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Plant Protection And Foliar Fertilizing Technology Of Apple (Malus Domestica Borkh)

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Abstract*: The systematic use of foliar fertilizers during growing season is a relatively new agronomic practice in Central Russia and it is still not widely used in horticultural enterprises of the region. One of the main reasons for this is the relatively high cost of this method. Producers prefer soil fertilization which adversely affect the environment. A significant reduction in cost of foliar fertilizing could be obtained by combining foliar nutrition with plant protection. The number of plant protection treatments, as well as toxicity of some products, is increasing annually. The use of fertilizers and plant protection products negatively affect the environment. It is very important to find ways of decreasing this load on surroundings. Currently, many different biological preparations for plant protection exist which are suggested to replace chemicals. The problem is in their relative low effectiveness compared to traditional plant protection products. The authors have studied the most popular plant protection products (in a traditional protection system) and application of foliar fertilizers (in a mineral foliar fertilizer system) in comparison with ecologized plant protection system (based on bacterial and low-toxic preparations) in tank mixtures with seaweed extracts-based foliar fertilizers. The authors have considered yield, scab development, content of calcium in leaves and fruits as the main criteria of this study. The research was carried out in the irrigated orchard (1,480 trees/ha), planted in leached meadow-chernozem soil. The investigation was carried out in 2013-2015. The results of traditional plant protection system in tank mixtures with mineral foliar fertilizer application, as well as ecologized products with seaweed extracts-based preparations, have been compared. Traditional plant protection system in combination with mineral foliar fertilizers have ensured a higher content of calcium in leaves and fruits, less damage from scab and higher yields. We can consider two ways of replacing traditional plant protection and fertilizing approach: the development of new highly efficient ecologized products or increased financial support.

***Index Terms*: calcium leaf and fruit status, foliar nutrition, plant protection, traditional and ecologized plant protection systems, scab lesions, yield.**

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I. INTRODUCTION

Apple is the most common fruit crop in Russia [1]. Apple growers must achieve two aims – good yield and high quality of fruits. Various fertilizing methods were developed for producing large yields during the last decennaries. Good quality of fruit implies lack of lesions from pests and diseases, fruit size required by consumers, optimal fruit mineral status, etc. Fruit growers apply large amount of fertilizers and use a lot of chemical products for managing abovementioned purposes. Many researchers proved that by-effect of this agronomical practices was contamination of soil, water, air and cultivated products, as well as emergency of resistance races of pests and pathogens [2]-[6]. Wide application of ecologized plant protection systems is a good opportunity for minimizing a negative impact on the environment [7], [8]. The effect from application of such products could be comparable with integrated plant protection management [9], [10]. Foliar fertilizing is one of the most low-cost and effective ways to optimize plant nutrition in orchard [11]. This agronomical practice cannot replace soil fertilizing but foliar nutrition can reduce soil application rates. However, spaying with seaweed extracts-based products didn't affect a yield in Italy [12]. From the other side, use of seaweed extracts could help to moderate the negative effects of alternate bearing in apple trees [13]. The aim of this study is to evaluate effectiveness of different approaches (traditional and ecologized) in irrigated apple orchard on fruit and leaf calcium status, susceptibility to scab and yield.

II. PROPOSED METHODOLOGY

A. General description

The research was carried out in I.V. Michurin Federal Scientific Centre (Michurinsk, Russia) in 2013-2015. Experimental plots were established in full bearing orchard (1,480 tr./ha, cultivars 'Lobo' and 'Zhigulevskoye' grafted on B396 rootstock, drip irrigated). Both cultivars are susceptible to scab. The orchard was planted in 2007. Trees were trained as spindelbush. The experiment was arranged in randomized blocks with 5 trees and 3 replicates.We recorded the number of flowers, small fruits after young fruit drop and fruits at harvest which were accounted visually on all reference plants in trial.

The index of fruit-setting was calculated as follows the percentage ratio of the fruit number at harvest to the number of flowers at full bloom. Average fruit weight (g) was determined on random samples of 100 fruits per each experimental plot of 5 trees. Leaf sampling was carried out in middle August, fruit sampling – immediately after harvest.
Calcium content in leaves and fruits was determined on flame photometer Jenway PHP-7, the content of element was expressed as % of dry matter (DM) [14].
We did not apply any fertilizers within 3 years before the trial in reserved plots (proposed for experiment) in order to correctly assess the impact of different foliar nutrition systems. Agrochemical properties of trial plot soil – leached meadow-chernozem, low of humus (2.6-3.2%, depth – 40-50 cm), heavily loamy on sand with pseudofibers, base saturation – 68-89%, the amount of absorbed bases – 27.3-31.2 meg/100 g soil. The reaction of topsoil was slightly acidic (pH=5.4-5.7). The content of easily hydrolyzed nitrogen – 121.2-137.6; mobile phosphorus – 128.8-139.7; exchangeable potassium – 186.5-197.3 mg/kg soil. The soil analyzes were done just before the experiment.
In our trial we studied the effect of Traditional (TPPS) and Ecologized Plant Protection Systems (EPPS) on scab development. The EPPS included some bacterial preparations. Plant protection products labeled "very toxic" and "toxic" were not used in this sustem.

We studied the effect of two different foliar fertilizer systems: based on artificial preparations (Mineral Foliar Fertilizer System – MFFS) and seaweed extracts-based foliar fertilizers (Seaweed Extracts-Based System – SWBS) on yield as well as leaf and fruit calcium status. Fertilizers and plant protection products were applied in tank mixtures during the growing season (Tables I; II and III).

Fruit scab damage was recorded by harvesting and accessed on random samples of 100 fruits per each experimental site where 0 = no scab lesions, 1 = 2-3 lesions and 2 = more than 4 spots per fruit.

B. Algorithm. Trial scheme

1. Control (TPPS without foliar fertilizing)
2. SWBS + TPPS
3. MFFS + TPPS
4. SWBS + EPPS
5. MFFS + EPPS

Table I. Active *ingredients* in seaweed extracts-based foliar fertilizers, %

Products	Alginic acid	N	P	K	Mg	B	S	Cu	Fe	Ca	Amino acids	Vitamins	Organic substance
SWB1	10-12	1		2-9	0.04		0.1	0.00007	Traces	Traces	Traces	Traces	
SWB2	2	4		3	0.0047				0.027	0.007	10-28		12
SWB3		5				14							15
SWB4	1	0.04	1.2	3									20
SWB5		5-10								12.5-14.0	10		

Table II. Active *ingredients* in mineral foliar fertilizers, %

Products	N	P	K	Mg	Cu	Fe	Mn	Ca	Zn	Amino acids	Mo	B
MFF1	18	18	18	3	0.005	0.070	0.030		0.010	28	0.001	0.020
MFF2	4.5		2.9									
MFF3												11
MFF4								15				

Table III. Plant protection schemes and foliar fertilizing systems

Growth stage by BBCH	Traditional Plant Protection	Ecologized Plant Protection	Seaweed extracts-based foliar fertilizer	Mineral Foliar Fertilizer
07-09	700 g/kg metiram + 15 g/kg hexamethylenetetramine (2.5 l/ha) 50 g/L lambda-cyhalothrin (0,4 l/ha)	700 g/kg dithianon (0.6 kg/ha) 250 g/kg thiamethoxam (0.1 kg/ha)	SWB1(0.5 kg/ha)	MFF1 (5 kg/ha) MFF2 (2.5 kg/ha)
57	700 g/kg dithianon (0.6 l/ha) 100 g/L alpha-cypermethrin (0.3 l/ha)	Bacillus subtilis IPM 215, BA-10000 U/g 10000 Spore titre, 10^9 spores/g -2.0 (10 kg/ha) 240 g/l diflubenzuron (0.5 l/ha)	SWB2 (0.5 l/ha) SWB4 (0,5 l/ha) SWB3(0.5 l/ha)	MFF1 (5 kg/ha) MFF3 (0.4 l/ha)
61	120 g/kg ditianon + 40g/kg piraklostrobin (2.5 kg/ha) 700 g/kg dithianon (0.2 l/ha)	500 g/kg Kresoxim-methyl (0.2 kg/ha)	SWB2 (0.5 l/ha) SWB3(0.5 l/ha) SWB5 (0.5 l/ha)	MFF1 (5 kg/ha) MFF3 (0.4 l/ha) MFF4 (2 kg/ha)
69	120 g/kg ditianon + 40g/kg piraklostrobin (2.5 kg/ha) 400 g/L dimethoate (1.5 l/ha)	250 g/l difenoconazole (0.25 kg/ha) 200 g/l chlorantraniliprole (0.2 l/ha)	SWB2 (0.5 l/ha) SWB5 (0.5 l/ha)	MFF1 (5 kg/ha) MFF2 (2.5 kg/ha)

72	700 g/kg dithianon (0.6 l/ha) 480 g/L thiacloprid (0.3 l/ha)	Pseudomonas fluorescens AP-33 10^9 CFU/ml 200 g/l chlorantraniliprole (0.2 l/ha)	SWB1(0.5 kg/ha) SWB5 (0.5 l/ha)	MFF1 (5 kg/ha) MFF4 (2 kg/ha)
74	120 g/kg ditianon + 40g/kg piraklostrobin (2.5 kg/ha) 400 g/L dimethoate (1.5 l/ha)	700 g/kg Dithianon (0.6 kg/ha)	SWB2 (0.5 l/ha) SWB2 (0.5 l/ha) SWB5 (0.5 l/ha)	MFF1 (5 kg/ha) MFF4 (2 kg/ha)
75	700 g/kg metiram + 15 g/kg hexamethylenetetramine (2.5 l/ha)	Bacillus subtilis IPM 215, BA-10000 U/g 10000 Spore titre, 10 ^{9} spores/g -2.0 (10 kg/ha)	SWB2 (0.5 l/ha) SWB2 (0.5 l/ha) SWB5 (0.5 l/ha)	MFF4 (2 kg/ha)
77	500 g/kg benomil (1 кг/га) 50 g/l lufenuron (1 l/ha)	700 g/kg dithianon (0.6 kg/ha) indoxacarb 150 g/l (0.35 l/ha)	SWB2 (0.5 l/ha) SWB2 (0.5 l/ha) SWB5 (0.5 l/ha)	MFF4 (2 kg/ha)
81	50 g/l difenoconazole + flutriafol 30 g/l (1 l/ha) malathion 570 g/l (1 l/ha)	trifloxystrobin 500 g/l (0.14 kg/ha) aversectin C 2 g/l (2 l/ha)	SWB2 (0.5 l/ha) SWB2 (0.5 l/ha) SWB5 (0.5 l/ha)	MFF4 (2 kg/ha)

The experimental data (yield, number of flowers and fruits, fruit average weight) were evaluated by general analysis of variance (ANOVA) described by B.A. Dospekhov [15], which is widely used in agricultural research in Russia. It is based on Fisher's least significant different test. Any difference larger than the Least Significant Difference (LSD) is considered as a significant result. We calculated the LSD at p=0.05. These research date were analyzed with AgStat add-in software for Microsoft Excel [16].

Also, we made regression analysis for determination the adequate analytical dependence (regression equation) between the indicators and factors in our research. The traditional approach for regression analysis assumes that there is a linear dependence in the form:

$$y_i = b_0 + \sum_{j=1}^{p} b_j x_{ij} + \varepsilon_i, \quad i = \overline{1,n} \qquad (1)$$

where y_i – n random values (observed output variables), represented as linear combination of x_{ij} with unknown constants $b_1, b_2, \ldots, b_p$ and mistakes $\varepsilon_1, \varepsilon_2 \ldots \varepsilon_n$;

x_{ij} – known observation values.

To define the unknown parameters of a linear model, usually the method of least squares is used, which allows to find parameters from the minimizing the sum of error squared $\sum \varepsilon_i^2 \rightarrow min$. Then, the standard errors of the regression coefficients are calculated $s\{b_i\}$.The significance of the regression coefficient could be checked by calculating the relationship:

$$t_i = \frac{|b_i|}{s\{b_i\}}, \quad i = \overline{1,n} \qquad (2)$$

where t_i is compared with coefficient t, which is given in Student t-distribution tables according to the preselected probability and the number of degrees of freedom.

To check the adequacy of a model, the Fisher's criterion is used:

$$F = \frac{s_y^2}{s_{res.}^2} \qquad (3)$$

where $s^2_{res.}$ – dispersion, which was not explained by regression equation, residual dispersion; s^2_y – the total dispersion of the effective index.

If F>F-table at a given reliability level, the model is considered adequate at this level [17]. As factors, variables with numerical values are considered in a certain range. To include in a model factors with two or more category levels, they must be digital tagged, i.e. categorical variables need to be converted to numerical ones and these variables are called fictitious. Fictitious variables that have two category levels are also called dichotomous (binary, Boolean variables) [18]. The following dichotomous variables were introduced for various treatments of our trial:

$$Z_1 = \begin{cases} 1 - for\ SWBS + TPPS \\ 0 - in\ other\ cases \end{cases}$$

$$Z_2 = \begin{cases} 1 - for\ MFFS + TPPS \\ 0 - in\ other\ cases \end{cases}$$

$$Z_3 = \begin{cases} 1 - for\ SWBS + EPPS \\ 0 - in\ other\ cases \end{cases}$$

$$Z_4 = \begin{cases} 1 - for\ MFFS + EPPS \\ 0 - in\ other\ cases \end{cases}$$

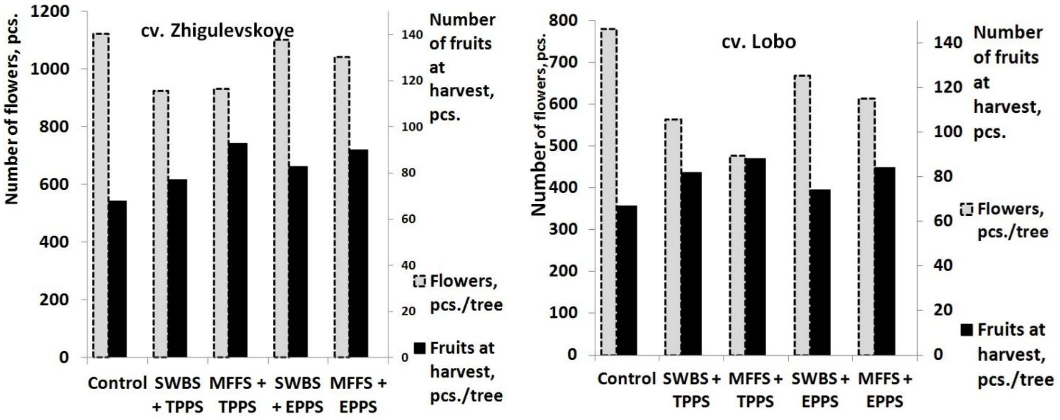
Leaf and fruit calcium concentration values were tabulated and subjected to regression analysis, using Statistica 8.0 software package.

C. Block Diagram

Various methods to optimize mineral nutrition and to improve plant protection are among the most significant agricultural practices, providing good yields of high-quality fruits. One of the most important factors in fruit production is to ensure an optimal level of fruit set. The application of foliar fertilizers allows to improve the fruit set and to reduce the fruit fall during their growth and ripening. Plant protection measures significantly reduce the harmfulness of pests and diseases.

The largest number of flowers of both cultivars was in Control (Figs. 1, 2; Table IV). The largest number of fruits at harvest was in treatments with mineral foliar fertilizing. We noted some difference between the cultivars – cv. 'Lobo' had not a significant variation in the number of fruits when using seaweed extracts-based preparations compared to mineral fertilizers.

The fruit-setting index fluctuated significantly in each year of research, which was determined by the difference of the annual crop load. We already have pointed out in our earlier studies, that two factors played an important role: optimization of fruit setting under the influence of boron and calcium and a decrease of fruit drop up to the harvest [19]. Cv. 'Zhigulevskoye' had the maximum fruit setting by mineral foliar fertilizers application in tank mixtures with TPPS. Application of mineral foliar fertilizers as well as SWBS in tank mixtures with TPPS provided better fruit setting as we observed in Control and SWBS + EPPS.



LSD_{05} = 174.14 (flowers); 6.62 (fruits at harvest)

LSD_{05} = 158.71 (flowers); 5.48 (fruits at harvest)

Fig. 1. Numbers of flowers, small fruits (<20 mm) after first fruit drop, and fruits at harvest, 2013-2015

The effect of different treatments in our trial on the fruit set of cv. ‘Lobo’ was generally the same like cv. ‘Zhigulevskoye’. The largest setting of fruits was in MFFS + TPPS treatment. We also observed significant increase of fruit number compared to Control by using the tank mixture SWBS + EPPS.

Table IV. Fruit set (free pollination), %

Treatments	cv. ‘Zhigulevskoye’				cv. ‘Lobo’			
	2013	2014	2015	Average	2013	2014	2015	Average
Control	8.3	6.3	7.1	7.2	10.1	10.7	9.7	10.2
SWBS + TPPS	10.4	7.5	8.3	8.7	12.6	16.5	13.4	14.2
MFFS + TPPS	12.9	9.0	10.2	10.2	15.4	17.0	18.6	17.0
SWBS + EPPS	9.2	6.9	7.7	7.7	11.7	12.7	10.8	11.7
MFFS + EPPS	10.9	7.8	8.8	8.8	12.2	15.6	11.2	13.0
LSD_{05}	1.74	1.07	1.12	0.77	1.84	1.88	1.42	9.23

Both cultivars (especially, cv. ‘Zhigulevskoye’) are characterized by large fruits. The average fruit weight changed year-on-year depending on the tree crop load (Table V). Maximum value was in 2013. The average fruit weight of cv. ‘Zhigulevskoye’ strongly decreased in 2014, then in 2015 we observed certain increase of this indicator, but it was not so large like in 2013. The largest average fruit weight of cv. ‘Lobo’ we also observed in 2013.

Table V. Fruit average weight, g

Treatments	cv. ‘Zhigulevskoye’				cv. ‘Lobo’			
	2013	2014	2015	Average	2013	2014	2015	Average
Control	187.4	155.7	171.2	171.4	155.6	140.4	125.2	140.4
SWBS + TPPS	191.2	166.9	179.1	179.1	163.3	126.5	145.8	145.2
MFFS + TPPS	204.5	155.5	179.8	179.9	167.7	163.5	157.4	162.9
SWBS + EPPS	188.5	158.8	178.7	175.3	161.7	143.1	148.9	151.1
MFFS + EPPS	193.2	162.3	172.1	175.9	164.2	157.8	162.8	161.6
LSD_{05}	21.4	23.2	19.8	12.2	18.2	17.1	20.0	11.4

We did not observed significant differences of the average fruit weight in various treatments on Cv. ‘Zhigulevskoye’ in each year of research. Otherwise, cv. ‘Lobo’ had essential distinction of average fruit weight in 2014 and 2015 among the treatments in our trial. We noted the largest fruit weight by application of mineral foliar fertilizers in tank mixtures with both studied plant protection systems. We thought that the main reasons were multiple application of nitrogen and amino acid fertilizers which were included in mineral foliar fertilizer system, since this led to the growth and elongation of cells [20]. Such phenomena we observed only on cv. ‘Lobo’.

Calcium is a very important nutrient in the life of plant organisms [21]. Chernozem soils have relatively high calcium content, but its absorption by plant roots is hampered because of soil barium and strontium, which are also abundant [22], [23]. That is why foliar fertilizing has a great impact on improving of leaf and fruit calcium status. The application of both studied foliar fertilizing systems significantly increased the calcium content in the leaves (Table VI).

Table VI. Calcium content in the leaves, % of DM

Treatment	cv. 'Zhigulevskoye'				cv. 'Lobo'			
	2013	2014	2015	Average	2013	2014	2015	Average
Control	1.37	1.59	1.31	1.42	1.55	1.69	1.25	1.50
SWBS + TPPS	1.98	2.15	1.64	1.92	1.69	1.31	1.45	1.48
MFFS + TPPS	1.62	2.20	1.79	1.87	1.90	2.00	1.53	1.81
SWBS + EPPS	1.88	2.07	1.73	1.89	1.55	1.47	1.34	1.45
MFFS + EPPS	1.75	1.93	1.84	1.84	2.09	2.12	1.63	1.95
HCP_{05}	0.11	0.12	0.10	0.06	0.11	0.08	0.14	0.06
Optimum	1.50-2.00 [24]							

We obtained the regression equation as a result of the sequential regression analysis of leaf calcium status (in 2013):

$$Y = 137 + 0.61Z_1 + 0.25Z_2 + 0.51Z_3 + 0.38Z_4 \quad (4)$$

Tank mixture SWBS+TPPS had promoted the increase of calcium content in cv. 'Zhigulevskoye' leaves by 0.61% DM, MFFS + TPPS only by 0.25% DM. If different foliar fertilizing systems were applied in tank mixtures with EPPS calcium content had risen by 0.51% DM (with SWBS) and by 0.38% (with MFFS). Calcium concentration had increased higher with application of seaweed extracts-based fertilizers in 2013. These equations are the results of sequential regression analysis of the research data obtained in 2014 and 2015.

2014 – $Y = 1.69 + 0.46Z_1 + 0.51Z_2 + 0.38Z_3 + 0.24Z_4$ (5)

2015 – $Y = 1.31 + 0.33Z_1 + 0.48Z_2 + 0.42Z_3 + 0.53Z_4$ (6)

The application of both foliar nutrition systems with TPPS had similar effect on leaf calcium status in 2014. But in mixtures with EPPS better result was obtained by applying seaweed extracts-based fertilizers (5). On the contrary, mineral foliar fertilizer application gave better impact on calcium concentration in apple leaves in 2015 (6).

Cv. 'Zhigulevskoye' had a good response to foliar fertilizing. SWBS had a higher impact on calcium concentration in leaves in 2013 and 2014 (in tank mixtures with EPPS). We didn't observed any significant difference between both nutrition systems regarding the leaf calcium status in 2015.

Cv. Lobo had another response to foliar fertilizing. We got the next regression equation in 2013:

$$Y = 1.55 + 0.14Z_1 + 0.35Z_2 + 0.54Z_4 \quad (7)$$

According to this model (with correlation factor 99.99%) application of SWBS + EPPS did not have a significant impact on leaf calcium status. Considerable effect was noted by application of mineral fertilizers, especially in tank mixture with EPPS (7).

The regression equation was as follows in 2014:

$$Y = 1.53 + 0.59Z_4 \quad (8)$$

Correlation factor of this model was 0.66. Statistical significant impact on calcium leaf status was done only by application of MFFS+TPPS in this year (8).

In 2015, the best results were obtained by application of MFFS in tank mixtures with both plant protection systems (9).

$$Y = 1.30 + 0.16Z_1 + 0.24Z_2 + 0.34Z_4 \quad (9)$$

However, the largest increase of calcium content was observed in treatment MFFS+TPPS. The most stable impact on optimizing the calcium content in apple leaves of both cultivars was done by the application of Mineral Foliar Fertilizer System in tank mixtures with Traditional Plant Protection System during the whole research period.

The optimum calcium fruit status is one of the most important factors for postharvest period [25], [26]. The calcium content in apple fruits varied significantly in treated trees in fruits of different cultivars (Table VII). As we mentioned earlier, c.v. 'Zhigulevskoye' had a good response to sprayings.

According to the models 10-12 (with coefficients of multiple correlation 0.97; 0.97; 0.94, respectively) calcium content in cv. 'Zhigulevskoye' fruits was really optimized only by mineral fertilizer system applied in tank mixtures with TPPS and EPPS.

2013 – $Y = 0.031 + 0.028Z_2 + 0.006Z_3 + 0.015Z_4$ (10)

2014 – $Y = 0.03 + 0.02Z_1 + 0.031Z_2 + 0.013Z_3 + 0.018Z_4$ (11)

2015 – $Y = 0.033 + 0.011Z_1 + 0.02Z_2 + 0.005Z_3 + 0.008Z_4$ (12)

Better impact on calcium fruit status was noted when MFFS was applied together with traditional plant protection products.

Table VII. Calcium content in apple fruits, % of DM

Treatments	cv. 'Zhigulevskoye'				cv. 'Lobo'			
	2013	2014	2015	Average	2013	2014	2015	Average
Control	0.029	0.030	0.033	0.031	0.024	0.019	0.016	0.020
SWBS + TPPS	0.034	0.050	0.044	0.043	0.029	0.032	0.035	0.032
MFFS + TPPS	0.059	0.061	0.053	0.058	0.029	0.043	0.038	0.037
SWBS + EPPS	0.037	0.043	0.038	0.039	0.027	0.035	0.035	0.032

MFFS + EPPS	0.046	0.048	0.041	0.045	0.038	0.045	0.038	0.040
LSD_{05}	0.005	0.006	0.006	0.003	0.006	0.003	0.005	0.002
Optimum	0.040-0.060 [24]							

The only treatment that made significant impact on calcium fruit status of cv. Lobo was MFFS+TPPS in 2013 (13). In 2014, mineral foliar fertilizer application made significant impact on fruit calcium content in tank mixtures with both plant protection systems – traditional and ecologized (14).

$$2013 – Y = 0.027 + 0.01Z_4 \quad (13)$$

$$2014 – Y = 0.019 + 0.013Z_1 + 0.024Z_2 + 0.016Z_3 + 0.026Z_4 \quad (14)$$

All treatments had a similar effect on calcium content in cv. 'Lobo' fruits, probably because of the weather conditions in 2015 (15).

$$2015 – Y = 0.016 + 0.019Z_1 + 0.022Z_2 + 0.019Z_3 + 0.022Z_4 \quad (15)$$

The precipitation was quite normal for our region (571.1 mm, but more than a half was as snow in wintertime) in this year. The most problem was because relatively low average value of air humidity (53.7%) compared to mean annual data (50 years) – 76.0% during the growing season.

Consumers preffer to buy fruits with possible lowest scab incidance. So, the number of liasons greatly affects the selling price. Both plant protection systems (traditional and ecologized) provided relatively high level of protection against scab. But application of EPPS did not give such a good effect as TPPS. This system had better result by applying on cv. 'Zhigulevskoye trees (espcially, in tank mixtures with mineral foliar fertilizers), but the impact on fruit damage had differed in certain years of research (Fig. 2). The average percentage of fruits without fruit scab lesions, which were treated with the traditional protection products, was 78-80%, and with ecologized – 66-69%.

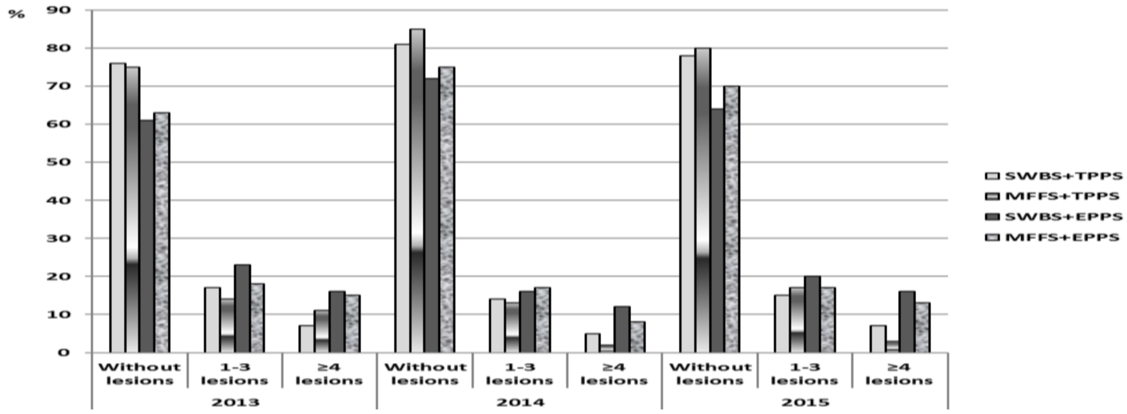


Fig. 2. The effect of traditional and ecologized plant protection systems on fruit damage at harvest (cv. 'Zhigulevskoye')

Application of traditional system provided the best protection against scab on trees of cv. Lobo (82-86% fruits without any lesions), while treatment according to ecologized system assured only 68-74% (Fig. 3). Application of mineral foliar fertilizing system increased the effect either TPPS or ERRS – the number of fruits at harvest without lesions was 4-6% more than when using seaweed extracts-based preparations in tank mixtures. Although the use of ecologized protection system provided a relatively high level of protection (60-70% fruits without lesions), the use of traditional protection system with more toxic preparations advanced the efficiency even more (number of fruits without lesions reached 80-90%).

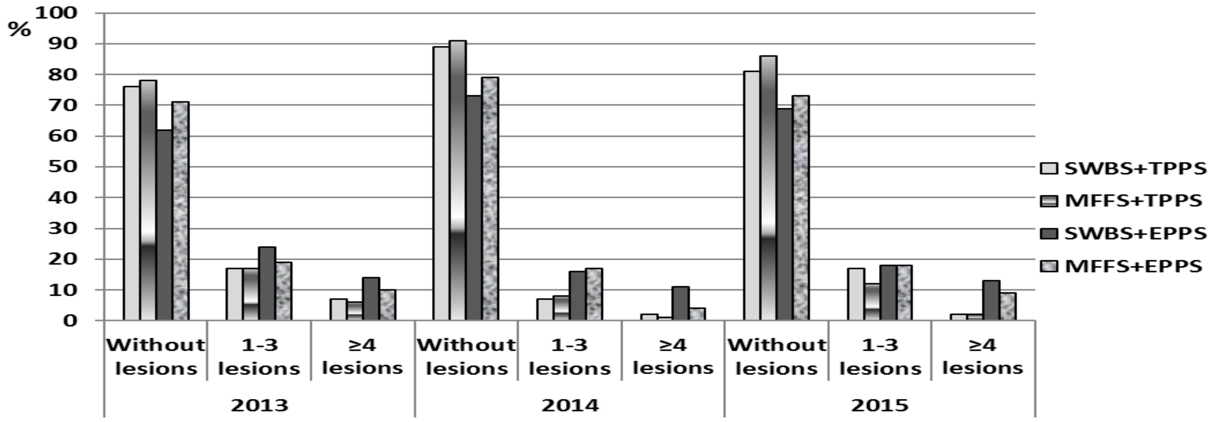


Fig. 3. The effect of traditional and ecologized plant protection systems on fruit damage at harvest (cv. 'Lobo').

The application of foliar fertilizers made significant impact on yield (Table VIII). The efficiency of fertilizer application depended on the protection system used. Mineral fertilizers in tank mixtures with TPPS provided significant yield increase compared to application seaweed extracts-based preparations. On the other hand, application of MFFS together with ecologized plant protection provided certain increase of cv. 'Lobo' yield but did not significant impact on the crop capacity of cv. 'Zhigulevskoye' trees.

Table VIII. Yield, T/ha

Treatments	cv. 'Zhigulevskoye'				cv. 'Lobo'			
	2013	2014	2015	Average	2013	2014	2015	Average
Control	13.2	25.9	18.2	19.1	10.9	20.5	17.0	16.1
SWBS + TPPS	13.5	24.2	22.3	20.0	10.5	21.4	18.9	16.9
MFFS + TPPS	16.1	30.3	24.9	23.8	11.5	25.7	21.7	19.6
SWBS + EPPS	14.1	27.3	21.8	21.1	10.1	22.4	19.2	17.3
MFFS + EPPS	15.7	29.7	23.3	22.9	11.3	25.0	20.8	19.0
LSD_{05}	1.9	3.0	2.4	1.9	1.3	3.6	2.6	1.7

Stable annual bearing is one of major factors for success in apple fruit production. The alternate bearing indexes showed that both cultivars had a relatively high index in 2013-2014, which was improved significantly in 2014-2015 (Table IX). We think that it was a result of combined use of plant protection products and foliar fertilizers.

Table IX. Alternate bearing index

Treatments	cv. Zhigulevskoye			cv. Lobo		
	2013/2014	2014/2015	Average	2014 /2013	2014/2015	Average
Control	0,32	0,18	0,25	0,31	0,09	0,20
SWBS + TPPS	0,28	0,04	0,16	0,34	0,06	0,20
MFFS + TPPS	0,31	0,10	0,21	0,38	0,08	0,23
SWBS + EPPS	0,32	0,11	0,22	0,38	0,08	0,23
MFFS + EPPS	0,31	0,12	0,22	0,38	0,09	0,24

The most positive impact on decreasing of the alternate bearing index had combination of seaweed extracts-based fertilizers in tank mixtures with ecologized plant protection products.

III. ANALYSIS OF RESULTS

Boron and calcium have a significant impact on pollination. Boron is involved in the germination of pollen tubes and provided them higher viability [27], [28]. Calcium is very important for tree physiological status and that is why has a significant influence on pollination and fruit set [29]. Seaweed extracts-based SWB3 product had boron content 0-14% (depending on the composition of raw materials – brown alga), mineral foliar fertilizer MFF3 had 11% boron complexed with ethanolamine EDTA. This preparation had more stable composition and, perhaps that is why made a better impact on pollen tube germination due to stimulation of the hydroxycinnamic acid synthesis with transforming them to chlorogenic acid [30]. Chlorogenic acid inhibited action of β-indolylacetic acid oxidase and, because of this, it was no auxin destruction which made better pollen tube growth and stimulated better fruitset. It is a well-known fact that calcium is one of the key regulators of plant growth and development as a second messenger [21]. Because of this calcium leaf status is great of importance. According to the results of our research, the content of calcium in leaves depended strongly on response of various apple cultivars on sprayings. Application of both foliar fertilization systems (despite moderate variations in some years) made a good impact on calcium content in cv. 'Zhigulevskoye' leaves. Application of mineral fertilizing system on cv. 'Lobo' trees also had good results increasing calcium leaf status. At the same time, using seaweed extracts-based products did not have such a good impact on calcium content in apple leaves. We think that chelate complex of *lignin*-derived *polycarboxylic acid with calcium provided* better penetration of this nutrient in the apple leaves The impact of seaweed extracts-based product application on leaf calcium status should be investigared further with wide range of apple cultivars.

It has long been known that calcium is important for increasing the resistance of apple fruits to physiological and fungal diseases during postharvest period [31]. The response of cv. 'Zhigulevskoye' fruits on treatment was better than cv. 'Lobo' ones. In both cultivars better results we observed when chelate complex of *lignin*-derived *polycarboxylic acid with calcium was applied compared to seaweed extracts-based product. But in both cases we also noted an impact of used protection system: application in tank mixtures with traditional plant protection products provided better impact on calcium status of fruits, especially in cv. 'Zhigulevskoye'.*

In some research papers was stated that conventional and integrated plant protection systems gave high scab control without any significant differences [32]. Application of traditional products with such active ingredients like *dithianon* (stage 57 and 61) and *metiram* (stage 75) instead of ecologized *Bacillus subtilis* and *Pseudomonas fluorescens* (in respectively stages) provided better scab control in our research. Alternate bearing is one of the strongest problems for many apple cultivars. The importance of proper mineral supply for controling the alternate bearing behavior of apple trees is well-known [33]. Good effect on decreasing of negative effect of alternate bearing was observed by application of seaweed extracts-based products in Italy [13]. These results were obtained by fertigation 'Fuji' trees which have strong tendency to biennial bearing.

The application of seaweed extracts-based products provided some decrease of alternate bearing index also in our study when it was used in tank mixtures with traditional plant protection chemicals on both studied cultivars. It is impossible to recommend seaweed extracts-based preparations to reduce the negative effect of alternate bearing, but this problem clearly needs further study.

IV. CONCLUSION

Traditional system provided better protection of apple trees against scab. Application of mineral foliar fertilizers stimulated significant yield increase, especially, in tank mixtures with TPPS. Using seaweed extracts-based fertilizers in tank mixtures with ecologized plant protection products decreased the value of alternate bearing index of both cultivars.

Traditional plant protection system in combination with mineral foliar fertilizers promoted higher content of calcium in leaves and fruits, less damages from scab and larger yields. More effective products or special finance support are needed to replace the traditional approach by the ecologized plant protection and fertilizing.

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