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Reaction of Sugar Beet Seedlings to Treatment of Seeds with the Chemical Zeroks® (High-colloidal Solution)

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Abstract*—Reaction of sugar beet seedlings to treatment of seeds with the chemical Zeroks® (high-colloidal solution) has been studied. The contact bactericide and fungicide Zeroks® (high-colloidal solution) in which silver nanoparticles are its active factor has been used to test growth regulation properties. Non-pelleted seeds have been treated with aqueous solution of the chemical Zeroks® (high-colloidal solution) (3000 mg/l of colloidal silver) in concentrations of 10 %, 20 %, and 30 %. It has been revealed that 10 % solution concentration is the most effective. Here, increase of seed emergence rate (by 4-12 %) and average seedling length (by 16.1-67.5 %) has been noted as compared to the control. The factor of seed treatment had more influence on the “seedling length” parameter than on the "emergence rate" one that testifies to liability of the former in comparison with the latter. Power of influence of sugar beet seed treatment with aqueous solution of the chemical Zeroks (high-colloidal solution) on the “seedling length” parameter was more than on the “emergence rate” one that testifies to liability of the former in comparison with the latter. Individual reactions of a hybrid embryo to the factor of treatment with the chemical Zeroks (high-colloidal solution) are possible; they are positive in seeds with less emergence rate and negative in seeds with high sowing qualities that is the evidence of different seed quality.

Keywords*—*sugar beet, seedlings, emergence rate, seedling length

I. INTRODUCTION

Every year, scientific achievements which promote significant increase in yield of agricultural crops and reduction of their cultivation technology expenses are more and more introduced into agricultural production practice. When cultivating sugar beet, many disease agents being able to affect plants even at initial growth and development stages accumulate in soil of crop rotations. Long-term practice of sugar beet cultivation has shown that control of pathogenic microflora is one of the major tasks of the crop yield and technological qualities’ increase. Using plant growth stimulants, it is possible to improve not only germinating capacity and productivity of many crops, but their resistance to unfavorable environment factors as well [1-2]. In this connection, studies of new growth regulators that could have not only stimulating, but protective influence on plants as well are topical.

When reproducing sugar beet hybrids, increase in yield and sugar content of mother roots after treatment of seeds with humic compounds has been revealed [3]. Further, planting of these roots for reproduction of hybrids improves yield and sowing properties (germinating capacity) of seeds [3].

Many new compounds have not been tested for gene-toxicity yet, and therefore, they cannot be recommended for using as plant growth and seed germination stimulants, fertilizers for vegetable, field (including sugar beet) and fruit crops used for food by humans. In this connection, ecologically safe substances among which is silver in low concentrations play an important part. One of the important compounds developed by the collective of the Moscow State University supported by the Group of Companies “AgroChimProm” is the contact bactericide and fungicide Zeroks® (high-colloidal solution) which active factor is silver nanoparticles specially modified by the bio-decomposable and absolutely safe surface-active substance [4]. It has been determined that effective concentration (EC_{50}) of Zeroks® for the most of the investigated fungi species varies from 3.1 to 10 mg/l; its maximum level (28 mg/l) is for *Alternaria alternate* [4].

Previously conducted experiments have shown suppression of radial growth of colonies of all the fungi species investigated when adding the modified colloidal silver (the chemical Zeroks) in concentration (active substance) more than 10 ppm (1ppm=1mkg/ml=1mg/l) [5]. Fungicidal properties have been evaluated on agar pea medium with addition of Zeroks in the concentrations of 0.1, 1, 10 and 100 mg/l (active substance). The fungicide effectiveness evaluation on the nutrient medium under laboratory conditions has shown that the stabilized colloidal silver (Zeroks) is effective against strains of all the investigated species of fungi and oomycetes (EC_{50} <19 ppm) [6].

Results of the Zeroks fungicidal effect evaluation were similar to the data obtained during evaluation of fungicidal effectiveness of silver nanoparticles in other laboratories of the world [7]. In works of other authors, similar EC_{50} values for unmodified silver nanoparticles are presented: *Alternaria alternata* (EC_{50}=38 mg/l), *A. solani* (about 10 mg/l), *Fusarium* (from 9 to 55 mg/l in different species), *Pithium* (about 2 mg/l), *Colletotrichum* (from 8 to 100 mg/l in different species) [8-9]. Effective concentrations (EC_{50}) for silver nanoparticles concerning sclerotium-forming species (6-7 mg/l) [10] exceed the EC_{50} for Zeroks regarding the same species (0.4-3.9 mg/l, accordingly) [6, 8-10]. Synergism of antibiotics and the chemical Zeroks® effect concerning the strains resistant to antibiotics has been revealed, though, with addition of the silver preparation, no intensification of effective antibiotics' influence has been registered [11].

A method of pre-sowing treatment for seeds of agricultural plants by spraying the seeds with solution of the biologically-active substance in which a source of silver ions is the colloidal solution of silver nanoparticles AgBion-2 before sowing is known; concentration of the substance in working solution is 0.0047 % and rate of its application is 10 l/ton of seeds [12]. However, the method of treatment by spraying seeds with solution of the biologically-active substance has a disadvantage: an uneven distribution of the compound over seed surface is possible. To avoid it, an additional device (generator) for even distribution of the compound is necessary [13]. Soaking of seeds in an aqueous solution of the chemical Zeroks® (high-colloidal solution) promotes even distribution of the compound over seed surface and allows the most entire use of its potentialities with minimal material inputs.

However, effect of the chemical Zeroks (high-colloidal solution) as sugar beet plant growth stimulants has not been studied. Besides, weather conditions and agricultural methods different from application of growth regulators are more often used as provocative backgrounds to study reaction of sugar beet as a field crop to environment influence. Thus, seed treatment of different sugar beet lines and hybrids with the chemical Zeroks (high-colloidal solution) allows not only formation of biologically active nutrient and fungicide medium on seed surface, but a complex stimulating influence on growth processes in an embryo.

Purpose of the study is to determine reaction of sugar beet seedlings (*Beta vulgaris* L.) to treatment of seeds with aqueous solution of the chemical Zeroks® (high-colloidal solution) (3000 mg/l of colloidal silver) in different concentrations.

II. Experimental

Object of the studies were non-pelleted seeds of 8 sugar beet hybrids and lines from collection of the A.L. Mazlumov All-Russian Research Institute of Sugar Beet and Sugar: O-type 709, MS 709, Karioka, Granate, Zephyr, Murray, Portland, and Tinker. They were soaked in 10 %, 20 %, and 30 % aqueous solution of the chemical Zeroks® (high-colloidal solution) within 15 seconds. To obtain silver solution, tap water was used. Seeds sprouted on a filter paper in plastic containers in four replications with 100 seeds per replication. The containers were kept under laboratory conditions at the constant temperature of 22-25°C. As a control, seeds of the same hybrid were used. They were soaked in tap water. Analysis of the solution influence on sugar beet seed sowing qualities – emergence rate, seedling length – was carried out. To study emergence rate of seeds, seedlings were counted at 4 day after beginning of seed sprouting according to GOST 22617.2-94. Emergence rate of seeds is the speed of germination expressed as percent of emerged seeds (the ones that have formed roots which length is half of the seed length, and seedlings) within the time period determined by preliminary seed sprouting experiments. For field crops, it varies in the range from 3 to 15 days [14]. A seedling is a plant at one of the initial ontogenesis stages, in the period from the moment of seed germination (that is, the moment when the developing embryo breaks through seed coat) till the moment when leaf of the main shoot (the shoot developed from embryo bud) appears [15]. Seedling length was measured with the help of a ruler at 4 day after the experiment starting.

Statistical processing of the results was conducted using Stadia software package. Procedure of data grouping and processing is stated in the work of A.P. Kulaichev [16]. Average values of seedling lengths ware compared using Student's *t*-test. Emergence rate of seeds in the control and experimental variants were compared using Z-test for equality of frequencies. Increase of sugar beet emergence rate and length of seedlings in the experiment as compared to the control (%) was calculated. Influence of the factor "treatment with the chemical compound" in different concentrations upon the listed traits was determined using one-way analysis of variance. Power of influence was calculated according to Snedecor (%).

III. Results and discussion

Quantitative data on germinative energy of seeds and seedling lengths are presented as average values in the table I.

The table I shows increase of emergence rate after processing of sugar beet seeds with 10 % aqueous solution of the chemical Zeroks (high-colloidal solution) in the investigated hybrids in comparison with the control ($P < 0.05$). The exceptions were Karioka, Portland, and Tinker for which seed treatment had no positive effect on the emergence rate. However, they as well as other hybrids displayed no increase of seedling length after treatment of seeds with 10 % solution in comparison with the control ($P < 0.05$, $P < 0.01$) (Table. 1). 20 % concentration of the solution for MS 709 and 30 % one for the hybrids Murray and Tinker inhibited seed germination (Table I).

In general, increase of seed emergence rate of the investigated hybrids by 4-12 %, as compared to the control, after treatment of seeds with 10 % solution of the chemical Zeroks (high-colloidal solution) was revealed. Increase of average seedling length in the variant with 10 % concentration of Zeroks (high-colloidal solution) was 37.8 % for in the O-type hybrid 709, 67.5 % for MS 709, 38.1 % for Karioka, 22.2 % for Granate and Zephyr, 22.4 % for Portland, and 16.1 % for Tinker as compared to the control.

TABLE I. SOWING QUALITIES OF SUGAR BEET SEEDS TREATED WITH AQUEOUS SOLUTION OF THE CHEMICAL ZEROKS (HIGH-COLLOIDAL SOLUTION)

No	Line/ hybrid	Control (tap water)		10 % solution of Zeroks		20 % solution of Zeroks		30 % solution of Zeroks	
		GE, %	*length, cm*	*GE, %*	*length, cm*	*GE, %*	*length, cm*	*GE, %*	*length, cm*
1	O-type 709	83	3.7±0.1	95 [a]	5.1±0.1 [b]	79	4.7±0.1 [a]	84	3.6±0.1
2	MS 709	81	4.0±0.1	85 [a]	6.7±0.2 [b]	72 [a]	4.7±0.1 [a]	85 [a]	4.1±0.1
3	Kari-oka	93	4.2±0.1	87 [a]	5.8±0.2 [b]	95	4.9±0.1 [a]	90	4.4±0.2
4	Gra-nate	81	5.4±0.1	92 [a]	6.6±0.2 [a]	91 [a]	4.2±0.1 [a]	84	4.2±0.2 [a]
5	Ze-phyr	92	5.4±0.2	97 [a]	6.6±0.3 [a]	96	5.6±0.2	95	4.0±0.1 [a]
6	Mur-ray	90	6.8±0.3	98 [a]	6.0±0.2 [a]	90	5.0±0.2 [a]	80 [a]	4.7±0.2 [a]
7	Port-land	81	4.9±0.1	81	6.0±0.3 [a]	81	4.8±0.2	82	5.8±0.3 [a]
8	Tin-ker	92	5.6±0.2	93	6.5±0.3 [a]	92	3.3±0.1 [b]	76 [a]	4.1±0.1 [a]

Note: GE – seed germinative energy; length – seedling length; [a] –differences with the control are reliable (P<0.05); [b] – differences with the control are reliable (P<0.01)

In the hybrid Murray that demonstrated increase of emergence rate, reduction of seedling length in comparison with the control variant (P <0.05) was determined. This testifies different reaction of hybrid embryos to treatment with the chemical Zeroks that is positive in seeds with less emergence rate and, on the contrary, negative in seeds with high sowing qualities thus indicating difference in seed quality. To confirm it, there has been used one-way variance analysis which results are presented in the tables II-III.

In most of the variants, positive influence of the treatment on seed emergence rate has been revealed. Power of influence of sugar beet seed treatment with aqueous solution of the chemical Zeroks (high-colloidal solution) on emergence rate and seedling length was evaluated by one-way dispersion analysis (tables II, III). Power of influence of sugar beet seed treatment with aqueous solution of the chemical Zeroks (high-colloidal solution) on the “seedling length” parameter was more than on the “emergence rate” one (tables II, III) that testifies to liability of the former in comparison with the latter.

TABLE II. POWER OF INFLUENCE OF THE FACTOR “SUGAR BEET SEED TREATMENT WITH AQUEOUS SOLUTION OF THE CHEMICAL ZEROKS (HIGH-COLLOIDAL SOLUTION)” ON EMERGENCE RATE (%)

No	Line / hybrid	With control	Without control
1	O-type 709	4.0 [b]	4.5 [b]
2	MS 709	3.0 [b]	3.7 [b]
3	Karioka	2.9 [b]	3.2 [b]
4	Granate	3.6 [b]	3.4 [b]
5	Zephyr	2.7 [b]	-
6	Murray	3.1 [b]	3.5 [b]
7	Portland	-	-
8	Tinker	3.0 [b]	3.3 [b]

TABLE III. POWER OF INFLUENCE OF THE FACTOR “SUGAR BEET SEED TREATMENT WITH AQUEOUS SOLUTION OF THE CHEMICAL ZEROKS (HIGH-COLLOIDAL SOLUTION)” ON SEEDLING LENGTH (%)

No	Line / hybrid	With control	Without control
1	O-type 709	6.0 [b]	6.5 [b]
2	MS 709	7.3 [b]	7.1 [b]
3	Karioka	6.5 [b]	6.3 [b]
4	Granate	6.5 [b]	6.8 [b]
5	Zephyr	6.4 [b]	6.9 [b]
6	Murray	5.7 [b]	5.2 [b]
7	Portland	6.1 [b]	6.3 [b]
8	Tinker	5.0 [b]	6.3 [b]

Note: [b] – influence of factor is reliable (P<0.01)

IV. CONCLUSION

Thus, treatment of sugar beet hybrid seeds with aqueous solution of the chemical Zeroks (high-colloidal solution) in 10 % concentration allows evaluation of growth indices and increase of seed emergence rate by 4-12 % and of average seedling length by 16.1-67.5 % as compared to the control. Treatment of seeds with aqueous solution of the chemical Zeroks (high-colloidal solution) in 10 % concentration provides stimulation of growth indices of the investigated sugar beet hybrids. Zeroks (high-colloidal solution) can serve as a plant growth stimulant and be used for growth regulation of sugar beet hybrids and lines. However, individual reactions of a hybrid embryo to the factor of treatment with the chemical Zeroks (high-colloidal solution) is positive for seeds with less emergence rate and negative for seeds with high sowing qualities that is the evidence of different seed quality.

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