The use of mycorrhizal drug Mycosoil in seed production of tomato and sweet pepper

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Abstract. Research has been conducted on the effect of the Mycosoil drug on economically valuable traits of tomato of Anahit-351 and Lia varieties, as well as pepper of Hayk and Loshtak varieties. After seed treatment with the Mycosoil drug, seed germination of tomatoes increased by 1.9–2.9%, and of peppers by 4.2–4.4%. Mycosoil contributed to an increase in germination energy: for Anahit-351 tomato variety by 4.3%, and for Lia variety by 6.6%. The germination energy of Hayk and Loshtak pepper varieties increased, respectively, by 1.6–2.5%. For all tomato varieties, the yield gain varied from 9.2 to 9.6%, and for Loshtak pepper variety – 7.5%. An increase in fruit mass was observed in tomatoes: within 20.6–23.1 g, and in peppers – 5.4–11.1 g. Both the number of seeds formed in one fruit and the mass of 1000 seeds increased. The increase in the number of seeds for tomato varieties ranged between 3.8–4.8 seeds, for pepper – 3.3–7.9 seeds per fruit, and the mass of 1000 seeds increased in the range of 0.5–0.6 g for tomato and 0.3–0.6 g for pepper. When studying the effect of Mycosoil on seedlings in tomato of Anahit and Lia varieties in the variant of Fusarium + Mycosoil, the FAM signal showed values of 20.05–25.40 and it was lower than with control + Fusarium (35.61–38.74).

1. Introduction

The search for natural means of increasing crop productivity has led scientists from different countries to isolate natural growth stimulants and plant protection products from living organisms [1, 2]. Extremely relevant today are the issues of optimizing mineral nutrition and water supply, increasing immunity and protecting plants from various forms of biotic and abiotic stresses without significant environmental load.

The new drug Mycosoil, created by the Austrian company “Osenum”, known for the production of arbuscular-mycorrhizal fungi (AMF) for agriculture, combines mycorrhizal fungi with bacteria, trichoderma, minerals and humic acids. Mycosoil has different forms and concentrations based on the endomycorrhizal fungus Glomus intraradices, which forms a mycelium that increases the absorption capacity of roots by hundreds of times. The fungus receives carbohydrates, amino acids, and phytohormones from plants and supplies water, minerals, and phosphorus compounds. When AMF enters the root system, the fungus spores become a part of the plant. Mycosoil can be used with herbicides, insecticides and even fungicides. According to the manufacturer's instructions, the drug has a fairly wide range of application [3].
In nature there is a close relationship between plants and mycorrhizal fungi in the form of mutually beneficial symbiosis. Having an order of magnitude finer root hairs, fungal filaments are able to penetrate the smallest pores of soil minerals. Gradually destroying them, the hairs extract plant nutrients from minerals that are not in the soil, including such important elements as phosphorus and trace elements – zinc and cobalt [4, 5, 6].

AMF is a widespread form of symbiosis with the roots of higher plants. They ensure the assimilation of nutrients (mainly phosphorus- and nitrogen-containing) from the soil, and also contribute to increasing seed germination capacity, plant survival in adverse environmental conditions. In turn, plants supply AMF with carbohydrates and lipids. Scientists have established a positive effect of AMF on growth and development, productivity, resistance to fungal diseases of plants, to adverse environmental conditions [7, 8, 9, 10, 11, 17, 21, 22].

The Mycosoil drug has the form of a powder containing spores. It is used for treatment of seeds or root seedlings.

The purpose of this paper was to study the influence of Mycosoil on the quality indicators of seeds of different varieties of tomato and pepper, on the plant productivity, as well as on the development of *Fusarium oxysporum* against an artificial background of infection.

2. Material and methodology

The experiment was performed at the experimental site of the Scientific Center of Vegetable, Melon and Industrial Crops, Armenia in 2019–2020. Its geographical position: 40,1058333°N, 44,4138899°E; altitude 750–900 m above sea level.

The objects of the study were the tomato varieties Anahit–351 and Lia which were zoned and widely cultivated in the Ararat plain, and also sweet pepper varieties Hayk and Loshtak.

Before sowing, the test seeds of tomato and pepper were powdered with Mycosoil pulvis (0.001 g of Mycosoil per 10 g of seeds). The control was seeds not treated with Mycosoil. In mid–March the seeds were sown in cells filled with peat. Agrotechnical measures generally accepted for tomato and pepper cultures were used. The experiment was conducted in 4 replications, each one of 50 plants. Nutritional area of one tomato plant was 0.22 m² and of one pepper plant – 0.2 m²; the number of plants per hectare was 45,000 and 50,000, respectively.

Germination energy was determined according to GOST [12]. Accounting for the crop was carried out according to the method of state testing of agricultural crops [13].

To determine the effect of Mycosoil on the development of *Fusarium oxysporum*, an artificial infectious background was created in pots by introducing *Fusarium oxysporum* strains previously grown on oats into the soil. Seedlings of control and Mycosoil-treated variants of the test varieties of tomato and pepper in the phase of two real leaves were transplanted into the soil infected in pots. In the phase of 5–6 of real leaves *Fusarium oxysporum* was identified in the diagnosed samples by polymerase chain reaction (PCR) method in FLASH format.

For PCR, the genomic DNA of the pathogen together with the genomic DNA of the plants was isolated from the tested samples. During DNA extraction the homogenization of tissues was carried out in the presence of the CTAB detergent (cetyltrimethylammonium bromide). Cationic detergent cetyltrimethylammonium bromide promotes cell membrane lysis and effectively destroys DNA–protein complexes.

The determination was carried out using diagnostic systems developed on the basis of the basic composition of the reaction mixture. Amplification mode: 1 cycle 94°C – 5 min; 40 cycles 94°C – 30 sec, 72°C – 10 sec, 1 cycle 62°C – 10 sec.

The DNA probes used to detect the amplification product included FAM fluorescent dye. In each series of samples, positive (Positive Control, Ctr+) and negative (Negative Control, Ctr−) controls of PCR samples were set.

Accounting and interpretation of the reaction results was carried out automatically using the software supplied with the PCR detector. The data obtained were subjected to analysis of variance using the Dospekhov method [14].
3. Results and discussion

According to the results of our research, it was revealed that in all the studied varieties of tomato and pepper, Mycosoil stimulated germination and seed germination energy.

In the tested tomato varieties, seed germination in the control (without treatment) varied between 92.0–94.6%, and in pepper varieties – 87.3–90.2%. As a result of treatment with Mycosoil the germination rates of all varieties of tomato and pepper significantly increased (table 1). For tomato varieties, seed germination increased by 1.9 – 2.9% above the control. Particularly high rates of germination were observed for seeds of pepper of Hayk and Loshtak varieties, for which, in comparison with the control, germination was higher by 4.2 and 4.4%.

Table 1. The effect of Mycosoil on germination capacity and germination energy of tomato and pepper seeds.

| Culture | Variety | Variant | Germinating capacity, % | Germination energy, % |
|---------|---------|---------|-------------------------|-----------------------|
| Tomato  | Anahit-351 | Control | 92.1±1.2 | 80.2±1.5 |
|         |         | Mycosoil | 95.0±1.1 | 84.5±1.4 |
|         |         | HCP<sub>0.05</sub> | 1.2 | 1.0 |
|         |         | Control | 94.2±1.3 | 76.0±1.4 |
| Tomato  | Lia     | Mycosoil | 96.1±1.4 | 82.6±1.2 |
|         |         | HCP<sub>0.05</sub> | 1.5 | 1.7 |
|         |         | Control | 87.3±1.0 | 65.7±2.0 |
| Pepper  | Hayk    | Mycosoil | 91.5±0.9 | 67.3±0.5 |
|         |         | HCP<sub>0.05</sub> | 1.2 | 1.4 |
|         |         | Control | 90.2±0.8 | 74.5±0.7 |
| Pepper  | Loshtak | Mycosoil | 94.4±1.1 | 77.0±0.9 |
|         |         | HCP<sub>0.05</sub> | 1.0 | 0.8 |

One of the important indicators of seed quality is the germination energy. The germination energy for the control tomato varieties ranged from 76.0–80.2% and for pepper varieties – 65.7–74.5%. Mycosoil contributed to a significant increase in germination energy: for the tomato of Anahit-351 variety by 4.3%, and of Lia variety – by 6.6%. For pepper of Hayk and Loshtak varieties, the germination energy increased, respectively, by 1.6–2.5%.

The crop productivity of tomato varieties in the control variant varied in the range of 75.1–82.3 t/ha, and of pepper varieties – 65.0–74.2 t/ha. Mycosoil contributed to the increase in both tomato and pepper crop productivity. For all varieties, the yield increase varied from 9.2 to 9.6%, and for Loshtak pepper variety – 7.5% (table 2). It should be noted that the data obtained by us are consistent with the data of other authors [7, 8, 15, 16]. The maximum yield increase in conditions of treatment with Mycosoil reached 9.6%, and when compost was added to the soil along with mycorrhiza, the yield increase reached 23% [15].

Mycosoil contributed to the increase in fruit mass. The fruit mass of tomato varieties in the control varied within 152.3–160.2 g, and of pepper varieties – 122.4–145.2 g. A significant increase in fruit mass, compared with the control, was observed for tomato varieties: within 20.6–23.1 g, and for pepper varieties – 5.4–11.1 g.

When determining the seed quality of seeds, the mass of 1000 seeds is important, since this is a sign that shows the usefulness of the seeds. It was established that, based on varietal characteristics, seeds with a larger mass contain more reserve nutrients, and thus are more valuable for sowing. Sowing such seeds in the offspring provides a high yield. In our experiments, when Mycosoil organic fertilizer was applied in the treated variants, both the number of seeds formed in one fruit and the mass of 1000 seeds...
The increase in the number of seeds for tomato varieties ranged from 3.8–4.8 seeds, for pepper – 3.3–7.9 seeds per fruit, and the mass of 1000 seeds increased in the range of 0.5–0.6 g for tomatoes and 0.3–0.6 g for peppers.

**Table 2.** The effect of Mycosoil on crop productivity and seed quality of tomato and pepper.

| Culture | Varieties | Variants | Crop productivity, t/ha | Average fruit's mass, g | Number of seeds in a fruit, pcs | Mass of 1000 seeds, g |
|---------|-----------|----------|-------------------------|------------------------|-------------------------------|-----------------------|
| Tomato  | Anahit-351 | control  | 75.1                    | 152.3±2.1              | 126.3±3.0                     | 2.6±0.8               |
|         |           | Mycosoil | 82.3                    | 175.4±1.5              | 130.1±3.4                     | 3.2±1.0               |
|         |           | HCP<sub>0.95</sub> | 1.3                    | 1.8                     | 2.7                           | 0.9                   |
|         | Lia       | control  | 82.3                    | 160.2±2.3              | 115.6±2.5                     | 3.5±0.9               |
|         |           | Mycosoil | 90.0                    | 180.8±1.7              | 120.4±2.7                     | 4.0±1.1               |
|         |           | HCP<sub>0.95</sub> | 1.2                    | 2.1                     | 2.6                           | 1.0                   |
|         | Hayk      | control  | 65.0                    | 122.4±2.3              | 162.3±3.1                     | 5.1±1.3               |
|         |           | Mycosoil | 71.2                    | 133.5±2.1              | 170.2±3.0                     | 5.4±0.9               |
|         |           | HCP<sub>0.95</sub> | 1.5                    | 2.2                     | 3.0                           | 1.1                   |
| Pepper  | Loshtak   | control  | 74.2                    | 145.2±2.5              | 150.1±3.5                     | 7.2±1.2               |
|         |           | Mycosoil | 80.1                    | 150.6±0.9              | 153.4±3.2                     | 7.8±1.1               |
|         |           | HCP<sub>0.95</sub> | 2.1                    | 1.7                     | 3.3                           | 1.1                   |

When studying the effect of Mycosoil on infected and non–infected with Fusarium disease (*Fusarium oxysporum*) seedlings of pepper and tomato, the FAM signal for tomato of Anahit and Lia varieties in the Fusarium+Mycosoil variant showed values of 20.05–25.40, while in the control +Fusarium variant this indicator was 35.61–38.74 (table 3).

**Table 3.** The effect of Mycosoil on seedlings of pepper and tomato infected and not infected with Fusarium (*Fusarium oxysporum*).

| Culture | Variety | Variant | *FAM value |
|---------|---------|---------|------------|
| Tomato  | Anahit-351 | Fusarium disease | 38.74 |
|         |          | Fusarium disease+Mycosoil | 20.05 |
|         | Lia      | Fusarium disease | 35.61 |
|         |          | Fusarium disease+Mycosoil | 25.40 |
| Pepper  | Hayk     | Fusarium disease | 30.5  |
|         |          | Fusarium disease+Mycosoil | 16.5  |
|         | Loshtak  | Fusarium disease | 32.3  |
|         |          | Fusarium disease+Mycosoil | 20.21 |

*at Ctr+38.5; Ctr–0.78

According to Samir and Gutovsky's research, mycorrhiza shortens the germination period and stimulates the growth rate of plants [18, 19]. The physiology of this process is difficult to explain, however, the fact that Mycosoil supplies plants with nutrients, in all probability, contributes to the increase of germination capacity and germination energy. The same can also explain the increase in yield, quantity and mass of seeds, since the Mycosoil, an integral part of which is the fungus of the endomycorrhizal fungus *Glomus intraradices* with humic acids, minerals, is able to some extent protect
plants from stressful conditions, supplying plants with nutrients. When studying the influence of endomycorrhizal fungi on various pathogenic fungi, many scientists noted the suppression of the development of *Verticillium, Fusarium oxysporum* in different vegetable crops [19, 20].

According to the results of studies, mycorrhiza is considered an alternative agro-measure in the fight against soil fungal diseases. The regularity of the response of plants to the treatment with Mycosoil in the studied tomato and pepper varieties is the same, a slight deviation is due to varietal characteristics. Our studies indicate a positive effect of Mycosoil on the quality of seeds.

4. Conclusion
The tried and tested biological drug Mycosoil has a high efficiency that contributes to realization of internal reserves of plants, which increases germinating capacity and energy of seeds of tomato and pepper varieties. In addition to seed germination capacity, in comparison with the control variant, the yield and average mass of a fruit increases. Mycosoil enables the increase in number and mass of seeds. All these changes are the result of optimizing the hormonal balance of plants, since endogenous hormones control all life processes by changing their ratio at different phases of development. Mycosoil helps to suppress the development of *Fusarium oxysporum* in tomatoes and peppers on an artificial infectious background, as evidenced by PCR in FLASH format.

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