corresponding to average level of the biomass index, published for comparison below. Unlike it, the control is coloured in yellow-orange, brown in some places, which falls in the low segment of the biomass index (Figure 1).

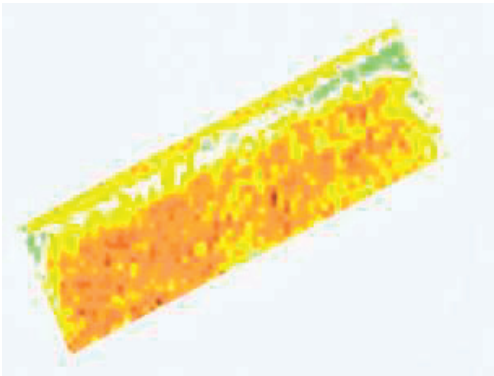

Figure 1. Map of the biomass as of 24 March 2019

The next map is documented on 28 April 2020 and clearly visualizes the nitric feeding with Yara Bela Sulfan (24N+15SO_3+11CaO) from 18 April 2020 (Figure 2). The experimental strip of 90 decare is coloured in green to shades of blue and begins to distinguish clearly in colour, following ascending the scale of biomass index, and in the control are noticed even spots in yellow, which clearly prove the nutrient deficiency of nitrogen, despite that until this moment of its development this part of the field is fertilized with 19.52 kg/decare active substance N.

Figure 2. Map of the biomass as of 28 April 2019

As of date 28 April 2020 more and more clearly is distinguished a difference in the advancing development of the plants from the fertilized plots with Yara fertilizers, which shading is already green to dark green. The control slowly begins to colour in light green.

On 3 May 2020 the plot of 90 decare is in shades of the green colour – a characteristic for a vigorous vegetation growth and it is clearly distinguished from the rest part of the field, in which light spots are still noticed (Figure 3).

Figure 3. Map of the biomass as of 3 May 2019

The last maps from 28 May and 2 June 2020 clearly show the differences in the two techniques in the assimilation of the nitrogen by the plants and the better, equalized vegetation growth, expressed by the index of the wheat biomass (Figures 4 and 5).

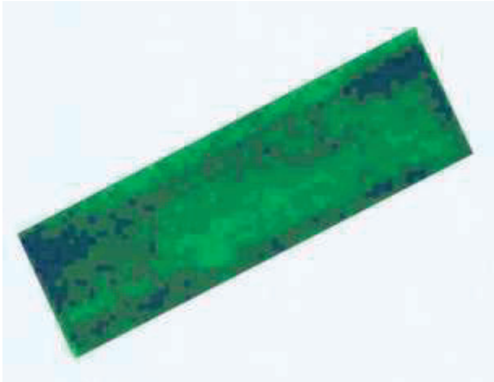

Figure 4. Map of the biomass as of 28 May 2019

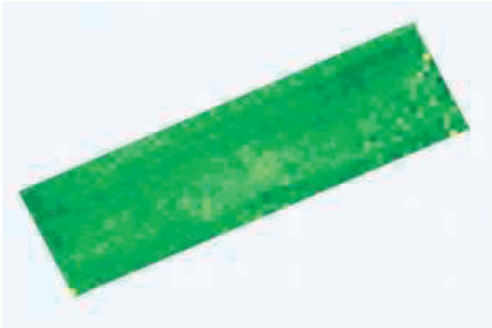

Figure 5. Map of the biomass as of 2 June 2019

In table 3 are presented the data for grain productivity and quality of wheat variety Avenue with the three variants of fertilization.

Table 3. Productivity and qualitative grain indicators

Indicators	Field 1	Field 2	Field 3
Yield, kg/decare	711	612	622
Moisture, %	10.5	10.8	11
Hectoliter weight, kg/hl	76.5	76.1	76
Protein, %	12.7	11.8	12.5
Wet gluten yield, %	25.8	24.4	25.5

The results of the productivity show that the yield from filed 1 is the highest in the carried out experiment (711 kg/decare), which is a result of the used higher nitric fertilizer norm (18 kg/decare N a.s.). The other two variants are with results similar between them – 612 kg/decare (field 2) and 622 kg/decare (field 3), as the differences in comparison with field 1 (respectively lower by 99 kg/decare and 89 kg/decare) are proven. Therefore there is present a statistically reliably higher productivity of the wheat plants in the present experiment with usage of the higher nitric fertilizer norm, which confirms the leading role of the macronutrient element as a factor of the yield. The differences in the yield between field 2 and 3 is only 10 kg/decare, as the same are not proven statistically. For comparison the obtained yield from the same field with usage of the same variety Avenue outside the carried out experiment with the used conventional scheme of fertilization is 596 kg/decare. The data about the grain moisture with the three variants indicate for similar values (10.5 – 11.0%). The hectoliter weight as an indicator of the milling properties of wheat provides the effective minimum of total yield flour with the wheat processing, which for the three groups as per quality (I, II and II B group) according to Bulgarian State Standard 602-87 is 76 kg/hl – a limiting value under which the efficiency of the technological process drops. In the present experiment the hectoliter weight of the grain is the highest with field 1 (76,5 kg/hl), but with the rest two fields the values of the indicator cover the required standard of 76 kg/hl. The results for content of protein indicate the same regularity – the grain collected from field 1 distinguishes with higher protein (12,7%). The value of the indicator with field 3 is close (12.5%), as both variants completely cover the base standard for bread grain. Only the content of protein is lower (11.8%) with field 2. The analysis of chemical technology of the grain shows presence of positive correlative connection between the content of protein and the wet gluten yield (WGY), which is absolutely reasonable, since both indicators are relevant to the proteins. The indicator wet gluten yield provides, on the one hand, the protein content and the nutrient value, and on the other hand guarantees respective quantity of gluten in the flours. The grain obtained from field 1 is with the highest wet gluten yield (25.8%), as it is a little bit lower with field 3 (25.5%), but the differences are insignificant. The results for the harvested grain from field 2 are lower (24.4%), but despite this they show satisfying values. At another our experiment (Naskova et al., 2019) the highest productivity in an experiment with wheat was determined with the variant with usage of liquid nitric fertilizer UAN, in comparison with unfertilized variants and variants, which are fertilized with granulated nitric fertilizers. According to a study of Horvat et al. (2006) the proteins content increases significantly by the application of 80 kg N ha^{-1}, 120 kg N ha^{-1} and 160 kg N ha^{-1}. The index of gluten is increased only by application of 80 kg N ha^{-1}, while the highest levels of N (200 kg N ha^{-1} and 240 kg N ha^{-1}) show drastic weakening of gluten. Taking into account the solidity of the grain, only the treating by 80 kg N ha^{-1} has significant ($P < 0{,}001$) impact. Simultaneously with this P and K do not influence the yield and the quality of the grain according to the authors' study.

CONCLUSIONS

The pro-sowing study of the soil indicators shows that phosphorus may be blocked and to be more difficult for access for the plants, because of the medium acid reaction of the soil. A high potassium level are reported, but despite this additional mineral fertilization is necessary. The magnesium values are very high, which imposes the soil solution to be saturated with potassium ions up to reaching the normal ratio of K:Mg at 3:1. The very low sulphur content renders direct impact on the nitrogen efficiency.

On the grounds of the obtained results may be affirmed that the fertilizer variants, suggested for testing, have exceptionally favourable impact on the soil reaction and the content of macroelements in the soil. The presented maps of the biomass show its growth after fertilization. Higher productivity, hectolitre weight and protein content in the grains are determined for the yield from field 1 (the highest nitric fertilizer norm), which confirms the leading role of the macronutrient element as a factor of the yield.

The data of the productivity in the carried out experiment show biggest values of the yield from field 1 (711 kg/decare), where the highest nitric fertilizer norm is used. The other two variants are with close results between them (611-622 kg/decare), but with statistically proven lower yield from field 1. The productivity is the lowest from the harvested wheat from the same field outside the carried out experiment (596 kg/decare), where a conventional scheme of fertilization is followed.

The analysis of the chemical technology of grain shows that the wheat production is with the best results, regarding the indicators hectoliter weight (76.5 kg/hl), protein (12.7%) and wet gluten yield (25.8%) as a result of fertilization with the higher nitric fertilizer norm in the experiment.

Therefore in the present experiment the variant with usage of the biggest nitrogen quantity active substance/decare distinguishes with the highest values for the yield quantities and quality of the obtained production.

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