BIO Web of Conferences **17**, 00152 (2020) https://doi.org/10.1051/bioconf/20201700152
FIES 2019

Influence of microelements-synergists on the yield and quality of winter wheat grain

V. I. Kostin, *F. A.* Mudarisov, *Yu. M.* Isaev, *A. I.* Semashkina, and *N. M.* Semashkin*

Ulyanovsk State Agrarian University, 432017 Ulyanovsk, Russia

Abstract. The article contains the results of winter wheat cultivation in the forest steppe of the Middle Volga region, as a result of the use of microelements. The object of research is winter soft wheat of the variety Saratovskaya 17. An empirical relationship was obtained between the options of using microelements (the first option is seed treatment; the second option is seed treatment in the combination with foliar top dressing at the end of the tillering phase – the beginning of shooting; the third option is only foliar top dressing) with the winter wheat yield for soil and climatic conditions of the region in question. The linear regression equations have been presented, obtained on the basis of correlation and regression analyses, which makes it possible to determine the analytical relationship between the ways of using microelements-synergists of manganese, zinc and the yield in the technology of cultivating winter wheat. At the same time, the mathematical processing of the data showed that the methods of using trace elements – manganese and zinc reliably influences the yield of winter wheat.

1 Introduction

The yield level is an integral indicator combining the realization of the yielding capacity potential inherent in the plant genome with the state of environmental factors and modern technological methods used as a means to bring out the metabolic capabilities of a particular cultivated crop more fully.

Under the conditions of the forest-steppe of the Middle Volga region, when cultivating winter wheat, in addition to moisture supply, the level of mineral nutrition is of great importance. Microelements are an important part of it, whose role in plant nutrition is great. Their deficiency in the soil leads to disruption of important biological processes in plants.

Microelements are contained in extremely low concentrations, have a significant effect on the growth processes of development, they improve metabolic processes, stimulate photosynthetic activity of plants, increase the yield and product quality. Most of them are cofactors of enzymes and contribute to an increase in the activity of oxidoreductases and hydrolases depending on those metabolic processes that have developed during their evolution [1–6].

Manganese works as a reducing agent in nitrate nutrition, and as an oxidizing agent in ammonia nutrition [7–11]. Chlorophyll decreases in plants with a lack of manganese [12-17].

Zinc plays an important role in the metabolism of DNA and RNA, in protein synthesis and cell division. In plants, zinc is a coenzyme of the carbonic anhydrase enzyme, which helps to increase the drought resistance of plants. This is very important for the risk farming area [18-23].

There is numerous data in the literature on various ways of using microelements in order to increase the yield and quality of winter wheat.

Pre-sowing seed treatment is one of the less expensive ways, but at the same time an effective way to improve the mineral nutrition of plants.

Pre-sowing treatment is highly effective, it has a positive effect at low doses, causing the increase in crop yields, including winter wheat. Foliar top dressing of vegetating plants with microelements can enhance the mineral nutrition of plants during certain periods of vegetation, they quickly and effectively regulate plant life.

Under contemporary market conditions with a constant increase in the prices of fuels and lubricants and other working capital, agricultural producers are looking for various ways to reduce the production cost of winter wheat while increasing yields with various practices and techniques.

Some farms use pre-sowing treatment of seeds with microelements, others – they treat plants during the growing season with solutions of microelements when applying herbicides, and still others – use other options for applying fertilizers.

Nowadays, grain producers do not have a clear understanding of which option of using microelements is the most profitable.

Therefore, the studies directed to determining the optimal way to use non-recyclable micronutrients-synergists of manganese and zinc to increase the yield of winter wheat is very important.

The purpose of the work was to obtain an empirical relationship between the options of using microelements

* Corresponding author: exis@yandex.ru

(the first option is seed treatment; the second option is seed treatment in combination with foliar top dressing at the end of the tillering phase – the beginning of shooting; the third option is only top dressing) with winter wheat yield for soil climatic conditions of the Middle Volga.

2 Materials and methods of research

The object of research is winter soft wheat of the variety Saratovskaya 17. The variety was bred at the State Scientific Research Institute of Agriculture of the South-East with the method of selection from a hybrid population obtained from crossing Saratovskaya 8/Lyutestens 329/* 3/Saratovskaya 8.

The design of the experiment:

1. Control (water treatment);
2. $MnSO_4$ (pre-sowing treatment of seeds);
3. $ZnSO_4$ (pre-sowing treatment of seeds);
4. $MnSO_4$ + $ZnSO_4$ (pre-sowing treatment of seeds);
5. $MnSO_4$ (pre-sowing seed treatment + top dressing of plants);
6. $ZnSO_4$ (pre-sowing seed treatment + top dressing of plants);
7. $MnSO_4$ + $ZnSO_4$ (pre-sowing seed treatment + top dressing of plants);
8. $MnSO_4$ (top dressing only);
9. $ZnSO_4$ (top dressing only);
10. $MnSO_4$ + $ZnSO_4$ (top dressing only).

The microelements were used in the form of 0.1 % solutions of manganese sulfate and zinc sulfate. The consumption of the working solution of microelements for seed treatment was 8–10 l/t, for spraying crops – 180–200 l/ha.

In the experimental field of Ulyanovsk State Agrarian University, where experiments were conducted during 5 years (2013–2017), the manganese content varied in the range of 4.7–10.9 mg/kg of soil (on average 7.0 mg/kg), zinc – in the range of 0.4–0.6 mg/kg of soil (average 0.47 mg/kg). Soils are classified as poor in terms of manganese content and very poor in terms of zinc content.

The grain yield was recorded by continuous threshing with the Terrion-Sampo SR2010 selection combine.

The statistical processing of the experimental yield data was carried out by the methods of correlation and regression analyses on a PC using the programs Excel 2017, Statistica 6.1. [24-30].

In general terms, the linear regression equation in code variables for determining the yield (y), depending on the options of using microelements, is as follows:

$$y = D + Ax_1 + Bx_2 + Cx_3,$$

where D is a constant; A, B, C are the coefficients of the regression equation, showing the qualitative level of influence of the corresponding method of microelements on the yield of winter wheat; x_1, x_2, x_3 – the factor of the first, second, third way of applying micronutrient fertilizers in code values.

The values of the constants in the equation for individual methods of using microelements differ, and this can explain the fact that different versions of the equations are used. Over time, the formulas need to be adjusted, since the interconnections of the methods of introducing microelements with the yield of the experimental crop change, taking account of the achievements in crop selection, agricultural chemistry and technological innovations in wheat cultivation.

3 Results of the research

We used the data on the yield of the experimental crop for 5 years for our analysis (Table. 1.). According to Table 1, the yield of winter wheat in the experimental field of USAU differed in the same options by the years, this is due to the meteorological conditions of the region. In average, over 5 years, the yield of the experimental crop during seed treatment increases by 6.9–15.7 %, with a double treatment of the crop – by 17–18.9 %, with a single treatment of vegetating plants at the end of the second phase of organogenesis – by 5.6–10.9 % compared with the control option. The combined use of 0.1 % solutions of manganese sulfate and zinc sulfate had a synergistic effect on all 3 ways of treating the crop, depending on the year of the studies.

On the basis of the data in Table 1 with the use of the methods of correlation and regression analysis [31], a linear regression equation is derived for calculating yields (t/ha), where the linear regression dependence $y = f(x_1, x_2, x_3)$ according to the years of the studies is presented in the form of a formula with various factors. The formulas are as follows:

Table 1. Yielding capacity of winter wheat

Way of treatment	№	Options	Yield, t/ha						Yield increase	
			2014	2015	2016	2017	2018	Average for 5 years	t/ha	%
	1	Control	4.39	1.90	4.32	4.10	4.11	3.76	–	–
Seed treatment	2	$MnSO_4$	4.73	2.16	4.72	4.26	4.23	4.02	0.26	6.9
	3	$ZnSO_4$	4.82	2.44	4.96	4.31	4.44	4.19	0.43	11.4
	4	$MnSO_4$ + $ZnSO_4$	4.86	2.38	5.57	4.36	4.58	4.35	0.59	15.7
Seed treatment + top dressing	5	$MnSO_4$ (+ veget. parts).	5.15	2.44	5.43	4.67	4.32	4.40	0.64	17.0
	6	$ZnSO_4$(+ veget. parts.).	4.94	2.43	5.54	5.02	4.43	4.47	0.71	18.9
	7	$MnSO_4$ + $ZnSO_4$(+ veget. parts)	5.00	2.48	5.74	4.52	4.36	4.42	0.66	17.6
Top dressing	8	$MnSO_4$(_ veget. parts)	4.52	2.28	4.5	4.12	4.42	3.97	0.21	5.6
	9	$ZnSO_4$(_ veget. parts)	4.56	2.23	4.74	4.42	4.32	4.05	0.29	7.7
	10	$MnSO_4$ + $ZnSO_4$(_ veget parts)	4.53	2.38	4.96	4.49	4.49	4.17	0.41	10.9

2014:
$$y = 4.39 + 0.41x_1 + 0.64x_2 + 0.15x_3.$$
2015:
$$y = 1.90 + 0.43x_1 + 0.55x_2 + 0.40x_3.$$
2016:
$$y = 4.32 + 0.76x_1 + 1.25x_2 + 0.41x_3.$$
2017:
$$y = 4.10 + 0.21x_1 + 0.64x_2 + 0.24x_3.$$
2018:
$$y = 4.11 + 0.31x_1 + 0.26x_2 + 0.30x_3.$$

The coefficients of the regression equation, showing the qualitative level of influence of the corresponding option of using microelements on the yield of winter wheat are shown more clearly in Table 2.

Table 2. Regression equation coefficients by the years of the studies

Years	Constant	**Regression Equation Coefficients**		
	D	A	B	C
2014	4.39	0.41	0.64	0.15
2015	1.90	0.43	0.55	0.40
2016	4.32	0.76	1.25	0.41
2017	4.10	0.21	0.64	0.24
2018	4.11	0.31	0.26	0.30
2014–2018	3.76	0.43	0.67	0.30

Analyzing Table 2, we can conclude that the main factor for obtaining the maximum yield of winter wheat is seed treatment in combination with top dressing at the end of the tillering phase – the beginning of shooting. Pre-sowing seed treatment is in the second place, with the exception of the year 2018. Apparently, this was due to extreme weather and climatic conditions in May – early June, when during the day the temperature did not exceed 5–8 °C, frosts were observed at night. During this period, the limiting factor in the development of plants was the ambient temperature.

The linear regression dependence of the average yield of winter wheat over 5 years is presented as the following formula:
$$y = 3.76 + 0.43x_1 + 0.67x_2 + 0.30x_3.$$

The values of the above coefficients are a quantitative assessment of the influence of the options of using microelements on the yield of the experimental crop on average for 5 years. For clarity, the representation of this dependence in three-dimensional space, the linear regression dependence y = f (x1,x2) is expressed as the formula:
$$y = 3.76 + 0.43x_1 + 0.67x_2$$

A graph of this dependence is presented in Figure 1.

The linear regression dependence $y = f(x_2, x_3)$ is expressed as the formula:
$$y = 3.76 + 0.67x_2 + 0.30x_3$$

A graph of this dependence is presented in Figure 2.

The verification of mathematical models has shown that the tabular value of the Student's t-test is less than the calculated one, the correlation coefficient is not less than 0.95, and the verification of the regression equations by the Fisher criterion confirmed their adequacy.

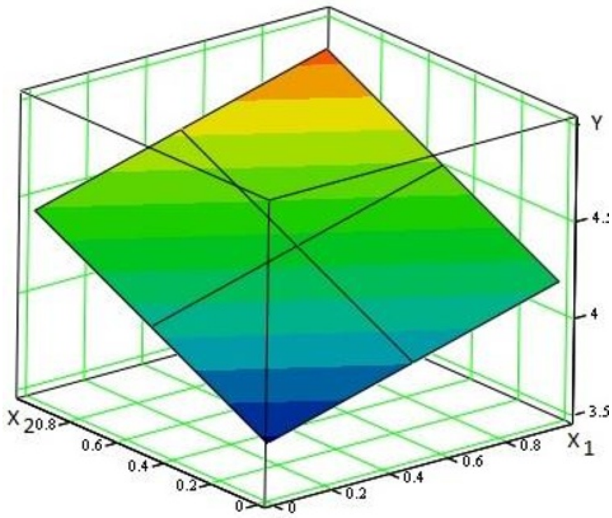

Fig. 1. Response surface of the average yield y, depending on the first x_1 and second x_2 options of using microelements

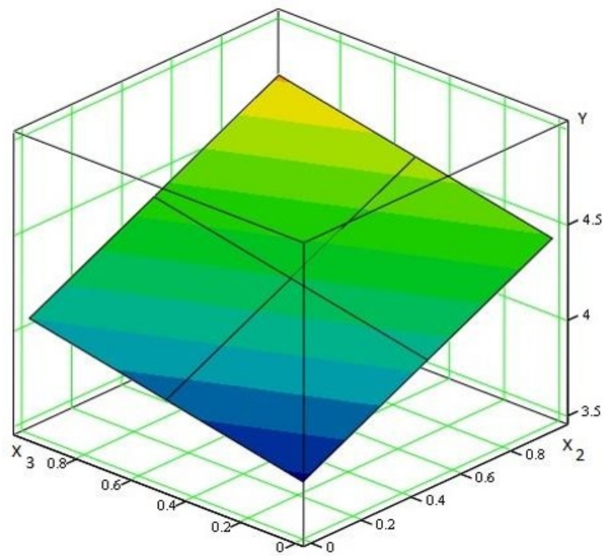

Fig. 2. Response surface of the average yield y, depending on the second x_2 and third x_3 options of using microelements

4 Conclusion

Mathematical data processing showed that the options of using microelements – manganese and zinc significantly influence the yield of winter wheat.

The same concentration of microelements during pre-sowing treatment of seeds of the experimental crop and pre-sowing treatment in combination with treatment in the course of the growing season increase the yield unequally, depending on the way of its use.

It has been reliably proven that, on average, over 5 years of the studies, treatment of winter wheat seeds before sowing and vegetative plants at the end of the tillering phase – the beginning of the shooting phase with 0.1 % solutions of manganese sulfate and zinc sulfate, gives the greatest increase in the yield of the experimental crop.

Based on the foregoing, we recommend food grain manufacturers of winter soft wheat under the conditions of the Ulyanovsk region on black soils with a low content of manganese and zinc to use double treatment of the crop with 0.1 % solutions of manganese sulfate and zinc sulfate, instead of single one.

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