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THE IMPACT OF MYCORRHIZAL PREPARATION MYKONET ON VALUABLE AGRONOMICAL AND ECONOMIC INDICATORS OF PEPPER

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The aim of the present study was to determine the effect of the Indian mycorrhizal preparation Mykonet (Mn) of Endo type on agronomical and economic indicators of the hot and sweet pepper production. The study was conducted with two sweet (Zmrukht and Nush-55) and two hot varieties of pepper (Kon and Punj). The experiments were carried out according to the block randomization method. It has been shown that Mn improves the biological and economic characteristics of sweet and hot peppers, depending on the treatment duration and variety. The most effective was 2 *h* treatment. The dry matter content was increased slightly, but increased for sugars and ascorbic acid. The best effect was obtained for Zmrukht. Given that Mn has improved the agronomical and economic characteristics of sweet and hot peppers, it can be recommended for pepper production.

***Keywords*:** mycorrhiza, Mykonet, pepper, vegetable quality and yield, economic efficiency.

Introduction. Healthy soil is a fundamental necessity for increased food production. The presence of soil fungi is a significant factor contributing to soil health, forasmuch as they can establish highly beneficial relationships with host plants [1, 2]. When researchers applied natural fertilizers, they noticed that certain extracts of living organisms can often function as natural stimulators of plant growth and protection [3, 4].

In natural conditions, the plants and mycorrhizal fungi are associated with mutually beneficial symbiosis. The fungal filaments can penetrate into the smallest pores of the soil minerals to their thinnest root hairs, and gradually destroying them, fungi extract elements that would otherwise be unavailable for plant nutrition, including such essential elements as phosphorus or trace elements zinc and cobalt. By marking minerals with radioactive isotopes, it has been proved that there is a whole underground system of the thinnest yarns, where plants communicate by transferring and sharing organic and mineral compounds [5, 6]. Thus, the total length of mycorrhizal filaments in the soil around the plant roots is 20–40 m/cm^3, due to

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which these fungi manage to get about 30% of the synthesized carbohydrates [7, 8]. Mycorrhiza can enhance the efficiency of plant roots to absorb water and macro- and microelements from soil or container media. This helps to enhance fertility and reduce irrigation requirements, increases drought resistance and plant resistance to pathogens [9–12].

Such natural stimulators were divided into bacterial (Bisolbifit, Azotovit, Azofobakterin, Azotseovit, Bioplant Flora, bacterial melanin (Btm, which was developed in the Scientific Research Center "ArmBiotechnology", NAS of RA)), fungal or mycorrhizal (Mykoplant, Mitsefit, Mykonet (Mn), Trichodermin, Trianum, etc.), and vegetable ones (Epin-Extra, Zircon, HB-101, Radifarm, Megafol, etc.). These preparations are studied and produced throughout the world, and Armenia has also been involved in this field for more than 20 years [13–17].

A new preparation to be studied was Indian mycorrhizal Mykonet of Endo type, produced as lignite with the spores of *Rhizophagus irregularis* (3000 spores/*g*). Mykonet™ (Mn) helps to enhance the power of mycorrhiza, a symbiotic relationship formed between plant roots and a special kind of fungi. These fungi supply the plants with water and nutrients in exchange for carbohydrates and nutrients. Not only that, the plant becomes protected from drought, fungal infections and nematodes [18].

Materials and Methods.

Plants and Field, Samples and Soil Analysis. There were chosen four varieties of pepper: two of sweet (Zmrukht and Nush-55) and two of hot pepper (Kon and Punj); varieties were released in Armenia (Tab. 1).

Table 1

The morphological-biological peculiarities of experimental varieties

Variety	Maturity	Growth habit	Fruits				Resistance
			weight, *g*	shape	color in technical ripening phase	color in biological ripening phase	
Zmrukht	middle early	determinant	70	conical	green	red	Fusarium, late blight
Nush-55	middle	determinant	80	elongated	light green	red	Fusarium, late blight
Kon	late	determinant	40	conical	Ivory	bright red	Fusarium, stolbur
Punj	middle	determinant	3	elongated	green	red	Fusarium

The seeds of the studied varieties were soaked in a 0.01% Mn solution for 1 *h* or 2 *h*, while the control seeds were placed in pure water for the same period, after which the seeds were sown in greenhouse soil After 45 days, the seedlings were planted in an open field, as well as in greenhouse soil for an additional experiment. Since Mn contains potassium humate, in order to find out the effect of each individual component, a supplementary experiment was carried out according to the following scheme: 1) control; 2) potassium humate (0.5%, 2 *h*); 3) Mn (0.01%, 2 *h*). After the formation of 2–3 true leaves, the seedlings were planted in 0.5-liter beakers. The experiments were conducted on the experimental field of the Scientific Center of Vegetable–Melon and Industrial Crops, Armenia (40.1058333°N, 44.4138899°E, 650–700 *m* above sea level) during 2016–2017. The open field soil had a heavy mechanical composition of light clay content (carbonates 0.95%). Its organic matter content and pH were 1.2 and 6.8%, respectively. The average temperature during the development season was around 30°*C*.

Soil samples (0–15 *cm* depth) were randomly collected before treatment using a core sampler. Samples of both soil and manure were transferred to the laboratory for analysis. Soil pH was determined in a 1:1 soil to water suspension using a pH meter. Total nitrogen was determined by the Kjeldal method. Available phosphorus was determined by the Machigin method, and potassium (K) was determined by the Maslova method [19]. Nitrogenous, phosphate and potassium fertilizers were applied according to soil analysis data. The plots were fertilized with 128 *kg*/*ha* P_2O_5 as triple super phosphate and 145 *kg*/*ha* K_2O in the form of potassium sulfate, each year before sowing. Nitrogenous fertilizer (ammonium sulfate) was applied manually at the rate of 124 *kg*/*ha* three times before planting, when flowering and fruit ripening began.

Determination Methods of Plants. Phenological and morphological observations of plants were made throughout growing season by the method of State variety trail of agricultural crops [20]. Fruit samples for chemical analyses were collected in mid-August (which was also the beginning of the fruiting stage), and in late September (just before experiment completion). The dry material content was identified by the refractometer IGF-454B2M, sugar – by the Bertrand's method and vitamin C – by Moore's method [21]. The harvest data and economic efficiency of Mn were also recorded. The economic efficiency assessment was calculated on the base of relation of the additional yield obtained from a unit area to that of control, including the expenses spent for it, the material costs of land pre-sowing tillage, plant care, harvesting and labor costs. Income from additional yield was also assessed.

Data Processing. The experiment was set up according to the block randomization method with 4 repetitions each consisting of 90 plants in each variant, the feed surface for each plant was $0.21m^2$. Analysis of variance (ANOVA) was performed. Significance of differences among treatments was tested using the least significant difference (LSD) method. Differences were judged as significant at $p < 0.05$ according to the *F*-test. Student's *t*-test was used to assess the statistical significance of the difference between means of phenological data of two samples [22, 23].

Results and Discussion.

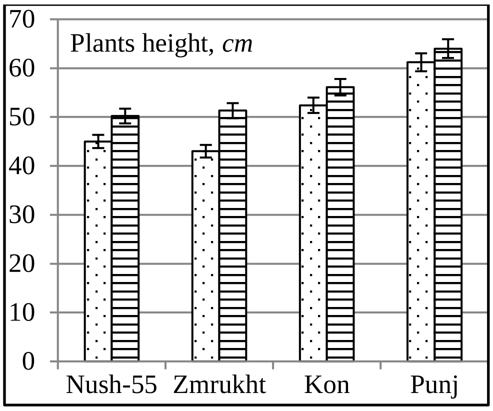
Impact of Mn on Pepper Growth and Development. It was found out that the seeds of all Mn treated peppers germinated 2–3 days earlier than control ones. They grew simultaneously and formed the extensive branched over-ground parts with larger (16–18%) leaf blades than that of control, as well as well-developed root systems. The phenological data varied depending on the type and duration of Mn treatment. In case of Mn treatment for 1 *h*, the flowering stage was 1–6 days earlier than that of the control, and fruit setting stage was 1–7 days earlier than that of the control. These durations of plant development stages were significantly reduced in the case of 2 *h* exposure. With Mn treatment for 1 *h*, the vegetation period was shorter than the control by 2–7 days, while the period of vegetable formation was longer by 2–5 days (Tab. 2). Similarly, in the case of 2 *h* treatment, the vegetation period was shorter by 7–9 days, and the period of fruits formation was longer by 4–12 days.

Table 2

The influence of Mn on pepper's phenophase durations, days
(means followed by the same letter indicate no significant differences at $p < 0.05$)

Crop	Variety	Variants	From germination to flowering	From germination to fruit setting	From fruit setting to technical ripening	From technical to biological ripening	Vegetation period	Period of harvesting
Sweet pepper	Nush -55	control (water)	75 ± 1.2^{a}	79 ± 1.1^{a}	35 ± 1.4^{a}	26 ± 1.0^{a}	140 ± 2.1^{a}	70 ± 1.1^{a}
		Mn 1 *h*	72 ± 1.1^{b}	78 ± 1.4^{a}	34 ± 1.2^{a}	24 ± 1.2^{ab}	136 ± 1.2^{b}	73 ± 1.2^{b}
		Mn 2 *h*	70 ± 1.5^{b}	76 ± 1.3^{c}	33 ± 1.0^{c}	22 ± 0.8^{b}	131 ± 1.5^{c}	77 ± 0.8^{c}
	Zmrukht	control (water)	74 ± 1.2^{a}	80 ± 1.2^{a}	39 ± 1.3^{a}	26 ± 0.3^{a}	145 ± 1.5^{a}	68 ± 0.9^{a}
		Mn 1 *h*	73 ± 1.4^{a}	78 ± 1.3^{b}	37 ± 1.0^{ab}	24 ± 0.3^{b}	139 ± 0.3^{b}	71 ± 1.2^{b}
		Mn 2 *h*	71 ± 1.0^{a}	77 ± 1.5^{b}	35 ± 1.4^{b}	24 ± 0.3^{c}	136 ± 1.2^{c}	72 ± 1.3^{c}
Hot pepper	Kon	control (water)	71 ± 0.5^{a}	79 ± 0.5^{a}	40 ± 1.5^{a}	23 ± 1.0^{a}	142 ± 1.0^{a}	63 ± 1.1^{a}
		Mn 1 *h*	67 ± 1.3^{b}	74 ± 1.1^{b}	38 ± 1.6^{a}	23 ± 1.3^{a}	140 ± 0.3^{b}	72 ± 0.8^{b}
		Mn 2 *h*	65 ± 1.0^{b}	72 ± 1.5^{cb}	35 ± 1.6^{b}	23 ± 1.0^{a}	135 ± 0.2^{c}	75 ± 0.5^{c}
	Punj	control (water)	67 ± 1.1^{a}	72 ± 0.6^{a}	37 ± 1.0^{a}	26 ± 1.4^{a}	135 ± 1.1^{a}	68 ± 1.2^{a}
		Mn 1 *h*	65 ± 1.1^{ab}	70 ± 1.2^{ab}	35 ± 1.2^{ab}	25 ± 1.0^{b}	130 ± 0.9^{b}	73 ± 1.1^{b}
		Mn 2 *h*	63 ± 0.8^{b}	68 ± 1.4^{b}	34 ± 0.8^{b}	24 ± 0.3^{b}	126 ± 0.2^{c}	77 ± 0.5^{c}

At the end of vegetation period, the stems of hot and sweet pepper varieties were 11.5%–19.5% and 4.0%–7.5% higher than that of control (Fig. 1). In this experiment, the seeds in the variant with Mn germinated first, then there germinated the seeds in the variant soaked in the potassium humate, and the last were control seeds. It should be noted that the additional experiment was carried out in December at a relatively low temperature, so the process of seed germination was strongly slowed down, but the difference in the timing of germination was obvious.



Control
Mn 2 *h*

$LSD_{0.05}$ – Nush 55 – 1.4
Zmrukht – 2.2
Kon – 0.93
Punj – 0.89

Fig. 1. The influence of Mn on the pepper plants' height at the end of vegetation, *cm*.

The observation of seedlings during the replacement showed that a more developed root system was observed under the influence of Mn and less developed in the variant with potassium humate, and in both groups the experimental sowings were superior to those from the control group (Fig. 1). The development of the overground part and the root system was also differentiated. Thus, the stem height of the seedlings from the control group achieved 7 *cm*, in the variant with potassium humat it was 11 *cm*, and the highest stems (17 *cm*) were in the variant with Mn. The latter variant differs with its large leaf surface. Mn also enhanced the development of big buds. Treated in Mn variants germinated earlier than the seeds soaked in potassium humate.

Indicators of Mn Impact on the Quality of Pepper Fruits. Fruit DM (dry matter) content of the control and Mn treated plants varied between 5.0% and 6.8% in the technical ripening phase and between 7.5% and 9.1% in the biological ripening phase (Fig. 2, a).

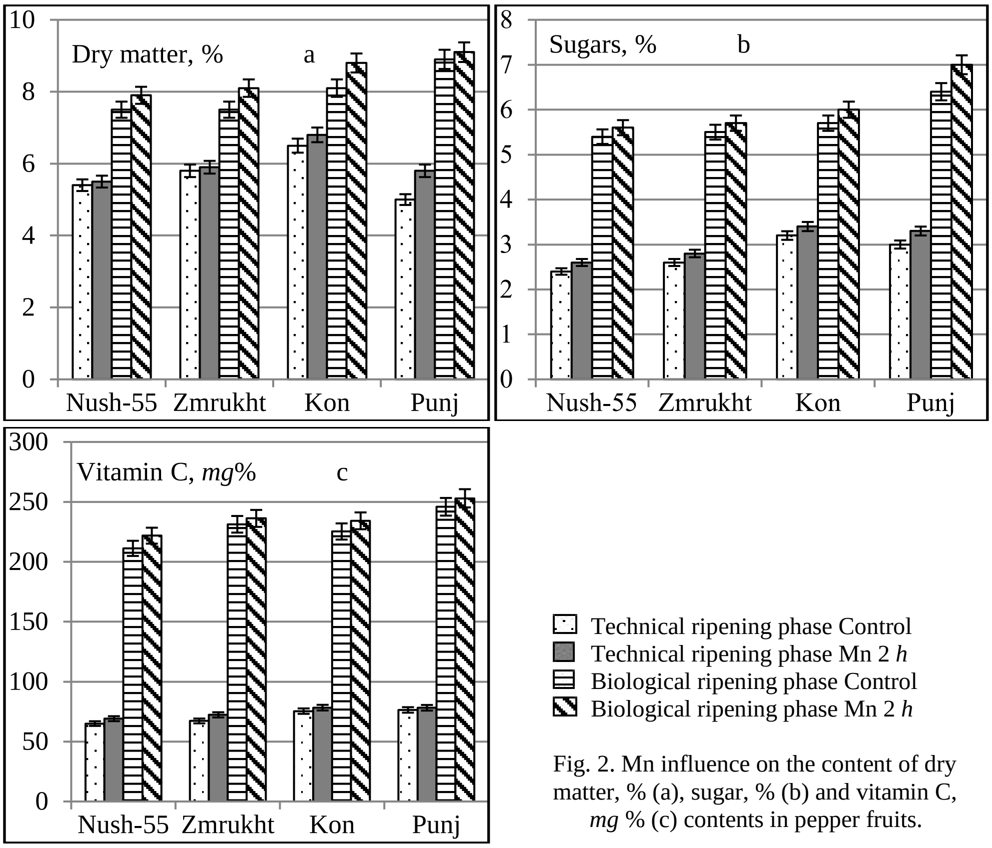


Fig. 2. Mn influence on the content of dry matter, % (a), sugar, % (b) and vitamin C, *mg* % (c) contents in pepper fruits.

The increase in sugar content in biologically ripe fruits varied between 3.6% and 9.7% (Fig. 2, b). The best result for vitamin C was recorded for Nush-55 (6.3%) compared to the control (Fig. 2, c).

Economic Efficiency of Mn Application. The economic efficiency of Mn application to pepper was also estimated. The cost of pepper cultivation was \$2666.7 per *ha*, while the average selling price for the sweet varieties of pepper was \$0.208 per *kg*, for the hot pepper Kon – \$0.313 per *kg*, and for Punj – \$0.417 per *kg*. As it can be seen from Tab. 2, the net income increased regardless of the soaking exposition for all the pepper varieties under experiment. With 1 *h* exposure, the net income increased compared to the control by 8.1%–15.7%, while with 2 *h* exposure it amounted to 15.8%–19.0%. The highest net income was received with Zmrukht and Punj (Tab. 3).

Table 3

Mn economic efficiency on pepper
(means followed by the same letter indicate no significant differences)

Crop	Variety	Variant	Total, fresh ripe fruit yield, *t/ha*	Yeild increase to control, %	Gain from sale, $/*ha*	Income, $/*ha*	Income increase to control, %
Sweet pepper	Nush-55	control (water)	45.0^{a}	–	9360.0	6693.3	–
		Mn 1 h	47.6^{b}	5.7	9900.8	7234.1	8.07
		Mn 2 h	50.1^{c}	11.3	10420.8	7754.1	15.8
		$LSD_{0.05}$	0.01				
	Zmrukht	control (water)	47.0^{a}	–	9776.0	7109.3	–
		Mn 1 *h*	52.2^{b}	11.0	10857.6	8190.9	15.2
		Mn 2 *h*	53.5^{c}	13.8	11128.0	8461.3	19.0
		$LSD_{0.05}$	0.015				
Hot pepper	Kon	control (water)	35.0^{a}	–	10955.0	8288.3	–
		Mn 1 *h*	37.6^{b}	7.4	11768.8	9102.1	9.8
		Mn 2 *h*	39.2^{c}	12.0	12269.6	9602.9	15.8
		$LSD_{0.05}$	0.06				
	Punj	control (water)	25.2^{a}	–	10508.4	7841.7	–
		Mn 1 *h*	27.0^{b}	7.1	11259.0	8592.3	9.5
		Mn 2 *h*	28.5^{c}	13.0	11884.5	9217.8	17.5
		$LSD_{0.05}$	0.05				

A significant effect was observed in relation to the growth rate of plants during periods of transition from budding to flowering and intensive fruit formation, when stem growth generally slows down. Our experimental results coincide with the data reported by different authors [12, 24, 25]. Biochemical analysis also revealed differences in the quality of plant sugars, significant substances that determine the taste of pepper fruits [26, 27] and stabilize vitamin C [28]. In general, the vegetables and fruits contain a lot of vitamin C, which is usually manifested in a high content of carbohydrates. Pepper has a high content of vitamin C and a high concentration of sugar [27–30]. The fruit dry matter (DM) in fruits of Mn treated Nush-55, Kon and Punj plants was significantly higher than that of the control plants.

Based on the data for sugar content (Fig. 2, b), it could be concluded that the hot pepper varieties were more sensitive to Mn than the sweet ones. The dry matter, sugars and ascorbic acid (Fig. 2, a–c) were significantly increased in peppers treated for 2 *h*. The growth of mycorrhiza on the roots of the treated plants stimulated fruit setting even during the longest hot period (39–40°*C*). This indicated the development of resistance of the treated plants without decline of their fruits' biochemical indices. Similar results were gotten for seeds of pumpkin, cucumber and beans soaked in Mn solution for our other field experiments [15]. There is no doubt that mycorrhiza development improved not only the supply of water and mineral elements, but also the development of the leaf blades, which also impacted fruits ripening.

Our previous experiments have already proven that Btm application was much more effective with double treatment (seed soaking before sowing and seedling watering before planting). This was due to the fact that melanin induces the development of an extra root system, branching, and an increase in flower number, which together increase plants' productivity [12]. The same results were obtained with the pepper seeds soaking in Mn for 2 *h*. The Mn impact was most clearly noticed on Zmrukht, whose crop surpassed the control by 13.8% (53.5 *t*/*ha* vs. 47.0 *t*/*ha* in the control). A similar result (13.0%) was recorded for variety Punj (Tab. 2). The latter was tested with Btm too; after soaking its seeds into Btm solution and watering seedlings with the same solution before planting in the field, a significantly higher crop and longer period of fruit formation have been observed (two weeks after withering of the control plants) [16].

Thus, Mn and the other biopreparations stimulated every stage of development, optimizing development of plants. Most likely, these changes occur due to the phytohormones from the auxins group, since processes that are mainly controlled by these hormones are amplified – increase in heght, thickening and branching of stems and roots due to activation of the apical and lateral meristem, cambium, respectively.

Conclusion. The results obtained allow us to conclude that Mn improves the agronomical and economic-valuable indicators of sweet and hot pepper in various degrees, which depends on the duration of treatment and on the crop variety. Effectiveness is high when the seeds are soaked in a 0.01% Mn solution for 2 *h*. Mn application on the vegetables is expedient and profitable in Armenia.

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ՄԻԿՈՆԵՏ ՄԻԿՈՐԻԶԱՅԻՆ ՊԱՏՐԱՍՏՈՒԿԻ ԱԶԴԵՑՈՒԹՅՈՒՆԸ ՊՂՊԵՂԻ ԱԳՐՈՆՈՄԻԱԿԱՆ ԵՎ ՏՆՏԵՍԱԿԱՆ ԲՆՈՒԹԱԳՐԵՐԻ ՎՐԱ

Ամփոփում

Ուսումնասիրության նպատակն է եղել պարզել Endo տեսակի Միկոնետ (Mn) հնդկական միկորիզային պատրաստուկի ազդեցությունը քաղցր և կծու պղպեղի արտադրության ագրոնոմիական և տնտեսական բնութագրերի վրա: Ուսումնասիրությունն իրականացվել է պղպեղի երկու քաղցր (Զմրուխտ և Նուշ-55) և երկու կծու սորտերի (Կոն և Փունջ) հետ: Փորձերն իրականացվել են պատահականության մեթոդով: Ցույց է տրվել, որ Mn-ը մեծացնում է քաղցր և կծու պղպեղի կենսաբանական և տնտեսական բնութագրերը՝ կախված մշակման տևողությունից և սորտից: Առավել արդյունավետություն դրսևորել է 2 ժամյա մշակումը: Չոր նյութի պարունակությունը ավելացել է ոչ զգալիորեն, բայց այն ավելացել է շաքարի և ասկորբինաթթվի համար: Լավագույն արդյունք ստացվել է «Զմրուխտ»-ի դեպքում: Հաշվի առնելով, որ Mn-ն ավելացնում է քաղցր և կծու պղպեղի ագրոնոմիական և տնտեսական բնութագրերը, այն կարող է առաջարկվել պղպեղի արտադրության համար:

Г. С. МАРТИРОСЯН, К. Г. АЗАРЯН, А. А. ТРЧУНЯН

ВЛИЯНИЕ МИКОРИЗНОГО ПРЕПАРАТА МИКОНЕТ НА ЦЕННЫЕ АГРОНОМИЧЕСКИЕ И ЭКОНОМИЧЕСКИЕ ПОКАЗАТЕЛИ ПЕРЦА

Резюме

Целью исследования было определение влияния индийского микоризного препарата Миконет (Mn) типа Эндо на агрономические и экономические показатели производства острого и сладкого перца. В экспериментах использовали два сладких (Змрухт и Нуш-55) и два острых (Кон и Пундж) сорта перца. Эксперименты проводились по блочной методике рандомизации. Было показано, что Mn повышает биологические и экономические характеристики сладкого и острого перца в зависимости от продолжительности обработки и сорта. Наиболее эффективными были 2-часовые обработки. Содержание сухого вещества увеличивалось незначительно, но оно увеличивалось для сахаров и аскорбиновой кислоты. Наилучший эффект был получен для сорта Змрухт. Учитывая, что Mn повышает агрономические и экономические характеристики сладкого и острого перца, Mn можно рекомендовать для производства перца.