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Spring wheat productivity and water consumption depending on the moistening conditions of leached chernozem and treatment with Manganese, Zinc, and Cobalt

Dmitry Ilyich Ivanov[a], Natalia Nikolaevna Ivanova, and Ahssan Dakhel Ridha Alhajemi

National Research Mordovia State University,
68 Bolshevistskaya Str., Saransk, 430005, Republic of Mordovia, Russia

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ABSTRACT

The grain and straw productivity and transpiration coefficients of spring wheat of the Tulaykovskaya 10 cultivar were studied depending on the conditions of moistening and foliar treatment with manganese, zinc, and cobalt. The main research method was a two-factor vegetation experiment in triplicate. Earlier, the interaction of minor nutrient elements – manganese, zinc and cobalt – against the background of drought and sufficient moisture in spring wheat crops has not been studied on the leached chernozems of Mordovia. It was revealed that against the background of sufficient moisture in the soil, the yield of spring wheat increased with foliar treatment with a combination of manganese and zinc, and against a background of drought – with a combination of manganese, zinc, and cobalt. Soil drought significantly increased the transpiration coefficient. Over 2 years of research, a decrease in the transpiration coefficient against the background of sufficient moisture was caused by the paired use of manganese and zinc, and against a background of drought – by manganese and cobalt, and by triple use of manganese, zinc, and cobalt.

Key words : *Spring wheat, Manganese, Zinc, Cobalt, Leached chernozem, Moisture, Productivity, Transpiration coefficient.*

Introduction

Mineral nutrition, including trace element nutrition, is one of the fast-acting factors that affect metabolism, plant growth and development. Regulation of this factor can be considered as a means of overcoming stressful conditions for the development of plants. According to a number of researchers (Aristarkhov *et al*., 2010; Volodko, 1983), trace element nutrition can increase cereal productivity (up to 13-36%) and improve product quality, increase the resistance of crops to adverse environmental factors.

Manufacturers of complex micronutrient preparations prove their high efficiency. However, various researchers in the middle zone of the Russian Federation obtained very mixed data on the effectiveness of the use of complex micronutrient fertilizers. In addition to the positive results from the use of these preparations on cereals (Isaev *et al*., 2009), there is evidence of no effect and even negative effect compared to the separately applied salts of trace elements (Kudashkin, 2008).

The studies of Sumina conducted in 1958-1960 on the leached chernozems of Mordovia (Klochkov, 1966) established the high efficiency of zinc and cobalt in increasing the yield and quality of spring wheat grain. However, the effect of the combined use of manganese, zinc, and cobalt on the development of spring wheat in these soil and climatic conditions has not been previously studied. On high-humus leached chernozems of Mordovia, manganese deficiency is likely. It is also of great interest to use trace elements in drought conditions, which most often limit the yield of spring wheat in Mordovia.

The aim of the work is to study the productivity of spring wheat and the efficiency of moisture use depending on the foliar treatment with a combination of manganese, zinc, and cobalt in the conditions of soil drought.

Materials and Methods

The studies were carried out in 2016-2017 by setting up the model two-factor vegetation experiment in triplicate.

The experimental design included 10 options. Factor A – humidification conditions: 1) Control (sufficient humidification – 60% of total moisture-holding capacity (MHC)), 2) Soil drought (30% of MHC); factor B – treatment with trace elements: 1) Control (treatment with distilled water); 2) Mn+Zn; 3) Mn+Co; 4) Z+Co; 5) Mn+Zn+Co. For each variant of factor A, 5 variants of factor B were superimposed. In accordance with the experimental design, the seeds were soaked for 6 hours in a trace element solution and then plants were sprayed during the 4th leaf-tillering phase (0.01% by trace element). Trace element solutions were prepared on the basis of pure salts: $MnCI_2 \times 4H_2O$; $ZnSO_4 \times 7\ H_2O$; $CoSO_4 \times 7\ H_2O$. The concentration of trace elements was consistent with that recommended for foliar processing of grain crops according to various researchers (Aristarkhov *et al*., 2010; Kudashkin, 2008).

The object of research was spring soft wheat of the Tulaikovskaya 10 cultivar, grown in a vegetation experiment. The soil was heavy-loamy leached chernozem, which was selected in the autumn in the workers' settlement Yalga and was characterized by the following indicators: pH_{KCl} = 4.8-5.0; Ng = 7.4-17.3 mmol/100 g; S = 27.2-33.8 mmol/100 g, the content of mobile forms of phosphorus – 249-280 mg/kg, potassium – 185-198 mg/kg; humus – 7.1%, mobile forms of Mn = 33-38 mg/kg; Co = 1.3-1.7 mg/kg; Zn = 0.5-1.2 mg/kg (poor availability). Four kilograms of absolutely dry soil were filled into plastic Wagner containers. When stuffing, for each kg of soil, 0.15 g of N, 0.1 g of P_2O_5 and 0.1 g of K_2O were added.

Sowing with sprouted seeds in the vegetation vessels was carried out on January 4-6, 2016 and March 2-3, 2017 with the density of 24 plants/container; after thinning, 12 plants were left in the vessel. Plants were grown in vegetation cabinets with adjustable parameters: air temperature in the daytime 24-26 ºC, in the night – 19-20 ºC, illumination of 7 klx, the photoperiod of 16 hours. Soil drought was simulated in the phase of the beginning of the exit to the tube, for which the moisture content of leached chernozem was reduced in vegetation containers to 30% of full moisture-holding capacity lasting 7 days. After a critical period, the normal level of moisture was restored (60% of the total moisture-holding capacity) (Zhurbitsky, 1968) throughout the growing season. Harvesting was carried out as the grain ripened on various options in June 2016 and in July 2017 in accordance with the accepted methodology for the growing experiment (Moiseichenko *et al*., 1996; Kidin *et al*., 2008).

The water consumption coefficient was determined by dividing the total water consumption by the yield of the main products and byproducts (Moiseichenko *et al*., 1996). The total water consumption was determined by summing the moisture reserves in the soil at the beginning of the growing season, rainfall (irrigation rate) for the growing season and subtracting the moisture reserves in the soil at the end of the growing season. In relation to the conditions of the growing experiment, the moisture content was expressed in g/container.

Results

According to Table 1, the simulated soil drought in 2016 significantly reduced the productivity of spring wheat grain by 1.12 g/container (23% relative to sufficient moisture). Against the background of sufficient moisture, a triple mixture of trace elements caused a tendency to increase grain yield. The exclusion of zinc from the ternary mixture led to a significant decrease in productivity by 0.76 g/container (14%).

Against the background of drought, the greatest effect in increasing the yield was caused by the joint application of zinc with cobalt (1.18 g/container, or 31.8%), as well as triple mixture of trace elements

(+39.4%). The exclusion from the ternary mixture of cobalt, as well as zinc, reduced grain yield by 0.92 and 1.2 g/container. The highest yield in 2017 against the background of sufficient moisture was formed on the option with the combined use of Mn + Zn (5.43 g/container), which in terms of hectare was 1.73 t/ha, the increase compared to the control was 0.32 t/ha. Against the background of soil drought, a significant decrease in grain yield by 2.98 g/container (68%) was observed. The greatest tendency to increase grain productivity due to drought was in the case of the combined use of Mn + Co (57% compared to the control). On average, over the 2 years of the study, the combined use of manganese with zinc caused a tendency to increase productivity with a sufficient level of moisture, and against the backdrop of drought, a significant increase in grain yield (by 0.91 g/container, or 35.4%) caused the use of a triple mixture of trace elements.

The productivity of spring wheat straw in 2016 was more stable and did not change significantly from the studied factors. In 2017 and on average in 2016-2017, straw productivity changed under the influence of the studied factors similarly to grain productivity.

The issue of increasing the drought tolerance of spring wheat should be related to the efficient use of moisture diagnosed by transpiration coefficients (or water consumption coefficients). The research data are presented in Figure 1.

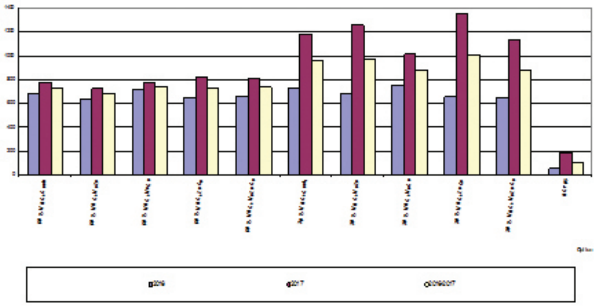

Fig. 1. Transpiration coefficients of spring wheat depending on moisture supply conditions and foliar treatment with trace elements, units

In 2016, manganese and zinc, as well as zinc and cobalt, were paired to reduce water consumption against the background of sufficient water supply. Against the background of drought, a significant decrease in the transpiration coefficient was caused by the paired use of zinc and cobalt, as well as by triple mixture of trace elements – by 71 and 85 units, respectively.

In 2017, soil drought significantly increased the transpiration rate (by 408 units, or 52%). In options with sufficient moisture supply, simultaneous treatment with manganese and zinc caused a tendency toward a decrease in the transpiration coefficient, and with manganese and cobalt – against a background of drought. The introduction of zinc and cobalt, on the contrary, increased the transpiration coefficient.

On average, the transpiration coefficient increased by 227 units over 2 years against the background of soil drought or by 31%. The paired application of manganese and cobalt and the triple use of manganese, zinc, and cobalt caused a tendency towards a decrease in the transpiration coefficient.

Results and Discussion

The change in the grain yield of spring wheat to a greater extent correlated with the preservation of plants for harvesting (r = +0.86) and the coefficient of total (r = +0.93) and productive (r = +0.69) tilling capacity, to a lesser extent – with the mass of grain from 1 spike (r = +0.55).

As a result of multiple correlation analysis, the following model of spring wheat grain productivity (g/container) was obtained:

$y = -5.61 ++ 7.50x_1 ++1.266x_2 +1.306x_3 +0.038x_4$; $R^2 = 0.997$ (1)

where x_1 was the mass of grain from 1 spike, g;

x_2 was the coefficient of productive tilling capacity;

x_3 was the coefficient of total tilling capacity;

x_4 was the safety of plants for harvesting, %.

The increase in spring wheat productivity under the influence of manganese and zinc is probably due to their high biological activity and inclusion into a number of enzyme systems. Perhaps the effect of zinc is associated with an improvement in the absorption of potassium, better water content of leaf tissues, greater intensity of the photosynthesis process due to the greater activity of the carbonic anhydrase enzyme. Manganese is able to activate the nitrite reductase enzyme, participate in the photochemical reactions of photosynthesis, and activate the enzyme complexes involved in glycolysis and the Krebs cycle. The role of cobalt in plants is a debatable issue. There are data that cobalt can stimulate cell reproduction of leaves, promote the concentration of chloroplasts in plant leaves due to the rep-

Table 1. Spring wheat productivity, g/container

Variant of experiments		Grains			Straw		
Factor A (conditions of moisturizing)	Factor B (treatment with trace elements)	2016	2017	average for 2016-2017	2016	2017	average for 2016-2017
1) 60% MHC	1) Control	4.83	4.41	4.62	15.66	13.15	14.41
	2) Mn+Zn	5.01	5.43	5.22	17.34	13.94	15.64
	3) Mn+Co	4.61	4.23	4.43	15.41	11.67	13.55
	4) Zn+Co	5.43	4.27	4.85	16.56	11.14	13.86
	5) Mn+Zn+Co	5.38	3.56	4.47	16.42	11.30	13.86
2) 30% MHC	1) Control	3.71	1.43	2.57	14.15	7.40	10.78
	2) Mn+Zn	4.25	1.94	3.10	14.77	6.30	10.53
	3) Mn+Co	3.97	2.25	3.11	13.20	8.11	11.06
	4) Zn+Co	4.89	1.40	3.15	14.88	6.45	11.66
	5) Mn+Zn+Co	5.17	1.78	3.48	15.03	7.89	11.99
LSD05 of	particular differences	0.71	1.34	0.83	1.95	2.03	1.73

lication and growth of organelles (Bityutsky, 2011). The increase in yield upon application of manganese and cobalt, as well as manganese, zinc and cobalt due to drought, is probably due to a decrease in the availability of these elements in the soil.

It should be noted that during the modeling period of soil drought in 2017, plants were affected by a four-legged wheat tick entered into the laboratory with a current of outdoor air. The plants were treated with insectoacaricides with a weekly interval. After treatments, paralysis and death of ticks occurred. Despite treatment with insectoacaricides (aversectin (Iskra Bio preparation) and malathion (Fufanon preparation)), there was a partial death of plants: 1 plant per each of options No. 3-5, 2 per each of options No. 6 and No. 10, 3 plants for option No. 7, and 6 plants for option No. 9, which affected reduced productivity, despite the best development of the photosynthetic apparatus in the early phases (Ivanov *et al*., 2017). This is probably due to the stretching of plant development, less coarsening of leaf tissue under the influence of zinc, which was revealed in previous studies (Ivanov *et al*., 2014).

Conclusion

Under the conditions of sufficient moistening, the highest productivity of spring wheat and the best use of moisture are formed by the joint application of Mn+Zn, and under the conditions of soil drought – by Mn+Co and Mn+Zn+Co by foliar treatment with 0.01% solution of each trace element in the tillering stage.

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