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Analysis Of Synergetic Effects From Multifunctional Growth Regulating Agents In The Of Sunflower Mineral Nutrition System.

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ABSTRACT

It is proved that application of high rates of mineral fertilizers to the southern chernozem of Yelanets district of Mykolaiv region without application of multifunctional growth regulating agents is ineffective. To increase their effectiveness, it is necessary to comprehensively treat the sunflower sowing with the agents that, firstly, can ensure prolongation of the photosynthetic activity of the leaf apparatus; secondly, increase the content of the total chlorophyll in the leaves with the predominant growth of the fraction "a"; thirdly, intensify the development and functioning of the root system. The result is an increase in the crop yield level with a clearly expressed synergetic effect of the impact factors against the background of the oily raw materials quality preservation.

Keywords: sunflower, mineral fertilizers, growth regulating agents, synergistic effect, photosynthetic potential, chlorophyll fractions, yield, quality.

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INTRODUCTION

Sunflower is a crop with a rather complicated response to the level of mineral nutrition. On the one hand, sunflower, forming a high yield of above-ground biomass, takes out a large number of macro-, meso- and micronutrients, and therefore positively responds to high rates of mineral fertilizers application. On the other hand, the practical implementation of high rates of mineral fertilizers in sunflower agrocenosis is insufficient, that is, with the increase of rates of mineral fertilizers application to $N_{90}R_{60}$, a decrease in the agrocenosis productivity level is observed. In addition, increasing rates of mineral fertilizers application, especially nitrogen ones, have a negative influence on the fat content in sunflower seeds. Thus, in the stationary researches of the All-Union Research Institute of Oil-Bearing Plants, the following results were obtained (Table 1). [1]

Table 1: Effect of fertilizers on sunflower yield and the oil content of its seeds

Nutrition background	Yield, t/ha	Increase in yield, t/ha	Fat content in seeds, %	Harvesting oil from 1 ha, t/ha
No fertilizer	2,64	-	55,3	1,40
$N_{60}P_{90}$	3,00	0,36	53,7	1,53
$N_{30}P_{60}$	2,94	0,30	53,5	1,49
$N_{60}P_{60}K_{90}$	2,96	0,32	52,5	1,48

Two negative phenomena associated with increasing of the fertilizers rates are traced here: 1) the increase in yield from a rate of $N_{60}R_{90}$ has no advantage in comparison with a rate of $N_{30}R_{90}$; 2) the fat content in the seeds is significantly reduced (by 1.6- 2.8% absolute). The aforementioned phenomenon put the sunflower crop on the same level with the plants characterized by low levels of response to fertilizers and forced researchers to seek to efficacious compensation for these negative effects. The inexpediency of applying high rates of mineral fertilizers is reported in the papers of a number of researchers [2-7]. Almost half a century ago, there were obtained the data on the possibility to neutralize the negative effects of fertilizers on the fat content by applying micronutrients. For instance, in the studies of D.S. Tom and V.D. Kravchuk, conducted during 1974-1976 in Moldova, the application of microfertilizers containing Zn, Cu and B almost leveled out the negative effect of fertilizers at a rate of $N_{90}P_{90}K_{90}$.

Over the past 20 years, the world market introduced new generation agents that are characterized by polyfunctionality and have shown themselves not only as stimulants, but also effective anti-stress agents and immune modulators. These agents (at least certain) can enhance the effect of mineral fertilizers at rates that in pure form are beyond the optimum. Scientific literature, highlighting the effectiveness of such agents, in the vast majority only states the presence and the level of this effect, ignoring the search for linkages that determine the integration effect. Therefore, we set task to trace the interaction of mineral fertilizers and the said agents.

MATERIALS AND METHODS

For the studies, a simple interline hybrid of Alamo (Euralis originator) sunflower and modern combined multifunctional agents were taken: Wuxal (Germany), Fitomare (Turkey), Helafit Combi (Ukraine).

Wuxal is the world-famous brand, widely used as a complex microfertilizer with chelate forms of micronutrients. Fitomare is sea kelp extract Agrophyllum Nodasum, enriched with a NPK complex, boron and molybdenum. This agent has a high level of anti-stress effect. Helafit Combi is an agent that simultaneously combines fungicidal, stimulating, nutritional and anti-stress effects.

Field studies were carried out during 2015-2017 in the conditions of Yelanets district of Mykolayiv region on the ordinary low humic chernozem by establishing a two-factor field study. Different backgrounds of mineral nutrition were presented by factor A – fertilizers were applied under the basic cultivation of soil, creating 3 backgrounds:

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1. Control with no fertilizers;
2. $N_{30}P_{45}$
3. $N_{60}P_{90}$

Factor B determined the cultivation of sunflower plants by using growth regulating agents, which were applied on each background of fertilizers: Wuxal – 4.5 l/ha as a foliar nutrition in the phase of the beginning of the capitulum formation; Fitomare – 0.4 l/ha similar to Wuxal; Helafit Combi – 1 l/ha twice (for the first time in the phase of 4-6 leaves and the second – at the beginning of the capitulum formation).

RESULTS AND DISCUSSION

The purpose of the research was to find a combination that would ensure a high level of interaction of basic mineral fertilizer and foliar fertilizing of sunflower plants by using growth regulating agents.

To achieve this purpose, the following tasks had to be solved:

- to give a comparative assessment of the photosynthetic activity indices of plants in all variants of the study;
- to determine the total content of chlorophyll in the leaf and its fractional composition;
- to analyze the sunflower yield level and the quality of oily raw materials.

To solve the first task, a dynamic measurement of the leaf area was carried out at different phases of the plant development. In parallel, the dry above-ground biomass yield was determined, and based on these data, the photosynthetic potential (PP) and the net photosynthesis productivity (NPP) were calculated by using the formulas:

$$PP = A_a * T;$$
$$NPP = (Y_2 - Y_1)/PP; \text{ where:}$$

A_a – average area of the leaf surface for the analytical period;
T – duration of the period;
Y_1 – dry biomass yield at the beginning of the period;
Y_2 – dry biomass yield at the end of the period.

The results of these calculations, summed up over the years of studies, are presented in Table 2.

Table 2: Main indices of photosynthetic activity of sunflower plants in the inter-phase period "capitulum formation – flowering" (average for 2015 – 2017).

Nutrition background (Factor A)	Agent (Factor B)	Leaf area ths.m^2/ha			Duration of period, days	Photosynthetic potential, ths. m^2/ha*days	Increase of dry above-ground biomass, t/ha	Net photosynthesis productivity, g/m^2 per day
		beginning of period	end of period	average				
No fertilizers	No agents (pure water)	21,2	33,1	27,2	33	898	2,81	3,13
	Wuxal	23,0	34,8	28,9	33	954	2,94	3,08
	Fitomare	22,1	34,8	28,0	35	980	3,01	3,07
	Helafit Combi	23,4	35,5	30,0	34	1020	3,12	3,06
$N_{30}P_{45}$	No agents	22,8	34,1	28,5	36	1026	2,98	2,90

	(pure water)							
	Wuxal	24,0	35,3	29,7	36	1069	3,09	2,89
	Fitomare	24,0	36,0	30,0	37	1110	3,13	2,82
	Helafit Combi	24,9	37,0	32,0	37	1184	3,25	2,74
$N_{60}P_{90}$	No agents (pure water)	24,0	34,0	29,0	37	1073	3,07	2,86
	Wuxal	25,0	37,0	31,0	37	1147	3,15	2,75
	Fitomare	25,0	37,0	31,0	38	1178	3,15	2,67
	Helafit Combi	26,2	38,2	32,2	38	1224	3,38	2,76

If we make a quantitative assessment of the effectiveness of fertilizers and agents, the effect of two factors on the size of leaf area and the photosynthetic potential of agrocenosis can clearly traced here. The latter grows both due to the growth of the total leaf area and the prolongation of its productive assimilation activity during the period between the beginning of the capitulum formation and the flowering. Thus, on a reference variant, it was an average of 33 days, and on a variant with the background of fertilizers ($N_{60}P_{90}$), and with applying of Helafit Combi agent, it was 5 days longer. Therefore, if the PP in this variant depended only on the average leaf area, then this index was not 1224, but 1063 ths.m^2/ha*days, that is, 15% less. So, we draw attention to an increase in the direct effect of fertilizers and agents by prolonging the period of productive activity of the photosynthetic apparatus of the plants.

Qualitative index NPP looks quite different. The reverse nature of dependence is observed here: application of fertilizers and agents reduced the size of this index. Thus, with no fertilizers applied, the average level of NPP was 3.09 g/m^2 per day, on the background of $N_{30}P_{45}$ it reduced by 8.1%, and on the background of $N_{60}P_{90}$ - by 10.1%. It points to the fact that the growth of the above-ground biomass is the result of an extensive process due to the growth of the assimilating surface of the plants. Therefore, there is a need for further search for ways to influence the intensity of photosynthesis.

Based on the results of the data from field studies in slowing and ceasing photosynthetic activity of the leaf apparatus, a clear tendency to prolongation of assimilating surface by applying multifunctional agents was discovered – data of these results are presented in Table 3.

Table 3: Dynamics of cessation of photosynthetic activity of the leaf apparatus in the seed plumping phase depending on the agents applied (average for 2015 – 2017)

Month	Date	Remaining green leaves, % of the maximum level			
		control	Wuxal	Fitomare	Helafit Combi
August	10	18,4	19,2	20,4	20,1
	15	15,0	17,0	17,5	18,4
	20	11,5	14,1	13,8	15,6
	25	7,6	10,4	11,0	13,1
	30	3,9	6,1	7,0	9,2
September	05	0	2,2	3,8	6,6
	10	0	0	0	2,8
	15	0	0	0	0

Over the years of studies, the sunflower plants at the reference variant, at the beginning of the seed plumping phase (the first decade of September), on average had almost no green leaves in the upper layer, though when applying multifunctional agent Helafit Combi, a complete cessation of photosynthetic activity of leaves was recorded 10 days later in comparison with the reference variant.

Over the years of studies, certain differences have been identified, but under all conditions, multifunctional agents tended to prolong the functioning of the assimilating apparatus, the result of which was the slowdown in the cessation of the photosynthetic activity of the leaf apparatus.

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In order to more objectively assess the comprehensive effect of mineral fertilizers and growth regulating agents, the need to analyze the underground part of the plants arose. Fig. 1 shows the productivity of the root system, in particular, the ratio of the formation of above-ground biomass to the mass of the roots.

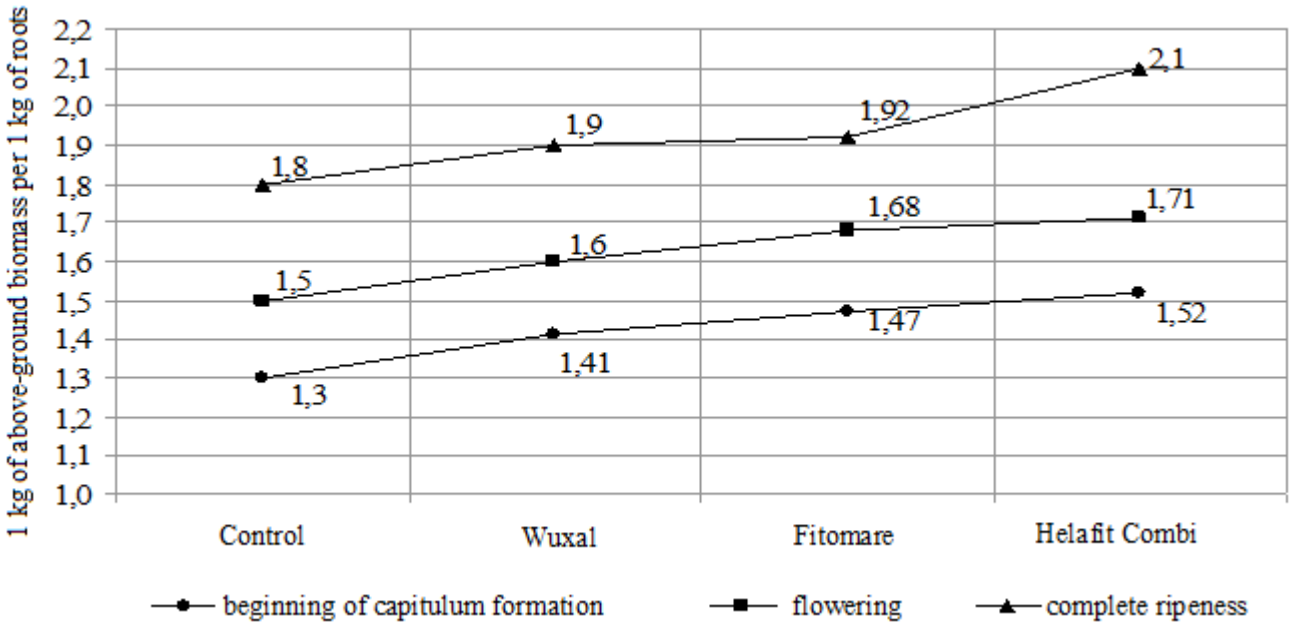

Fig1: The nature of formation of the above-ground biomass and the mass of the roots depending on the growth regulating agents applied, (average for 2015-2017)

Based on the results of the research, it is apparent that the advantage of the variants with the application of agents is clearly traceable throughout all periods of conducting investigations. It should be noted that all the applied agents had a significant influence on the root productivity, which was characterized by a tendency to increase in intensity of growth as compared to the reference variant, in particular: Wuxal – by 5,0 – 6,8%; Fitomare – 6,1 –10,5%; Helafit Combi – by 13.2 – 14.9%. This is the result of the fact that most agents in their composition (at least Helafit Combi) have cytokinins that stimulate the development of the root system. When applying a mineral fertilizer, this phenomenon was not observed, except for occasional sporadic moments.

The research program envisaged the determination of the fractional composition of the green pigment of plants – chlorophyll, which is crucial for the process of agrocenosis photosynthesis. We predicted that such factors as fertilizers and agents would have a significant influence on the formation of the whole system and the chlorophyll activity. Field and laboratory studies have proved the validity of these expectations, the results of which are presented in Table 4.

Table 4: Chlorophyll content in sunflower leaves in the flowering phase (average for 2015 – 2017)

Nutrition background (factor A)	Agent (factor B)	Chlorophyll content, mg per 1 g of dry matter			Ratio of fraction «a» to «b»
		total	fraction		
			«a»	«b»	
No fertilizers	No agents (pure water)	5,18	3,60	1,59	2,26
	Wuxal	6,29	4,58	1,71	2,67
	Fitomare	7,07	5,27	1,80	2,93
	Helafit Combi	7,03	5,34	1,69	3,16
$N_{30}P_{45}$	No agents (pure water)	7,36	5,60	1,76	3,18
	Wuxal	8,63	6,83	1,80	3,79

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	Fitomare	8,94	7,02	1,91	3,68
	Helafit Combi	8,32	6,66	1,66	4,01
$N_{60}P_{90}$	No agents (pure water)	7,50	5,69	1,81	3,16
	Wuxal	8,81	6,12	2,69	2,28
	Fitomare	8,97	6,17	2,80	2,20
	Helafit Combi	8,44	6,05	2,39	2,53

The results of studies showed that chlorophyll content increased significantly under the effect of fertilizers and agents, the maximum value of this index was marked in the variant when applying agent Fitomare on the background of $N_{60}P_{90}$ – 8,97 mg/g of dry matter, which is 73% more than on the reference variant (with no fertilizers or agents applied). Interestingly, under the effect of program factors, not only the total content of green pigment, but also the fractional composition of chlorophyll changed. In all cases there was a priority increase in the content of the fraction "a". Thus, the maximum growth of this fraction was 90%, while the fraction "b" did not exceed 76%. On non-approved background, these indices were 48 and 13% respectively. This means that the optimal selection of a multifunctional combined agent can become an effective way of regulating the number of chlorophyll and its fractional composition.

Under these conditions, a higher yield was obtained when applying fertilizers and agents, specifically, when combining them (Table 5).

Table 5: Yield of sunflower depending on the rate of mineral fertilizers and agents applied, t/ha

Nutrition background (factor A)	Agent (factor B)	Years			Average by year
		2015	2016	2017	
No fertilizers	No agents (pure water)	1,83	2,12	2,34	2,10
	Wuxal	2,0	2,20	2,45	2,22
	Fitomare	2,04	2,26	2,51	2,27
	Helafit Combi	2,10	2,29	2,60	2,33
$N_{30}P_{45}$	No agents (pure water)	2,06	2,19	2,48	2,24
	Wuxal	2,13	2,28	2,50	2,30
	Fitomare	2,33	2,33	2,63	2,32
	Helafit Combi	2,28	2,40	2,69	2,35
$N_{60}P_{90}$	No agents (pure water)	2,10	2,26	2,14	2,27
	Wuxal	2,26	2,30	2,54	2,37
	Fitomare	2,30	2,36	2,59	2,42
	Helafit Combi	2,49	2,48	2,67	2,52
$LSD_{0,5}$, t/ha	A	0,14	0,15	0,21	-
	B	0,09	0,11	0,13	-
	AB	0,16	0,18	0,19	-

First of all, it is important to note the decrease in the fertilizers effectiveness level while their rate increases. As one can see, over the all years of studies, the increase in yields by increasing the fertilizers from $N_{30}P_{45}$ to $N_{60}P_{90}$ proved to be insignificant.

With regard to the agents, their positive effectiveness was manifested in almost all cases. Particularly noteworthy is that the combined effect of fertilizers and the agent can be equal to or even exceed the effect of individual factors. Thus, on average, over the years of studies, fertilizer $N_{60}R_{90}$ ensured an increase by 0.17 t/ha, and the agent Helafit Combi – by 0.23 t/ha. Thus, in aggregate, these increases amount to 0.40 t/ha. At the same time, the increase from the combination of fertilizer ($N_{60}P_{90}$) + agent (Helafit Combi) was 0.42 t/ha, that is, exceeded the sum of both factors. This phenomenon is called synergism, when the effect of two or more factors in their combined effect exceeds the simple sum of the effect of each factor. In the practice of agronomic studies, as a rule, the sum of effect of individual factors significantly outweigh their interaction.

For such industrial crop as sunflower, not only the level of yield, but also the quality of the resulting product is important. Laboratory studies on the fat content in the sunflower achenes and kernels showed that

the increase in fertilizers rates significantly lowered the quality of the oily raw materials (results are presented in Table 6).

Fat content in sunflower seeds depending on the rate of mineral fertilizers and agents applied (average for 2014-2017).

Nutrition background (factor B)	Agent (factor B)	Fat content, %		Proportion of oleic acid in oil, %
		in achenes	in kernels	
No fertilizers	No agents (pure water)	43,8	55,4	61,0
	Wuxal	45,0	55,9	61,4
	Fitomare	44,6	55,8	62,4
	Helafit Combi	45,2	56,0	62,8
$N_{30}P_{45}$	No agents (pure water)	41,9	54,4	61,1
	Wuxal	44,3	54,9	61,2
	Fitomare	44,0	54,9	62,2
	Helafit Combi	44,8	55,6	62,9
$N_{60}P_{90}$	No agents (pure water)	40,7	53,5	62,8
	Wuxal	44,0	54,3	62,2
	Fitomare	43,8	54,4	62,1
	Helafit Combi	44,7	55,3	63,3

The maximum rate of fertilizers studied in the experiment resulted in a loss of 3.1% of fat, and the minimum - lowered this index by 1.9%, while all growth regulating agents compensated for the negative effect of fertilizers and increased the oil content of seeds, which also proves the synergistic effect. In addition to the total fat content, the studied agents positively influenced the fatty acid composition of the oil, causing an increase in the proportion of oleic acid to 73 – 75%, which brought the products closer to the quality of the high-oleic hybrids.

CONCLUSION

Based on the analysis of field studies, laboratory tests and observations, the following conclusions can be made:

1. Fertilizers and growth regulating agents promote increasing of the area of the assimilating surface of sunflower plants (up to 16%) and at the same time inhibit the process of cessation of the photosynthetic activity of the leaf apparatus.
2. Both studied factors increase the total content of chlorophyll in the leaves by 30-70%, and this increase is mainly due to the fraction "a".
3. Application of agents activates the growth of the root system and increases their mass, which results in the increase in the productivity of the roots activity, on average, over the years of studies, by 14-15%.
4. The combined effect of mineral fertilizers and the agent Helafit Combi exceeded the aggregate effect of both factors studied, that is, we observed a phenomenon of synergism: increase in the yield when applying $N_{60}P_{90}$ was 0.17 t/ha, and when applying Helafit Combi - 0.23 t/ha; the increase due to complex application was 0.42 t/ha.
5. Multifunctional growth regulating agents neutralize the negative effect of mineral fertilizers on the index of fat content in the seed. They also improve the quality of the oil, increasing the specific content of oleic acid in it.

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