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Assessment of 'Complex–co' preparation efficiency for some cereal crops growth stimulation

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Abstract. The problem of obtaining environmentally friendly products, which are free from unwanted compounds that are harmful for human health like residual nitrates is very actual. The solution to this problem should be started from the initial stage of crop cultivation: seed disinfection. For that goal the new organic origin preparation 'Complex-Co' was used. In current paper the effect of a new plant growth stimulation preparation of complex influence 'Complex-Co', was studied on cereal crops cultivation. It was produced by the acidic processing of winemaking waste product: the natural cream of tartar.
Unlike the high risk classical organic and inorganic fertilizers, 'Complex-Co' preparation is based on absolutely vital compounds and can be considered ecologically safe. It contains: amino derivatives of natural tartaric acid (TA), coalmine and micro-nutrient elements, which provide the target properties and improve soil behavior. The effect of 'Complex-Co' preparation was studied on three common agricultural crops: barley, emmer and triticale. As a result of the experiments and field-trials it was proved as an effective preparation for root and foliar nutrition of crops. After the usage of the elaborated preparation the significant growth stimulation effect was observed for all the tested cereal crops. Also, the disinfection effect of 'Complex-Co' preparation was observed for the seeds of the tested plants.
The preparation is being recommended for the further research of its effect on various plants cultivation in farms, greenhouses and orangeries.

Key words: tartaric acid, plant growth stimulator, complex organic fertilizer, emmer, barley, triticale.

INTRODUCTION

The quality of food products is decisive for the protection of the health of the population and for improving the quality of their life. In this regard, cereals occupy a primary place as grain products, which are an irreplaceable daily component of the human diet (Barton & Colmer, 2006; Rampalli et al., 2023). A special attention is paid to the control of the absence of various toxic compounds in food products, including nitrates, such as like the monitoring of their residue and trace concentrations in

agricultural products. In these regards, the deficiency of micronutrients in crops is one of the most significant problems for modern agriculture production (Assunção et al., 2022). That is why the importance of micronutrient fertilizers grows day by day. It plays a key role for the food crops and grains production stability and sustainability. One of the possible methods of solvation of a particular problem is the elaboration of new effective preparations with the consistence of micronutrients by the production of compounds with regulable solubility and stability in water and soil environment. One of the prospective directions is the creation of chelating complexes (Zuo & Zhang, 2011). Inorganic sources, synthetic chelating compounds and natural organic complexes are the main classes of micronutrient sources, which are well-known. Inorganic salts are the most useable forms of fertilizers in industry, because of their ready availability and water solubility. Usually, they contain the main metals and the salts anions, which are necessary for normal growth of plants. But there are some disadvantages of their usage including their accumulation in environment and in final agricultural product, what has the negative impact on ecology and people health (Mengel & Kirkby, 2004; Abdelhameed et al., 2019).

That is why the green agriculture technologies, being based only on natural row materials and focused on an exclusion of any synthetic chemical compounds from the usage, are very important. In these regards, the usage of chelates is more expedient (Astakhov, 2009; Vigar et al., 2019; Martirosyan et al., 2023). They are usable for cultivation of a wide diversity of agricultural crops as: fertilizers additives, seed dressing, foliar sprays, as well as the component of hydroponic systems. The absorption of microelements in this form is significantly higher than in form of sulfates, chlorides and other inorganic salts, what makes their biological availability increased (Ball et al., 2005; Bodirsky et al., 2014).

Thus, based on the cream of tartar (one of the wastes of winemaking production which consist of mainly potassium bitartrate, such as like the residues of cellular debris of grape fruit cells and yeasts cells) via acid treatment, in our laboratory it was elaborated an easy implementable technology of creation of 'Complex-Co': new complex preparation production. This preparation has combined effect including plant growth stimulation, and the inhibition of growth of pathogens, including phytopathogenic bacteria by amino derivatives of natural tartaric acid (TA), ethanolamine (colamine) and following biogenic elements (micronutrients): Fe, Zn and Cu in chelated form, as well as K and B (Babayan et al., 2019; Grigoryan et al., 2020; Mikaelyan et al., 2022).

In current research the effect of 'Complex-Co' new plant growth stimulation preparation of complex influence was tested on following cereal crops: triticale, barley and emmer. The main goal of current research was to study the growth of the mentioned three varieties and to discover the grade of their efficiency, in the case of usage of only natural 'organic' origin compounds during the entire vegetation and the exclusion of mineral fertilizers application (Simon & Kalbe, 2022).

MATERIALS AND METHODS

The studied 'Complex-Co' preparation has the following consistence ($g\ L^{-1}$): Fe - 6, Zn - 8.7, Cu - 12.5, B - 5, K - 16–18.5, $[SO_4]^{2-}$ - 79, colamine - 142.5, TA - 61.5–71, benzylamine complex salt of TA (BAS) - 20. The pH of 'Complex-Co' preparation is 3.8–4.0 and the relative density (d_4^{20}) of it is 1.28–1.30.

All the experiments with 'Complex-Co' preparation were carried out due to the generally accepted methodologies (Ricci M., et al. 2019). The effect of 'Complex-Co' micronutrient preparation on cereal crops cultivation, experiments were carried out upon the conditions of cultivated irrigated soils of Armavir region in Republic of Armenia (RA). During the last ten year in the test field where the studies were carried out, no mineral fertilizers, pesticides have been applied. Then, these soils were certified by the 'Ecoglobe' organization (a soil certification organization operating in RA) as completely clean and free of unwanted impurities (Luttikholt, 2007; Khan et al., 2020).

The tested crops were sown annually in the second decade of October. Their seeding rates were respectively: 6.0 million viable germinating seeds per hectare for triticale and were 5.0 and 4.5 million viable seeds respectively for barley and emmer. The experiments were carried out in three variants, with four repetitions, the estimated area of the experimental garden beds was 25 m^2. Thus, the seeds of the cereal crops (barley, emmer, triticale) before the sowing were treated by 1.5% solution of testing preparation in order to combat microbial diseases. The quantity of the applied 'Complex-Co' preparation 1.5% solution was calculated based on the following application rate (per 1 ton seedling materials): 450 L for emmer, 300 L for barley and triticale, respectively.

During the tillering period of winter triticale in late autumn (11/29/2021) and early spring (05/03/2022) the plants were sprayed with a 1% solution of the same preparation as a foliar top-dressing fertilizer (Martirosyan, 2020; Khomphet, 2023) at an application rate 300 L ha^{-1}.

For the investigation of after-effects of 'Complex-Co' preparation on plants, some phytopathological studies were carried: the monitoring of the presence/absence of fungal infections of plants. After the harvesting, an average sample in the size of 1 kg was separated from the grain mass and sent to the state-certified Food and Drug Administration (FDA) examination laboratory (https://www.fdalab.am/en/Home/) operating in Abovyan district of Kotayk region of RA to determine the chemical composition of grains and the amount of nitrate residues in them.

During this research there were studied some varieties of emmer, barley and triticale, which were obtained and cultivated in 'Agrobiotechnology' Scientific Center, branch of Armenian National Agrarian University (ANAU) Foundation. They provide not only a harvest with high and qualitative indicators, but also stand out for their high tolerance to environmental abiotic factors, in comparison to the traditional varieties of same crops (Martirosyan et al., 2020). The experiments were carried out on spring emmer 'Zvartnots', autumn barley 'Hayk 1' and 'Barnched' triticale varieties (Martirosyan, 2023).

Statistical assessment was performed with the help of ANOVA test. Single factor or one-way ANOVA (analysis of variance). The MS Excel package was used to compare the average data in the experimental variants. The indicator of the least significant difference ($LSD_{0.5}$) was used with the lower limit of the permissible level of significance $p < 0.05$.

RESULTS AND DISCUSSIONS

During the experiments both disinfecting and the growth stimulator effect of mentioned preparation on seed germination and germination duration characteristics were studied. The results of the research are presented on Table 1.

Table 1. The effect of 'Complex-Co' on cereals seeds germination and the duration of their germination. $LSD_{.05}$ – The least significant difference with alpha of 0.05

Cereal crops	Sample	Number of seeding grains, grain per 1 m^2	Number of sprouts, per 1 m^2	Field germination, %	Germination duration, days	Period since tillering to spikes forming, days
Barley (*Hordeum L.*)	Control	600	543.0	90.5	10	17
	Experimental		583.8	97.3	7	13
LSD_{05}			42.7	-	1.4	1.8
Emmer (*Triticum dicoccum Schuebl.*)	Control	450	403.7	89.7	10	16
	Experimental		429.3	95.4	8	14
LSD_{05}			44.5	-	1.3	1.1
Triticale	Control	500	453.5	90.7	9	18
	Experimental		481.0	96.2	7	15
LSD_{05}			47.1	-	1.4	1.2

According to the presented data the comparison of control and experimental samples after the usage of the studied preparation, the significant increase in number of spikes. It's especially notable for emmer: 40.8 sprouts Also, it's notable for barley - 25.6 sprouts and 27.5 for triticale.

The carried-out experiments have demonstrated the significant influence of the tested 'Complex-Co' preparation on field germination of the tested cereal crops, what was expressed in its increase. The maximal percentage of field germination increase was observed for emmer (93.7%), what was 6.8% higher than in control samples. The similar patterns were detected also for barley and triticale.

The experiments also have demonstrated that the studied 'Complex-Co' preparation significantly have shortened the period of vegetation. In experimental samples germination period duration became 2–3 days shorted than in control samples, while Period since tillering to spikes forming, days became shortened to 2–4 days. Thus, the studied 'Complex-Co' preparation has demonstrated the presence of disinfectant properties, plant growth stimulation activity, such as like the after-effect of stimulator.

As the next step of research, the structural elements and the biological yield of the tested cereal crops Barley (*Hordeum L.*) Emmer (*Triticum dicoccum Schuebl.)* Triticale (*Triticale Wittm ex A.*) were studied (Tables 2–3).

Table 2. 'Complex-Co' Influence on structural elements of the tested crops spikes

Cereal Crops	Sample	N_p	N_e	For one spike		
				L	N_s	W_g
Barley (*Hordeum L.*)	Control	425.3	467.8	6.8	34.7	0.84
	Experimental	466.4	510.4	7.4	36.8	0.88
Emmer (*Triticum dicoccum Schuebl.)*	Control	368.5	412.7	7.0	30.7	0.71
	Experimental	380.2	423.5	7.9	34.8	0.76
Triticale *(Triticale Wittm ex A.)*	Control	405.1	429.3	9.4	31.7	1.2
	Experimental	420.4	504.4	10.9	39.5	1.3

N_p – The number of plants per 1 m^2 at the end of vegetation, pieces; N_e – the number of spike-carrying stems per 1 m^2; L – Length of spike, cm; N_s – number of spikelets; W_g – weight of one spikelet, g.

The tested preparation had a significant impact on quantitative and qualitative characteristics of spikes. As a result, the length and the weight of spike had a significant

increase: in 0.6–1.5 cm in comparison to control samples and in 0.04–0.1 g respectively. The increase in weight of 1,000 grains in 0.2–0.5 g was also noted.

Table 3. The effect of 'Complex-Co' on biological yield of cereal crops

Cereal Crops	W	Y	Biological yield (Centner ha^{-1})		
			Total	Including the following:	
				Grain	Straw
Barley (*Hordeum L.*)	38.8	392.5	89.0	39.2	49.8
	38.4	433.3	100.5	43.7	56.8
Emmer (*Triticum dicoccum Schuebl.)*	34.8	294.7	68.5	29.8	38.7
	35.1	317.4	72.1	31.3	40.8
Triticale *(Triticale Wittm ex A.)*	52.3	511.3	119.3	51.8	67.5
	52.8	674.1	156.3	67.8	88.5

W – Weight of 1,000 grains, g; Y – Grain yield from 1 m^2, g.

The amount of obtained grain and straw actual yield was defined by the amount of harvest from the entire garden bed. The grain yield addition was defined due to the comparison to control samples (centner ha^{-1} and %). The maximal yield addition was observed for triticale samples: 12.7 centner ha^{-1} or 30.6%. For barley it was 3.3 centner ha^{-1} or 10.4% and for emmer it was 3.5 centner ha^{-1} or 14.6%, respectively (Table 4).

Table 4. The effect of 'Complex-Co' on actual yield

Cereal Crops	Sample	Harvest (Centner ha^{-1})			Grains harvest difference in comparison to control	
		Total	Including		Centner ha^{-1}	%
			Grain	Straw		
Barley	Control	72.9	31.7	41.2	-	-
(*Hordeum L.*)	Experimental	80.5	35.0	45.5	3.3	10.4
	$LSD_{.05}$	8.7	7.6	7.8	1.4	-
Emmer	Control	52.6	23.9	28.7	-	-
(*Triticum dicoccum*)	Experimental	60.1	27.4	32.7	3.5	14.6
	$LSD_{.05}$	9.7	8.4	7.1	1.6	-
Triticale	Control	95.4	41.5	53.9	-	-
(Triticale Wittm ex A.)	Experimental	124.7	54.2	70.5	12.7	30.6
	$LSD_{.05}$	11.0	5.2	7.1	1.9	-

LSD_{05} – The least significant difference with alpha of 0.05.

The use of 'Complex-Co' have demonstrated the significant impact on the quality parameters of the obtained grains harvest of tested crops. The tested 'Complex-Co' had demonstrated the high efficiency as disinfection agent and it might be used instead of classical chemical origin analogous compounds. At the same time, the mentioned preparation greatly contributes to the increase of the yield, what is extremely important for obtaining of ecologically clean agroproducts. Also, the usage of the organic preparations like 'Complex-Co' is very actual for the ecological safety of soil and ground and surface waters, what is now extremely important due to the aggravation of that problem in Lake Sevan of RA (Gabrielyan et al., 2022).

The specified characteristics of these varieties have been proven as a result of long-term research, within a period of which it was convinced that the yield of the mentioned crops varieties was 8.5–10.2% higher than in traditionally cultivating varieties of them (Martirosyan, 2020).

For this purpose, an average sample was isolated from the grain yield obtained as a result of scientific experiments and subjected to laboratory examination to find out the chemical composition of the grain, emphasizing the amount of harmful nitrogen (residual nitrates) presentage in it, the results of which are introduced in Table 5.

Table 5. The effect of organic fertilizers on the chemical composition of grain

Cereal Crops	Sample	Proteins, %	Carbohydrates, %	Nitrate residues, mg kg^{-1}
Barley	Control	10.1	68.8	11.1
	Experimental	11.8	72.2	5.1
Emmer	Control	10.2	71.8	12.4
	Experimental	11.7	79.4	4.1
Triticale	Control	9.9	77.8	10.9
	Experimental	10.8	81.9	7.8

According to the results of the chemical analysis of the average sample separated from the harvest, it was found that the concentration of residual nitrates in grains was the maximum 11.6 mg kg^{-1}, while the permissible limit of the latter is 60 mg kg^{-1} (Shi et al., 2021).

The energy value of food used for both food and feed purposes is first of all estimated based on the percentage content of proteins and carbohydrates present therein. In this regard, when using again organic fertilizers, according to the results of chemical analysis ('FDA laboratory' LLC), considerable increase in the amount of those substances was observed in the grain composition. Thus, the protein percentage in the grains of the fertilized variants of the tested cereal crops increased by 0.9–1.5%, and carbohydrates - by 3.4–4.1%, compared to the control variants of the same crops. Here the issue related to the production of ecologically safe food and fodder is highly important, which is determined by the amount of their nitrate content. In this regard, it should be noted that a certain amount of residual nitrogen was observed in the grain yield obtained from the control variants cultivated in the traditional way, which significantly exceeded the same indicators of the variants cultivated with organic fertilizers.

CONCLUSION

During the experiments, the newly elaborated 'Complex-Co' preparation has demonstrated the high efficiency. The mentioned preparation of complex influence, was obtained in our laboratory by an optimized technology based on a comparably cheap row material: TA with the addition of colamine (ethanolamine) and the chelate form of the various important micronutrients. The described innovative formula of 'Complex-Co' preparation ensured its intensive target influence, what was demonstrated by the high efficiency on grain crops both for pre-treatment of seeds and for foliar feeding.

The conducted research has convinced that, 'Complex-Co' preparation can be used during the entire growing season of cereal crops. It might reduce the amounts of nitrogen fertilizers consumption, what is the one of the most important challenges of green agriculture. 'Complex-Co' preparation is recommended for further more detailed research on other crops and other plants of various taxonomic groups, to determine the range of the maximal effective fluid concentrations and application rates. The tested 'Complex-Co' preparation has demonstrated itself as the highly active plant growth stimulator. Also, it was noted the positive influence of it, as the seeds disinfectant, because of the activity of colamine component against the range of pathogenic microorganisms, such as like phytopathogenic bacteria.

Thus, 'Complex-Co' preparation might be recommended for cereal farmers to introduce into production, as an ecologically friendly biofertilizer.

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