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EFFICIENCY OF DIFFERENT FORM SAND APPLICATION WAYS OF MICROFERTILIZERS UNDER CROPS CULTIVATION

Iryna Loginova, PhD, associate professor, PhD

Nataliya Bilyera, PhD, seniorlecturer, PhD

National University of Life and Environmental Sciences of Ukraine

Abstract *The data on the influence of different forms of microfertilizers (inorganicsalts, chelates, nano Zn) and ways of their application (soil and foliar application) to corn and spring wheat are showed. It was studied, that chelats are better on meadow-chernozemic calcareous soil if compared to inorganic salts. Both ways of application are effective. Nano Znperformed was more effective than the other microfertiizers, but further experiments are necessary for its recommendation on a big scale.*

Microfertilizers, chelates, inorganicsalts, nano Zn, Kemira, corn, spring wheat.

The problem of microfertilizers application in farming has been discussed for a long time[11, 12], but during the last decades it became much more important for scientists and farmers due to production of high yield ed cultivars[6,9]. It was caused by under standing of physiological role of micronutrients; further more, their application can increase the utilization rate, what is economically reasonable [13].

Besides, the problem of microelements in the worldis emphasized based on the new cultivation technology implementation, loss of soil fertility due to erosion, leaching, overliming, applicationofchemical fertilizers and decreasing the rate of organic fertilizers in fertilization management [1].

The efficacy of microfertilizers application depends on two factors: (1) forms of microelement and (2) application way. Crop tolerance also influences the efficacy of microfertilizers application[7].

The forms of microfertilizers are commonly use din farmingare: (1) inorganiccompounds (metaloxidesandsalts, industrial wastes); (2) synthetic chelats; (3) frits (fritted glass products), and (4) nanometals.

Along with low prices and prov en efficiency of inorganics alts, their application into the soilleads to rapid interaction with components of the soil solutionand reduces the availability for plants. The problem of industrial wastes is low micronutrient concentration and its uncontrollable release into the soil, and, as a result, high application rates and significant amount of ballast substances.

Now a dayssyn the ticche latsare common form of micronutrient fertilizers. Their advantages are low retrogradation when applied into the soil, better absorptionby plants through leaf by affinity component of organic compounds to the components ofleafcover,reduced phytotoxicity risk [2].

Fritted micronutrients have the least share of the fertilizers, and generally are used only on sandy soils in regions with high rainfall and high potential for leaching. This class of materials is more appropriate for maintaining optimal concentrations of micronutrients in the soil rather than for correcting severe micronutrient deficiencies [3].

Nanoformof fertilizer is a new one with the proven efficiency[8]. However, plan up take of nanoparticles and their influence on environment are still not clear. To date ther eexist almost no analytical methods for quantify ingnano particles inenvironmental samples[4].

There are some methods of micronutrients application: (1) soilapplication, (2) foliar application, (3) seed treatment, and (4) fertigation. Micronutrients can beappliedas ordinary or compound fertilizers (mixed with liquid fertilizers, bulk blending or coating granular fertilizers). When applied into the soil, micronutrients are transformed in soil solution, what can be solved by foliar application [14].

The aim of our research was to study the influence of different form sandways of microfertilizers application on corn and spring wheat yield.

Materials and methods. The research was fulfilled by the Agrochemistry and Crop Quality Department of the National University of Life and

Environmental Sciences of Ukraine on a medium-loam textured calcareous meadow-chernozem. The plot was located in the Kyiv region (lat. 50°05′N, long. 30°12′E). Field trials were carried out in the temperate Forest Steppe zone of Ukraine, on the background of 570 mm annual precipitation and 7.5 ^{o}C of a mean annual air temperature. The SOM content was – 4.22 %, pH_{H_2O} - 8.0, $CaCO_3$ - 1.20%, ehe amount of available N, P, K was 72.5, 27.0, 89.3 mg kg^{-1} respectively, average content of available Zn, Cu was 2.31 and 2.24 mg kg^{-1} respectively.

A small-plot harvester was used for harvest crops and the yields of corn and spring wheat grain was converted to 14 % humidity. Protein and crude protein content was measured by infrared spectroscopy using an Infratek 1225.

Experiment Design

Experiment 1. Inclusion micronutrients into granular fertilizers vs. bulk blending were studied on spring wheat cultivar Sonata (2004-2005). Kemira (manufacturer: Kemira Grow How, Finland), a complex fertilizer (Table 1). Equivalent mixture (EM) consisted of ammonium nitrate, granular ordinary superphosphate, muriate of potash. Salt of micronutrients ($CuSO_4$, $FeSO_4$, $MgSO_4$, $MnSO_4$, H_3BO_3) were added to mixture to get the same level as in Kemira. Fertilizers were applied as basic application in autumn. The treatments of field experiment were: 1) Control (without fertilizers); 2) Kemira45 kg ha^{-1}; 3) EM45 kg ha^{-1}; 4) Kemira90 kg ha^{-1}; 5) EM90 kg ha^{-1}.

Experiment 2.The effectiveness of compound micronutrient fertilizers was tested on corn (2003-2004) and spring wheat (2004-2005) in the small-plot field experiments on the meadow-chernozemic calcareous soil. Tested fertilizers were: Aquarin 5 (A5) (Manufacturer: Buyskiy chemical factory, Russia), and Krystalon special (KS) (Manufacturer: Yara Hydro, Norway).The content of nutrients in both fertilizers is presented in table 1. Fertilizers were applied with knapsack sprayer, application rate was 3 kg^{-1} for corn and 2 kg ha^{-1} for spring wheat (250 l/ha of solution). Plots were replicated four times and had a size 25 m^{-2} for corn and 10 m^{-2} for spring wheat.

Table 1. Fertilizers characteristics

Fertilizer	Content, %											
	N	P	K	S	MgO	CaO	Fe	Cu	Zn	Mn	B	Mo
Kemira	10	19	20	11	4.2	1.0	0.1	0.1	0.1	0.7	0.15	0.01
KS	18	18	18	5 (SO_3)	3 Mg		DTPA 0.07	EDTA 0.01	EDTA 0.025	EDTA 0.04	0.025	0.004
A5	18	18	18	1.5	2.0		DTPA 0,054	EDTA 0,01	EDTA 0,014	EDTA 0,042	0.02	0.004

Corn plots were fertilized with macronutrients in fall at the rate $N_{90}P_{90}K_{135}$ as ammonium nitrate, ordinary superphosphate and muriate of potash. Compound microfertilizers were applied in three stages of corncob organogenesis by Kuperman [5]: 1) IV stage (laying of kernels number in the cob); 2) VI stage (formation of fertile flowers), and 3) X stage (formation of embryos and kernels). Trail design includes the following foliar applications: 1) H_2O; 2) KS (or A5) on IV stage; 3) IV and VI stages; 4) IV and X stages; 5) VI stage; 6) X stage.

Kemira and EM were applied to spring wheat cultivar Sonata in fall as basic fertilization. Top dressing by compound fertilizers was applied twice at IV andXorganogenesis stages by Kuperman [5] which correspond to booting and milk ripening of the grain, respectively. The treatments were: 1) Kemira 45 kg/ha + H_2O; 2) Kemira 45 kg/ha + A5; 3) Kemira 45 kg/ha + KS; 4) EM 45 kg/ha + H_2O; 5) EM 45 kg/ha + A5; 6) EM 45 kg/ha + KS; 7) Kemira 90 kg/ha + H_2O; 8) Kemira 90 kg/ha + A5; 9) Kemira 90 kg/ha + KS. Early stages of crops organogenesis were detected using microscope, the last stage visually.

*Experiment 3.**Effect of different sources of Zn* was studied in the small-plot field experiment established on the meadow-chernozemic calcareous soil in corn field. Corn plants were treated with following zinc fertilizers as foliar sprays (300 l/ha): 1) H_2O; 2) $ZnSO_4$ (as $ZnSO_4 \cdot 7H_2O$ in the rate 200 g/ha); 3) chelate of Zn (3 l/ha, produced by "Reacom", Ukraine; chelating agent 1-hydroxyethylendiphosphonic acid); 4) Nano Zn solution (50 mg/l of nano Zn, 1 l/ha, producer: NULES of Ukraine[10]. Application rates were assigned using producer recommendations and our previous studies. Fertilizers were applied with knapsack sprayer at twocorn growth stages V5 and V9. Foliar applications were made on the background of macrofertilizers applied in fall at the rate $N_{90}P_{90}K_{135}$ as ammonium nitrate, ordinary superphosphate and muriate of potash. Corn varieties grown in the trail: 2011 – Sandrina F1 (originated by Pioneer, FAO 220), 2012 – Matheus F1 (originated by Saaten Union, FAO 190). Seedling rate was 80.000 kernels per hectare; row spacing was 70 cm.

In all experiments crop management was handled according to standard farm practices for corn and spring wheat. Disease and pest control was conducted according to methods valid for plant protection.

Results and discussion. In our *experiment 1*, application of 45 kg/ha Kemira (Table 2) was resulted in significant spring wheat yield increasing compared to both control (1.46 t ha^{-1} or 64%) and EM 45 kg/ha (0.32 t ha^{-1} or 8%). The increasing of application rate to 90 kg/ha has no economical reason, since fertilization costs have doubled, and yield increasing did not cover it.

Table 2. Spring wheat yield and quality

Treatments	Wheat grain yield			Quality indexes		Wheat Quality class
	t ha^{-1}	± to control t ha^{-1}	± to control %	Protein content, %	Crude protein content, %	
Control	2.69	-	-	10.3	24.9	fodder
Kemira 45 kg/ha	4.15	1.46	64	11.2	25.4	IV
EM 45 kg/ha	3.84	1.15	50	11.2	25.8	IV
Kemira90kg/ha	4.55	1.86	82	10.7	26.9	fodder
EM 90kg/ha	4.56	1.87	82	11.2	25.4	IV
LCD_{05}	0.20			0.4		

The results of experiment indicated that basic application of compound fertilizers with chelate micronutrients as well as bulk blending of salts with mineral fertilizers had significant positive effect on protein content. Furthermore, the form of micronutrients at the application rate of 45 kg/ha did not affect quality indexes, and at the rate of 90 kg/ha lower protein content was under Kemira application. These findings require additional application of micronutrients during vegetation for improving spring wheat quality.

To conclude, application of Kemira at the rate 45 kg/ha performed higher wheat yield increasing if compared to EM, and costs to its application are repaired with higher profit than application of 90 kg/ha. Quality indexes were also improved when applying 45 kg/ha of Kemira, but no significant effect occurred in comparison with EM.

*Experiment 2.*Application of foliar compound micronutrient fertilizers appeared to be the efficient way to increase corn and spring wheat yield. However, the effect of fertilizers depended rapidly on the time of application. The best result on corn was reached when foliar applications were made twice during plant vegetation at IV and VI stages of corncob organogenesis (Table 3). This fact confirmed the exclusive importance of these stages for yield formation. Fertilizers applied on IV and VI staged promoted laying of more kernels in the corncob of higher weight. The same tendency was noted for both fertilizers KS and A5 (grain yield increased by 29% and 27% respectively). One-time treatment on IV and on VI stages was less effective. We also mentioned the tendency to the increase of grain protein content when fertilizers were applied at early stages (from 8.17% in control to 9.21% in variant IV & VI). Application of fertilizers on X stage of corncob organogenesis showed no effect on both yield and protein content (8.21%) in grain.

Table 3. Effect of compound micronutrient fertilizers on corn yield

Treatment	Stages of corncob organogenesis	Corn grain yield, t ha^{-1}	± to control	
			t ha^{-1}	%
H_2O (control)	–	6,24	–	–
KS	IV	6,91	0,66	11
	IV & VI	7,89	1,65	29
	IV & X	6,84	0,59	10
	VI	6,65	0,41	11
	X	6,38	0,13	2
A5	IV	6,71	0,67	11
	IV & VI	7,66	1,62	27
	IV & X	7,10	1,06	18
	VI	6,65	0,61	10
	X	6,21	0,18	3
LCD_{05},		0.23		

In our trial with spring wheat foliar application of KS was resulted in additional 7.9-12.5% of grain yield (Table 4). KS application also led to quality and profitability increasing in their experiment. We have found that both compound fertilizers increased significantly grain protein content from 10.2-11.1% in control to 11.9-12.3%, and, thus, improved grain quality and consequently, its price on the market.

It should be mentioned, that KS and A5 efficacy is higher in EM application treatments, than Kemira. It may be due to intensive chemical processes with basic applied micronutrients in calcareous soil. As a result, foliar application of micronutrients is preferable on this soil.

Table 4. Effect of compound micronutrient fertilizers on spring wheat yield and quality

Treatments		Spring wheat yield			Protein content, %	Crude protein content %	Wheat Quality class
		$t\ ha^{-1}$	± to control				
			t ha-1	%			
Kemira 45 kg/ha	H_2O	4,10	-	-	11,1	24,4	IV
	A5	4,27	0,17	4,2	11,9	25,4	IV
	KS	4,42	0,32	7,9	11,9	25,7	IV
	LSD_{05}	*0,18*			0,4	-	-
EM 45 kg/ha	H_2O	3,96	-	-	10,2	24,0	fodder
	A5	4,41	0,45	11,4	12,2	25,8	III
	KS	4,46	0,50	12,5	12,3	26,3	III
	LSD_{05}	*0,19*			0,5	-	-

*Experiment 3.*Our study showed that different zinc fertilizers influenced corn yield in different ways (Table 5). The zinc sulfate application was less effective on corn yield in comparison with other treatments. Chelate of zinc has shown the sufficient positive effect on corn yield in both years.

Table 5. Effect of different Zn sources on corn yield

Treatment	Corn grain yield, $t\ ha^{-1}$	
	2011	2012
H_2O	10.1	6.0
Salt Zn	10.2	6.5
Chelate Zn	10.7	7.0
Nano Zn	11.1	8.0
LCD_{05}	*0.5*	*0.4*

Nano Zn solution had the tendency to be more effective comparing to $ZnSO_4$ and chelate of Zn in both years. The way of zinc utilization by plants from Nano Zn is not clear and needs deeper analysis. The difference in grain protein content depending on zinc source was not sufficient.

Conclusions

Application of compound fertilizer Kemira with microelements as chelates has been resulted in yield and quality increasing. Chelate micronutrients is more effective on calcareous soil, when applied by spraying than as a component of basic fertilization in spring wheat.

Compound fertilizers KS and A5 were efficient for corn and spring wheat yield and quality improving, when applied at defined stages of organogenesis. KS application resulted in additional 7.9-12.5% yield of wheat and 10-29% of corn, whereas A5 gave extra 4,2-11,4% and 10-27%, accordingly.

Nano Zn solution had the tendency to be more effective comparing to $ZnSO_4$ and chelate of Zn on corn. The way of zinc utilization by plants from Nano Zn is not clear and needs deeper analysis.

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