

Influence of plant immunity inducers on the degree of apple scab development when applied in plant protection systems in the zone of humid subtropics of Abkhazia

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Abstract. One of the ways to reduce pesticide load and prevent emergence of pathogen resistance can be the use of plant immunity inducers in plant protection systems. The purpose of these studies was to evaluate an efficiency of natural plant immunity inducers Albit® (poly-beta-hydroxybutyric acid), Immunocytophite® (arachidonic acid ethyl ether) and Ecogel® (chitosan lactate) in apple scab protection systems in Abkhazia. The maximum resistance of apple trees to this phytopathogen was recorded in the experimental variants with Albit® and Ecogel® application in half dosages of fungicides and in the variant of production processing (biological efficiency reached 79.4 %). Plant immunity inducers used on apple trees showed cultivar-specificity. For the four-year research period, the greatest efficiency of immunity inducers was achieved on the susceptible cultivar Idared in the second year of the experiment, while on the relatively scab-resistant cultivar Golden Rangers – it was achieved only in the third year. The greatest stability in the efficiency for a four-year period was observed for the tank mix Albit with half dosages of fungicides. Immunocytophyte® was characterized by lower inducing activity, which is associated with its activation of the jasmonate pathway for the formation of non-specific induced immunity.

1 Introduction

Among apple diseases, scab is the most common and harmful (the pathogen is *Venturia inaequalis* (Cooke) Wint). This disease is widespread throughout the area of apple tree cultivation and leads to significant crop losses [1, 2]. The use of chemical fungicides in plant protection systems worsens the environmental situation and increases the risk of developing resistant forms of the pathogen. Despite the fact that the pathogen is fairly well

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studied, the existing apple tree protection systems do not provide a reliable crop protection from scab [3].

There is a tendency to increase the harmfulness of *V. inaequalis*, loss of cultivars resistance to scab, changes in the symptoms of pathogenesis, and an increase in the pathogen's resistance to widely used effective fungicides [4, 5, 6]. So, it is necessary to develop a new, environmentally safe approach to apple scab protection.

One of the ways to reduce the pesticide load and prevent the emergence of pathogen resistance is to use plant immunity inducers in plant protection systems [7]. The protective action of plant immunity inducers is based on the activation of natural plant resistance mechanisms that block the pathogen development [8]. In many crops, plant immunity inducers of various natures have proved to be effective means of reducing the degree of fungal diseases development [9-12].

In the conditions of humid subtropics on the Black Sea coast of the Caucasus, the study of plant immunity inducers in fruit crops is at an initial stage. However, it has been proved that plant immunity inducers used on peach crops allow us to reduce the consumption rate of chemical fungicides by 2 times while maintaining the efficiency of plant protection systems [13, 14].

Abkhazia is a country where agricultural production occupies a leading place in the economy. Among fruit crops, apple tree occupies one of the leading places, and there is a need to improve apple protection system in the region in order to obtain environmentally safe products.

The purpose of these studies was to evaluate the efficiency of plant immunity inducers Albit®, Immunocytophyte® and Ecogel® in apple scab protection systems in Abkhazia.

2 Materials and methods

The experiment was started in experimental apple orchards (3 × 1.5 m planting scheme, 1 ha area, M9 rootstock on an espalier with drip irrigation) of the Institute of Agriculture of the Academy of Sciences of Abkhazia (Gulripsh district, Abkhazia) in 2016-2019. The study involved apple cultivars with different scab resistance – *Idared* (susceptible cultivar) and *Golden Rangers* (relatively resistant cultivar). Both cultivars are late-maturing, high-yielding, common in industrial plantings in the region. The experiment was based on generally accepted methods [15].

The research was conducted during weather anomalies that affected the plants and phytopathogen development. In 2016, there was a significant temperature drop during the vegetation period. In April and May, the average air temperature was +14.8...+17.5 °C (max +28.9 °C, min +10 °C). In April 2017, the air temperature was similar to 2016, but there was heavy precipitation in May. In 2018, the average air temperature in the spring was by 3.9 °C higher than in the spring of 2017. Precipitation was uneven. In June, only 11.2 mm fell, in the second ten-day period of July and the first ten-day period of August – up to 292.1 mm, in the second ten-day period of August – 107 mm. The vegetation period of 2019 was characterized by heavy precipitation and sharp temperature changes. In June, there was a large amount of precipitation (240 mm). At the same time, the average air temperature in June was +28 °C.

The experiment included plant immunity inducers of a different chemical nature – Albit®, poly-beta-hydroxybutyric acid-based, added by magnesium sulphate (29.8 g/kg), potassium phosphoric acid (91.1 g/kg), potassium nitric acid (91.2 g/kg), carbomide (181.5 g/kg); Immunocytophyte®, arachidonic acid ethyl ether-based; Ecogel®, chitosan lactate-based. The first preparation activates the salicylate pathway of non-specific

immunity, the second one activates the jasmonate pathway, and the third one activates both of these pathways [16, 17].

Scheme of the experiment (the variants were laid in 5-fold repetition):

1. Control: water treatment, without fungicides and plant immunity inducers;
2. Standard (production treatment): Score®, (diphenconazole, 250 g/l) 0.2 l/ha - I ten-day period of May; Topaz®, (penconazole, 100 g/l) 0.3 l/ha – I ten-day period of June; Strobitek®, (cresoxime-methyl, 500 g/kg) 0.2 kg/ha – I and III ten-day periods of July;
3. Albit®, (poly-beta-hydroxybutyric acid, 6.2 g/kg), 250 ml/ha with 1/2 of the fungicides consumption rate, 4 treatments: I ten-day period of May; I ten-day period of June; I and III ten-day period of July;
4. Immunocytophyte®, (arachidonic acid ethyl ester, 0.167 g/kg), 0.6 g/ha with 1/2 of the fungicides consumption rate, 4 treatments: I ten-day period of May; I ten-day period of June; I and III ten-day period of July;
5. Ecogel®, (chitosan lactate 30 g/l), 1.5 l/ha with 1/2 of the fungicides consumption rate, 4 treatments: I ten-day period of May; I ten-day period of June; I and III ten-day period of July.

The terms of treatments with tank mix fungicides and plant immunity inducers corresponded to the production ones. Scab development was diagnosed on the 7th day after the treatment.

Research data were processed statistically using MS Excel 2010. The results are expressed as an average value ($M \pm SEM$).

3 Results and discussion

The assessment of immunostimulating effect from Albit®, Immunocytophyte® and Ecogel® was carried out in the years differing by scab development degrees. In 2016, *Idared cultivar* showed a moderate intensity of the phytopathogen development on leaves in the control, and in 2017-2018 – insignificant (Table 1). The highest degree of scab development in the control variant was observed in 2019, which is associated with heavy precipitation in early summer and a prolonged drought in July. During a four-year research period, the disease development in the standard was 2-3 times lower than in the control variant.

Immunity inducers used with half dosages of fungicides on *Idared cultivar* showed a result comparable to the standard. First two years of observation, the variants with Albit® and Ecogel® showed the best results. The third and fourth years of observation significantly better results showed the variant with Immunocytophyte®. Even in 2019, when the degree of scab development in the control variant reached 21.2 %, production processing reduced the degree of scab development to 8.4 %, while Immunocytophyte® with half dosages of fungicides – up to 5.2 %.

Thus, the inclusion of plant immunity inducers in the protection system of *Idared cultivar*, susceptible to scab, showed a stable decrease in scab development when they were applied four times during the vegetation period. Moreover, the nature of the action of immunity inducers in different years of observation differed.

On the relatively scab-resistant *Golden Rangers cultivar*, scab development in 2016-2017 was higher than on *Idared cultivar*, and in 2018 it was almost at the same level. In 2019, against the background of abnormal weather conditions, scab development on *Golden Rangers cultivar* was insignificant, 3-4 times lower than on *Idared cultivar*. The fungicides used in the standard significantly restrained the intensity of scab development in all years of observation and reduced its harmfulness. In the variants of the experiment with tank mixtures of Albit®, Immunocytophyte® and Ecogel®, the initial degree of protective

action was maintained. However, on the *Golden Rangers* cultivar, the effect of immunity inducers did not exceed the positive effect of the standard.

In 2019, with repeated use of plant immunity inducers for four years, their protective effect at the level of the standard was noted, despite the halving of chemical fungicides dose. This is evidenced by a decrease in the disease development degree at the end of the experiment.

Table 1. Dynamics of scab development on apple leaves (Gulrypsh district, Abkhazia, 2016-2019)

Variants of the experiment	Scab development (R), %							
	Idared				Golden Rangers			
	I ten-day period of May	I ten-day period of June	I ten-day period of July	III ten-day period of July	I ten-day period of May	I ten-day period of June	I ten-day period of July	III ten-day period of July
	2016							
Control	8.3±2.1	10.2±1.0	12.4±1.1	12.4±1.1	11.6±2.9	9.0±3.3	15.0±1.6	22.0±1.5
Standard	6.6±1.6	5.6±1.5	3.8±1.4	4.0±1.5	2.6±0.8	3.8±1.9	6.0±1.5	7.0±0.7
Albit*	3.4±1.1	5.6±0.5	3.8±1.3	3.0±1.0	3.8±2.1	4.0±1.5	4.4±0.5	7.6±5.1
Immunocytophyte*	2.4±1.5	4.0±1.2	4.4±0.8	4.4±0.8	2.6±1.3	4.8±1.9	6.4±3.2	9.8±1.9
Ecogel*	3.6±2.3	3.8±1.3	3.4±1.1	2.6±0.5	2.8±1.3	4.0±0.7	6.0±1.4	7.8±2.2
<i>LSD</i> ₀₅	0.7	0.8	0.8	0.8	0.7	0.9	0.7	0.7
	2017							
Control	3.2±0.4	5.8±0.8	6.6±1.1	10.6±1.1	4.0±0.7	6.2±0.4	6.8±0.8	8.8±0.8
Standard	1.2±0.4	2.4±0.8	3.0±0.7	2.8±0.8	1.8±0.8	3.2±0.4	3.6±0.5	3.2±0.8
Albit*	1.0±0.7	2.6±1.1	3.6±1.0	3.0±0.7	2.0±0.7	2.4±0.5	3.8±0.4	3.2±1.3
Immunocytophyte*	1.4±0.5	3.4±0.8	3.6±0.5	4.0±0.7	2.4±0.8	3.2±0.8	4.0±0.7	3.6±0.5
Ecogel*	1.2±0.4	2.0±0.7	3.4±0.8	3.0±0.7	1.8±0.4	2.8±0.8	3.2±0.4	3.0±1.2
<i>LSD</i> ₀₅	0.2	0.4	0.5	0.7	0.3	0.4	0.5	0.6
	2018							
Control	5.6±0.4	9.0±0.1	11.2±0.2	14.6±0.4	5.6±0.4	7.8±0.8	10.4±1.1	14.0±1.1
Standard	1.4±0.2	2.0±1.0	3.2±0.3	3.0±0.5	1.2±0.4	1.8±0.8	4.0±0.7	4.0±0.8
Albit*	1.4±0.2	2.2±0.5	3.4±0.3	4.4±0.3	1.4±0.5	2.4±0.8	5.6±0.5	5.2±0.7
Immunocytophyte*	1.0±0.5	1.8±0.3	3.2±1.0	3.2±0.3	1.4±0.7	2.6±1.1	4.8±1.0	4.2±0.7
Ecogel*	1.0±0.4	1.8±0.3	3.0±0.1	3.0±1.0	1.0±0.4	2.6±0.7	5.2±0.8	4.6±0.7
<i>LSD</i> ₀₅	0.4	0.6	0.8	1.0	0.4	0.5	0.8	1.0
	2019							
Control	12.8±2.5	15.8±4.2	20.6±2.7	21.2±0.8	2.6±1.1	6.4±1.3	6.2±1.3	5.8±0.8
Standard	5.6±2.7	6.4±2.4	8.0±3.6	8.4±5.0	1.6±0.6	2.6±0.5	2.0±1.0	1.8±0.8
Albit*	6.6±3.2	7.0±2.8	8.4±2.7	7.2±1.0	1.4±0.6	3.4±1.1	3.6±0.8	3.2±1.3
Immunocytophyte*	5.6±2.9	5.0±2.2	5.4±1.3	5.2±1.3	1.2±0.4	3.8±1.3	2.0±0.7	1.6±0.5
Ecogel*	5.4±2.4	6.2±1.6	6.0±1.5	6.6±4.5	1.4±0.5	3.6±0.8	2.4±1.1	2.6±0.8
<i>LSD</i> ₀₅	0.9	1.1	1.5	1.5	0.2	0.5	0.4	0.4

* All variants of plant immunity inducers application are tank mixtures with half dosages of fungicides compared to the standard

The values of biological efficiency from the standard and experimental variants are shown in figure 1. In years of observation, biological efficiency of plant immunity inducers used on *Idared* cultivar was higher than on *Golden Rangers* cultivar. In 2018, biological efficiency of plant protection variants on the susceptible *Idared* cultivar was the highest for

the entire observation period. The results of the standard as well as variant with Ecogel® reached 79.4 %.

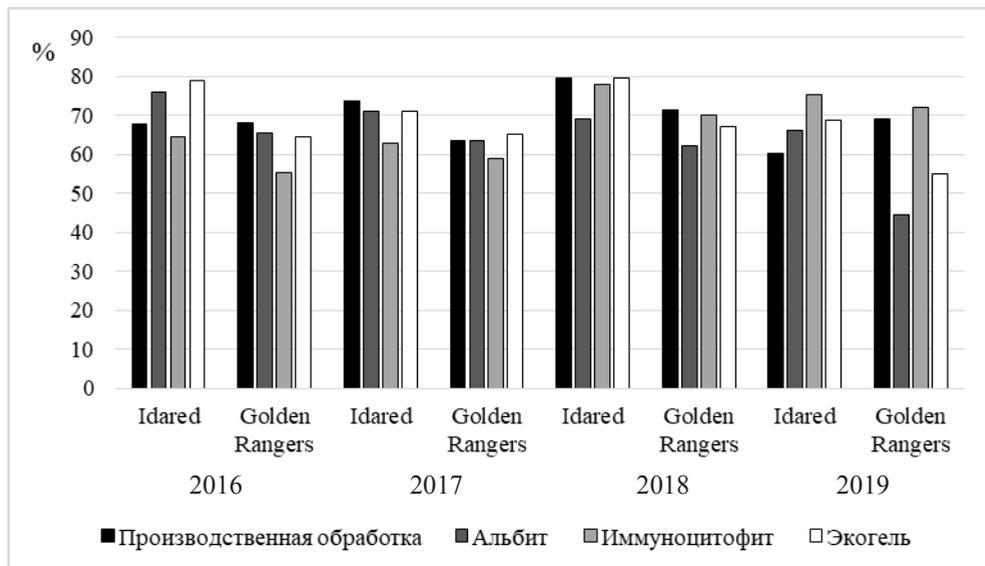


Fig. 1. Biological efficiency of industrial treatment and plant immunity inducers in tank mixtures with fungicides against apple scab (2016-2019, July)

The efficiency of Immunocytophyte® in the first and second year of use was lower than in all other experimental variants, but in the third and fourth year of application, its efficiency was at the same level or higher than Standard, exceeding in most cases the efficiency of other immunity inducers.

At *Golden Rangers* cultivar, the nature of the action of immunity inducers and the level of their biological efficiency persisted for the first three years. In 2019, in the fourth year of the experiment, a decrease in the biological effectiveness of the variants with Albit® and Ecogel® was noted, while maintaining the high efficiency of Immunocytophyte®.

4 Conclusion

The obtained data indicate a significant role of non-specific immunity induced by Albit®, Ecogel® and Immunocytophyte® in relation to apple scab. The nature of the inducing effect of immunity inducers differed in the years of the experiment. These results are explained by the fact that the protective action of plant immunity inducers is based on the activation of various natural pathways for the formation of non-specific induced immunity – salicylate and jasmonate [16].

The maximum resistance of apple trees to the phytopathogen in the first two years of research was recorded in the experimental variants with Albit® and Ecogel® application, and for the third and fourth year - in the variant with with Immunocytophyte®. The maximum biological efficiency of variants with immunity inducers reached 79.4 %.

Plant immunity inducers used on apple trees showed a cultivar-specificity. For the four-year research period, the efficiency of plant immunity inducers on the susceptible *Idared* cultivar was stable, and its maximum values were noted in the third year of the experiment.

On the relatively scab-resistant *Golden Rangers* cultivar a sharp decrease in the effectiveness of Albit® and Ecogel® was noted in the fourth year.

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