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Peculiarities of tomatillo (*Physalis philadelphica*) field production in Ukraine with the use of different elements of technology

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ABSTRACT

Tomatillo is a fairly common plant in South America but is rare for the conditions of the European continent. Therefore, in Ukraine there are no recommendations for its cultivation in specialized vegetable farms. Such recommendations should take into account the biological characteristics of the plant and the application of new elements of technology for plant productivity. The article is devoted to the study of the influence of the main elements of the technology of growing tomatillo for open ground conditions. The aim of the research was to find and optimize such elements in the open ground. To achieve this goal, the tasks solved were selection of high-yielding varieties, identification of the most effective factors for pre-sowing seed treatment and the term of planting seedlings is substantiated. This research was conducted during 2016 to 2018 on the research fields of Vinnytsia National Agrarian University (Central part of Ukraine) on gray-podzolic soils. The experimental varieties of tomatillo were divided into two groups (short and tall) according to plant height. Three varieties *viz.*, Ananasovyi, Jemovyi and Kondyter were in the first group with a height of 80.1 to 81.4 cm and the second group included two varieties *viz.*, Marmeladnyi and Korolyok. The varieties of foreign selection including Ananasovyi and Korolyok and, a domestic variety Likhtaryk were characterized by higher yields (30.6 to 32.0 t/ha). By studying the effect of pre-sowing seed treatment with heating the seeds at 40°C for 4 hrs or seed treatment with a magnetic field of 50 E for 12 hrs or Baikal EM-1 solution at a dose of 1.0 l/tonne provides an increase in total yield of tomatillo to 33.0 t/ha. When studying the impact of seedlings planting in the open ground, it was found that planting of seedlings was done in the third week of April or first week of May with a seedling age of 60 days under temporary film shelters. The varieties Likhtaryk and Ananasovyi were characterized by early budding in 47-48 days, flowering in 56-57 days, fruit tying in 69-70 days and fruiting in 101days. These varieties form a higher fruit yield of 33.4 t/ha. The biochemical composition determined a higher content of dry matter, protein and ash in the fruits of the variety Korolyok, with an index of 10.7, 1.6 and 1.0 %, respectively. These studies did not research the impact of tillage, pest control to obtain quality and environmentally friendly products and methods of harvesting, therefore, there is a need to further improve the technology of growing tomatillo in the open ground of Ukraine.

Key Words : Biological agents, biometric, fruit yield, marketability, morphological features, planting period, tomatillo, variety

INTRODUCTION

Tomatillo belongs to the nightshade family and is widely grown and consumed on the South American continent, where the technology of its cultivation is developed and

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constantly improved. However, this representative is also a rare plant for the conditions of the European continent and. Therefore. in Ukraine there are no recommendations for its cultivation in specialized vegetable farms. Such cultivation is restrained first of all, by a small number of grades, lack of the recommended elements of technology to modern cultivation in the conditions of an open ground. Such recommendations should take into account the biological characteristics of the plant and the use of new elements of technology with their subsequent positive impact on plant productivity. In Ukraine, at a sufficient level there are recommendations for growing such plants of the nightshade family as: tomato (Wahab and Hasan, 2019; Tumanyan *et al.*, 2020), sweet pepper and eggplant. However, there is no information about the technology of growing tomatillo to the soil and climatic conditions of Ukraine, which prompted us to conduct these studies.

The aim of our research was to develop and optimize the elements of the technology of growing tomatillo for the conditions of the open fields of Ukraine. To achieve this goal, the following tasks solved were to select high-yielding varieties adapted to the conditions of Ukraine; evaluate physical and biological factors and determine the most effective of them for pre-sowing seed treatment, to justify the term of planting seedlings in open ground and recommend the most optimal as well as to establish the relationship between overall yield and plant biometrics.

According to del Carmen *et al.* (2019), Lopez-Sandoval *et al.* (2018), Valdez *et al.* (2018) and Ulyanich (2018), there were a large number of varieties adapted for growing in the plains and hills in Mexico, Venezuela, Peru and Guatemala. In the former Soviet Union, the first varieties intended for technical processing and production of sweets were bred for the industrial use of tomatillo. The bred varieties were grown in the open ground by the seedling method, which ensured a stable yield of the plant.

In Eastern Europe, where Ukraine belongs also carried out research on the breeding of new high-yielding varieties of tomatillo, which can be adapted for organic and intensive cultivation technology. Such varieties must be characterized by friendly fruit ripening, be resistant to bacterial and viral diseases. However, given modern innovations in vegetable growing, there is a need to improve the field production technology. In recent years, Sych and Bobos (2013), Bell *et al.* (2015), Hernandez (2016), Mierzejewski (2016), Vdovenko and Polutin (2016), Sych *et al.* (2018) and Ulyanich (2018) dealt with the influence of elements of the technology of growing tomatillo. However, the solution to new problems has not been sufficiently reflected in modern cultivation technologies, which hinders the further effective development of field production of this plant.

In tropical and subtropical climates, tomatillo is grown mainly in a generative way (Berry, 2003; Hernandez, 2016; Nehayyan, 2007). However, the seedling method is used in countries with temperate climates, which significantly reduces the seeding rate, the crop is taken early and plants with a long growing season are used (Bublyk, 2015). Based on the data of Perez-Herrera *et al.* (2020), Smirnova (2010), Strelets (2015) and Wen *et al.* (2019), the main factor in seedling quality is air temperature and sowing time. We observed that the optimal time for the sowing of tomatillo seeds is the second week of March when air temperature ranges from 20.0 to 25.0°C. Seedlings are planted in open ground when the threat of frost is over, the soil warms up to a temperature of 10.0 to 12.0°C and the root system of the plants is able to absorb water and minerals (Bublyk, 2016; Chernyshenko *et al.*, 2017). Keeping all this in view, this research was conducted with an objective to develop suitable elements of agrotechnology for obtaining the high yield of tomatillo namely selection of promising varieties, reasonable pre-sowing seed treatment, suitable planting time for 60 days old seedlings in between the third week of April to the first week of May under temporary frame tunnel protection.

MATERIALS AND METHODS

Experiments on the study of varietal characteristics, pre-sowing seed treatment and planting dates of tomatillo seedlings were conducted in the experimental field of Vinnytsia National Agrarian University (Central Ukraine) in 2016 to 2018 on Gray-podzolic soils. Seedlings were grown in a film arch greenhouse. Seedlings were planted to a permanent place of cultivation at a spacing of 70 x 35 cm.

To study the effectiveness of the elements of technology, tomatillo varieties of different selection, pre-sowing seed treatment and seedling planting dates were studied. The varieties of tomatillo used in this study were - Likhtaryk (Ukrainian selection used as control) and Ananasovyi, Jemovyi, Marmeladnyi, Korolyok and Kondyter (foreign selection).

Brief Description of Varieties

Likhtaryk - a medium-ripe variety obtained by multiple selection from a population of free-pollinated forms, the parent forms of which are obtained from Italy. An annual plant. Fruits are used for salad preparation and canning, which contain pectin, sugar, ascorbic acid and are a dietary and prophylactic food product to prevent intoxication of the human body. Fruit yield is 21.4–21.7 t/ha.

Ananasovyi - is a medium-ripe variety, up to 1.5 m tall. The fruits are yellow, round-flat, ribbed in shape, weighing 65.0–75.0 g, sour-sweet, with a pineapple taste. Not demanding on environmental conditions, resistant to disease.

Jemovyi is a medium-ripe variety, 1.4–1.6 m high. Fruits in biological ripeness are green in color, weighing 50.0–60.0 g with high iron content, and productive.

Marmeladnyi is a medium-ripe variety, up to 1.5 m high. Cream-colored fruits, flat-rounded, weighing 30.0–40.0 g, very fragrant, plum-flavoured, resistant to stress and temperature changes.

Korolyok - is a medium-ripe variety, 60.0–80.0 cm high, yellow fruits, flat-rounded shape, fleshy weighing 60.0–90.0 g, sweet and sour, with a high pectin content, cold-resistant.

Kondyter - medium-ripe variety, height 60.0–80.0 cm, yellow fruits, flat-rounded shape, fleshy, weighing 30.0–40.0 g, stored for up to 2-3 months. Used for salting, making jelly and jam.

In this study, the variants were placed according to the method of conducting research in triplicate (Bondarenko and Yakovenko, 2001). During the growing season, biometric measurements were performed on the height of 30 typical plants using a ruler, stem and fruit diameter on 30 typical plants using a Calliper, weight of 30 typical fruits using electronic scales, area of 50 leaves by weight, dry matter content in 50 leaves - laboratory method and total plant yield by mathematical method, fruit quality was determined by laboratory method and performed as mathematical data processing to determine averages and statistical data processing with the smallest significant difference using Fisher's criterion at 95 % using the program Statistica 6. The first fruits with the first flowering brush were collected in the phase of biological ripeness of the fruit, which occurred in the second week of August.

Seedlings of Likhtaryk and Ananasovyi varieties were sown in the seedling compartment of the film greenhouse. Planting of 60 days old seedlings was done in the third week of April under temporary film tunnel shelters, in the first week of May 60 days old seedlings under temporary film tunnel shelters, in second week of May 60 days old seedlings without the use of temporary tunnel shelter (control), in third week of May 60 days old seedlings without the use of temporary tunnel shelter; in third week of May 50 days old seedlings without the use of temporary tunnel shelter and in the third week of May 40 days old seedlings without the use of a temporary tunnel shelter.

Pre-sowing treatment of seeds of Likhtaryk and Ananasovyi varieties was carried out using bubbling for 24 hrs, heating at a temperature of 40°C for 4 hrs, treatment with a magnetic field of 50 E for 12 hrs and the use of drugs of bacterial origin Baikal EM-1@ 1.0 l/tonne, Azotobacterin @ 5.0 ml/kg, Biomag @ 2.5 l/tonne, Biopolicide @ 5.0 ml/kg, Phosphoenterine @ 5.0 ml/kg and a complex solution of these biological products @ 1.0 ml/kg, where untreated seeds served as a control option.

Brief Description of Biological Products

Baikal EM-1: It is a concentrate in the form of a liquid in which anabiotic microorganisms are grown. They produce amino acids, nucleic acids, enzymes, physiologically active substances that directly or indirectly affect the growth and development of plants.

Azotobacterin: It is a highly effective bacterial composite preparation based on the association of soil bacteria of the genus *Azotobacter*, capable of fixing nitrogen from the atmosphere to the soil.

Biomag: It is a biotechnological drug of prolonged action. The drug contains live cells of the bacterium *Azotobacter chroococcum* and products of their metabolism (antibiotics, amino acids, vitamins, phytohormones, biofungicides).

Biopolicide: It is a bacterial preparation based on the spore bacteria *Paenibacillus polymyxa*, which promotes the activation of growth processes, increases plant immunity, inhibits the development of phytopathogenic fungi, improves the phytosanitary condition of the soil.

Phosphoenterin" It is a highly effective bacterial preparation based on growth-stimulating and phosphatomobilizing soil bacteria *Enterobacter nimipressuralis*, which improve mineral nutrition of plants, stimulate their growth and development, increase plant resistance to phytopathogens and stress, increase yield and quality of mineral products.

RESULTS AND DISCUSSION

The beginning of plant growth processes is an important step in the cultivation technology. In case of the phenological phase violation, further success of the cultivation technology is impossible. Therefore, it is important to ensure an accordance of the main stages of growth and development of the tomatillo with its morphological features. Since the seedlings of tomatillo were grown in a film greenhouse, first of all, special attention was paid to the observance of the optimal temperature and humidity regime. By the time of planting the seedlings into the open soil the plant parameters *viz.*, plant height (25.0-30.0 cm), number of true leaves (4 to 5), seedling weight (20.0-24.0 g), root system weight (4 to 5 g) was recorded. However, after planting them into the open soil, the main phases of development depended on the varietal features, pre-sowing seed treatment, the time of planting the seedlings, that is why, we investigated the occurrence of the main plant development phases.

Thus, as a result of the engraftment of plants in the open ground, the term of planting seedlings affected the phenological parameters of two varieties of tomatillo. The beginning of budding was observed on the 47-69th day after germination. Earlier budding was characteristic of the variants, whose seedlings were planted in the third week of April or in the first week of May with the age of seedlings of 60 days under temporary frame protection for the Likhtaryk and Ananasovyi varieties. At the same time, mass tying of fruits, by varieties Likhtaryk and Ananasovyi, was observed for 69-70th, and the beginning of fruiting – 101th from the emergence of seedlings for planting seedlings in the first week of May with a seedling age of 60th (Table 1). However, after setting the air temperature in the frame shelter +25°C…+30°C, the beginning of flowering of the

Table 1. Beginning of the tomatillo plant growth and developmental stages as influenced by time of planting and the age of seedlings in days (average of 2016, 2017 and 2018)

Varieties	Time of planting (seedlings age)	Beginning of budding	Beginning of flowering	Beginning of fruit inception	Beginning of fruitage
Likhtaryk	III decade of April (60 days)	57±0.2	67±0.3	80±0.3	113±0.7
	I decade of May, (60 days)	47±0.3	56±0.4	69±0.5	101±0.5
	II decade of May, (60 days), (C)*	69±0.2	80±0.4	92±0.4	125±0.8
	III decade of May, (60 days)	68±0.3	78±0.4	89±0.3	122±0.8
	III decade of May, (50 days)	69±0.3	77±0.4	90±0.4	123±0.6
	III decade of May, (40 days)	68±0.2	77±0.3	89±0.4	119±0.4
Ananasovyi	III decade of April, (60 days)	59±0.2	68±0.3	81±0.4	115±0.5
	I decade of May, (60 days)	48±0.2	57±0.3	70±0.4	101±0.5
	II decade of May, (60 days), (C)*	66±0.4	76±0.4	88±0.5	120±0.4
	III decade of May, (60 days)	67±0.2	76±0.2	88±0.4	119±0.4
	III decade of May, (50 days)	69±0.3	79±0.4	91±0.4	126±0.6
	III decade of May, (40 days)	69±0.3	79±0.4	92±0.5	122±0.6

*: Control.

plant occurred on 56-57 days for planting seedlings in the first week of May at the age of 60 days. Later flowering was observed for the Ananasovyi variety when the seedlings were planted in the third week of May at the age of 50, 40 days into the open soil without any special tunnel protection, where the specified phase was observed on the 79th day. At the same time, mass fruit inception for the Likhtaryk and Ananasovyi varieties was observed on the 69-70th day, and the beginning of fruitage – on the 101st day from germination of seedlings, if seedlings were planted in the first week of May at the age of 60th.

During the tomatillo cultivation period, the biometrics indicators of the plant significantly depended on the climatic conditions and the application of the studied elements of the cultivation technology. The air temperature during the years of the experiment was much higher than the average, and exceeded the values 1.1 to 1.2 times, and the precipitation was insufficient, which also affected the biometrics indicators. The plants height was variable due to the different selection varieties. In general, the plants were typical and corresponded to the characteristics of each variety.

According to the height of the plant, all the studied varieties were divided into two groups: the first group included low-growing varieties, the second - tall. In the fruitage phase, the Ananasovyi, Jemovyi and Condeter varieties belonged to the first group, where the plant height ranged from 80.1 to 81.4 cm. The second group included the plants of the Marmeladnyi and Korolyok varieties, where the height was 82.7 cm and 84.8 cm, respectively (Fig. 1a).

As a result of the use of physical or biological factors, as a pre-sowing treatment of seeds, the height of the plant increased. In the field conditions of the Right-Bank Forest Steppe of Ukraine, higher indicators of plant height were obtained for the Likhtaryk variety due to the seed warming and magnetic field application. In those variants, the height of the plants was 95.0 cm and 93.7 cm, where the gain was 8.5 cm and 7.2 cm comparing to the control, respectively.

No significant increase in height was observed during the Ananasovyi variety cultivation, but the plants showed the tendency to the height increase when Baikal EM-1 preparation was used 91.3 cm, what was 6.1 cm higher than for the control plants. It is obvious that a 40°C temperature and magnetic field with the intensity of 50 E for 12 hr, as well as anabiotic microorganisms included in the biological preparation Baikal EM-1, had a stimulating effect on the growth processes of the plant at higher air temperatures (Figs. 1b and 1c).

It was observed that the early period of planting seedlings under tunnel shelters provided an increase in plant height due to the existence of an optimal microclimate. Increased plant height was characteristic of the Likhtaryk and Ananasovyi varieties, the seedlings of which were planted in the third decade of April and the first decade of May in the age of 60 days under tunnel protection – 111.1 cm, 109.0 cm for the Likhtaryk variety, and 112.6 cm, 110.6 cm for the Ananasovyi one, that was 19.2 cm, 17.1 cm and 23.0 cm, 21.0 cm higher than the control. The lower height was characteristic of the Likhtaryk and Ananasovyi varieties due to planting seedlings in the third decade of May at the age of 40 days. The specified value was smaller than the control by 1.7 cm and 0.7 cm.

In the process of formation of a large vegetative mass, the area of leaves during the process of photosynthesis and dry matter content also increased. Among the studied varieties, the highest index of leaf area was characteristic of the Ananasovyi variety – 126.0 thousand m^2/ha and Korolyok variety – 104.7 thousand m^2/ha. The Jemovyi variety had a smaller value of this indicator – 76.2 thousand m^2/ha (Fig. 2a).

At the same time, from the use of bubbling or heating the seeds provided the largest area of leaves at the level of 78.1 thousand m^2/ha or 75.7 thousand m^2/ha, which was 31.3 thousand m^2/ha and 13.7 thousand m^2/ha was larger for control plants, and the use of a set of biologicals reduces the area of leaves to 55.1 thousand m^2/ha for the variety Ananasovyi, which was 6.9 thousand m^2/ha less than the control (Fig. 2b).

Seedlings planted in the third decade of April under tunnel protection, which provided better temperature conditions, differed in the parameters of leaf area relative to the control plants. The area of leaves, when planting seedlings in the third decade of April under a frame protection with the seedlings age of 60

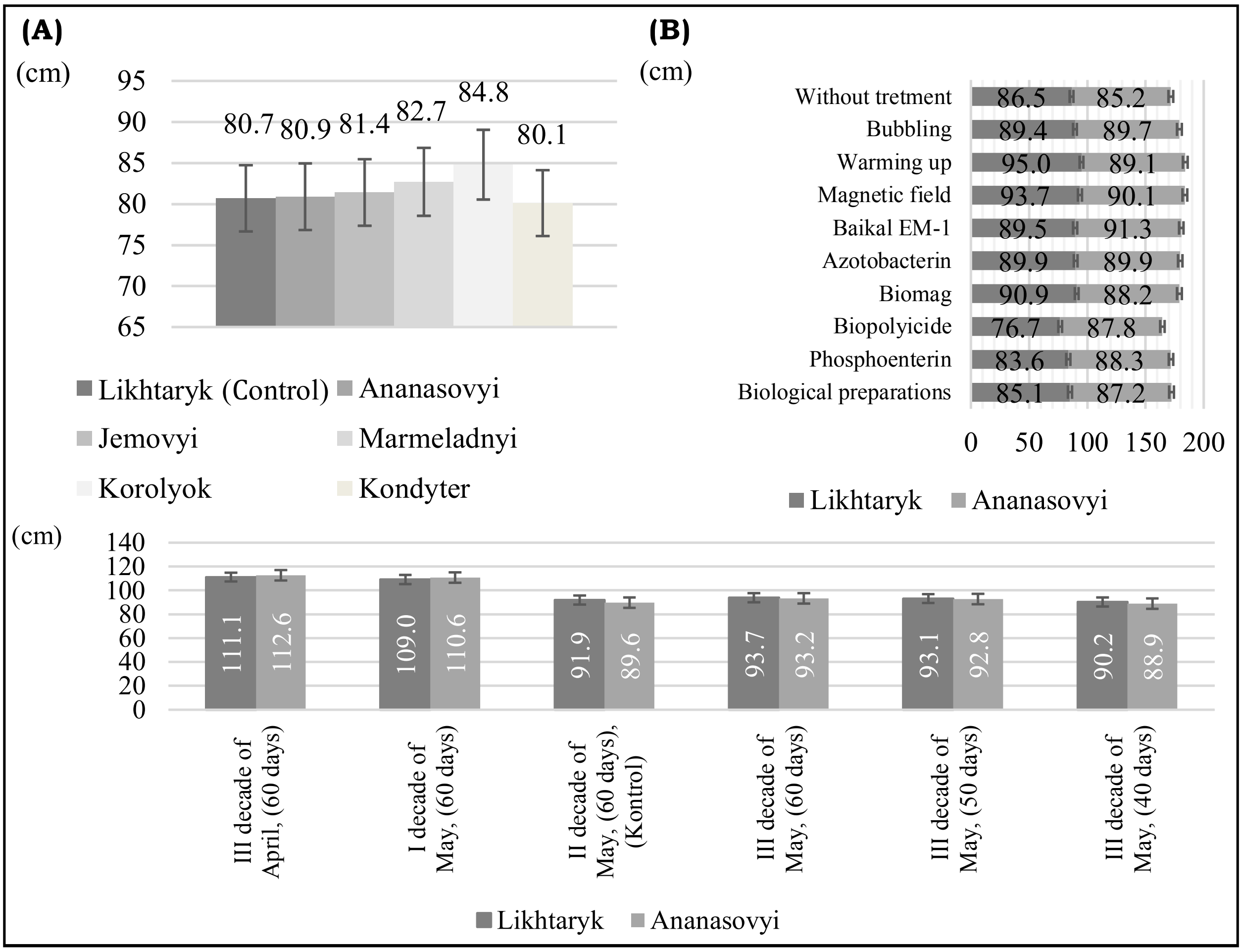

Fig. 1. Tomatillo height (cm) before fruitage depending on the varietal characteristics, pre-sowing treatment of seeds, time of planting and seedling age (average of 2016, 2017 and 2018).

days, was characterized by a greater number of leaves on the plants, but their size was smaller relative to the control group. At the same time, planting the seedlings of the Likhtaryk variety in the third decade of April or in the first two decades of May at the age of 60 days or in the third decade of May at the age of 50, 40 days helped to increase the area of leaves relative to the control group by 22.0-57.2 thousand m^2/ha (Fig. 2c).

The largest leaf area and the dry matter content of the leaves contributed to the formation of a larger mass of fruit. A higher mass index was characteristic of the Ananasovyi variety with a value of 8.1 g, which exceeded the control Likhtaryk variety by 1.1 g, while a smaller fruit mass was characteristic of the Jemovyi, Marmeladnyi varieties with a value of 7.7 g (Fig. 3a).

The pre-sowing seed treatment ensures a stable growth of the fruit mass. Thus, the Likhtaryk variety had the largest fruit mass (8.3 g, 8.1 g) due to seed warming, bubbling or use of a magnetic field. We also established an increase in fruit mass for the Ananasovyi variety in the variants with seed treatment with magnetic field and Biomag (7.9 g), what exceeded the value of the control variant by 0.9 g (Fig. 3b).

The weight of the food organ increased and depended on the number of fruits on the plant and the age of the seedlings. The highest value of the fruit mass was obtained for the Likhtaryk variety subject to planting seedlings under tunnel protection in the third decade of April and the first decade of May, with the seedling age of 60 days and the mass of 7.9 g and 8.2 g, which were 1.1-1.4 g more than control ones. The seedlings planted in the third decade of May in the age of 40, 50, 60 days were characterized by a smaller weight, and exceeded the control variant only by 0.8-1.0 g. At the same time, for the Ananasovyi variety an increase in the fruit weight of 8.5 g was

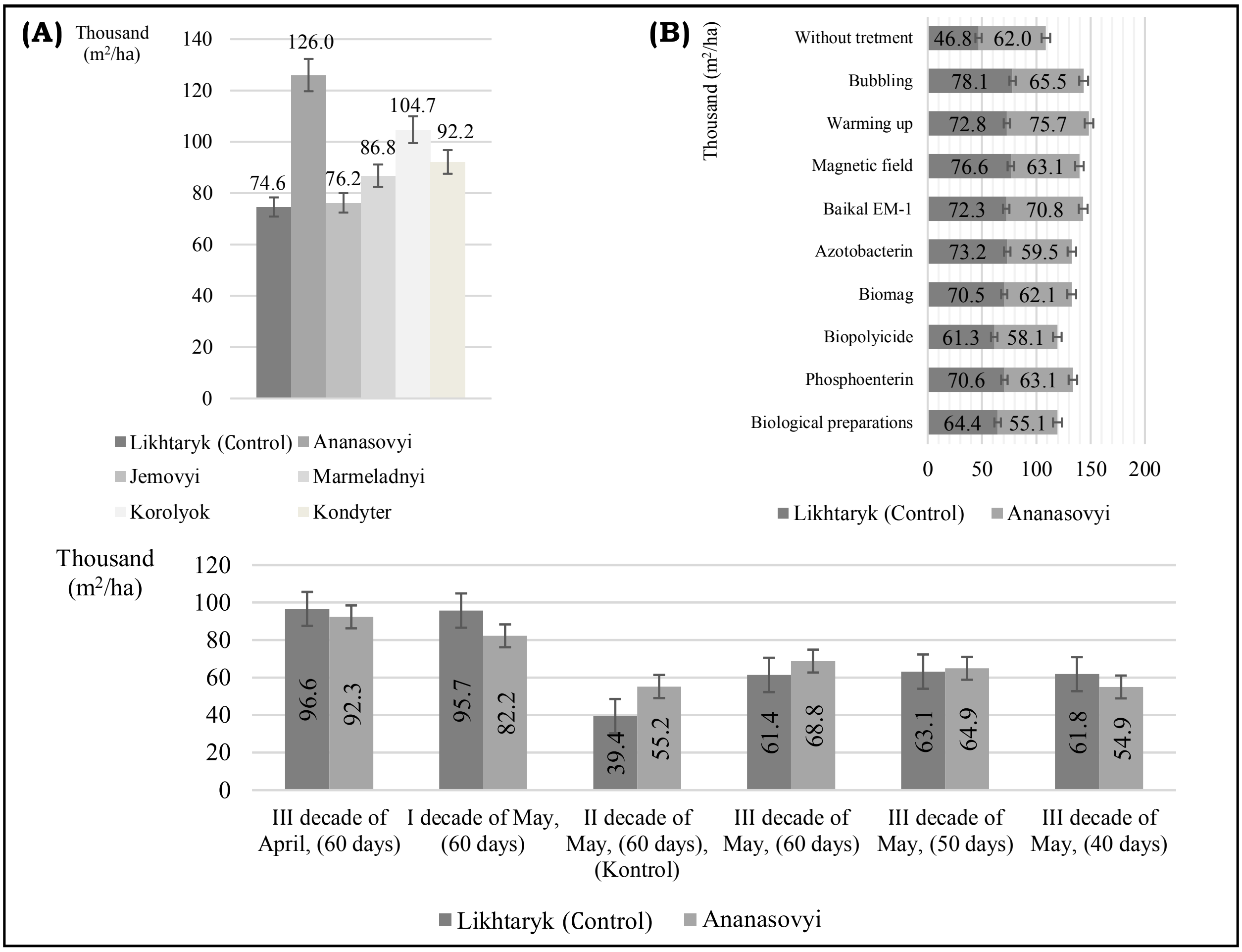

Fig. 2. Area (thousand m^2/ha) of tomatillo leaves before fruitage as affected by varietal characteristics, pre-sowing seed treatment, time of planting and age of seedlings (average of the 2016, 2017 and 2018).

recorded in the variant of planting the seedlings under the tunnel protection in the third decade of April. However, planting seedlings in the first decade of May in the age of 60 days, and in the third decade of May with the seedlings age of 40, 50, 60 days resulting in the weight exceeding the control group by only 0.1-0.6 g (Fig. 3c).

In the conditions of open ground of Ukraine with increase in weight of a fruit the diameter of a food body increased. The largest diameter was characteristic of the Ananasovyi variety (3.1 cm), slightly smaller - the Jemovyi and Condeter varieties, with the size of 3.0 cm, while the Marmeladnyi and Korolyok varieties had the lowest values – 2.9 cm (Fig. 4a).

However, with the improvement of cultivation technology through the use of pre-sowing seed treatment and the time of planting seedlings, the diameter of the fruit varied from 2.9 to 3.1 cm (Figs. 4b and 4c).

Growing tomatillo by seedling method in the open ground of Ukraine provided higher yields of the Ananasovyi variety - 32.0 t/ha, which makes it possible to obtain an additional 3.9 t/ha. The yield growth of other tomatillo varieties was 7.8-9.6 %, and of the Kondyter one – only 3.6 %.

In the studies, the Lewis phenotype stability factor K_{sfn} ranged from 1.6 to 1.9. Based on the conducted mathematical analysis, it was the lowest in the variety Korolyok with a rate of 1.6, which indicated a more stable yield over the years of cultivation. However, the Marmeladnyi variety showed unstable increase in yield (Table 2).

As a result of pre-sowing treatment, different yields were observed. The use of bubbling or heating or the effect of a magnetic field on the seeds, or the use of solutions of Baikal EM-1, Azotobacterin, Biomag, Biopolycid, Phosphoenterin or a complex of biologicals in the tank mixture of the variety Likhtaryk increased the total yield by 2.9-6.3 t / ha. During cultivation the Ananasovyi variety, the highest yield was provided when the seed were treated with bubbling or warming, magnetic field or Baikal EM-1 solution. These options of the experiment exceeded the control group by 2.6-3.3 t/ha. The use of Azotobacterin, Biomag, Biopolyicide or Phosphoenterin solutions, or a complex of biological preparations in the tank mixture exceeded the yield of the control variant by only 0.8-2.0 t/ha.

Under the conditions of field production in Ukraine, the increase in the yield of tomatillo is possible in case of planting seedlings in the third decade of April at the age of 60 days, or under the tunnel protection in the first-third decade of May at the age of 60 days, or in the third decade of May at the age of 50 days. The excess compared to the control was 3.1-5.7 t/ha. The lowest Lewis K_{sfn} factor was observed in the Likhtaryk variety in the variant where the seedlings were planted in the first decade of May at the age of 60 days under the tunnel protection (1.4), and the largest – in the variant where seedlings were planted in the second decade of May at the age of 60 days without frame protection (1.9) (Table 3).

Correlation analysis of plant biometrics indices depending on the tomatillo productivity was made by calculating the correlation coefficients of the Ananasovyi variety, since it was characterized by the highest yield. The correlation function established the degree of interrelation between the variables and the effect on the overall productivity. In the process of analysis of correlation coefficients it was found that there was a strong positive correlation between fruit number and fruit diameter (r=0.95), between fruit diameter and stem diameter (r=0.96), between fruit diameter

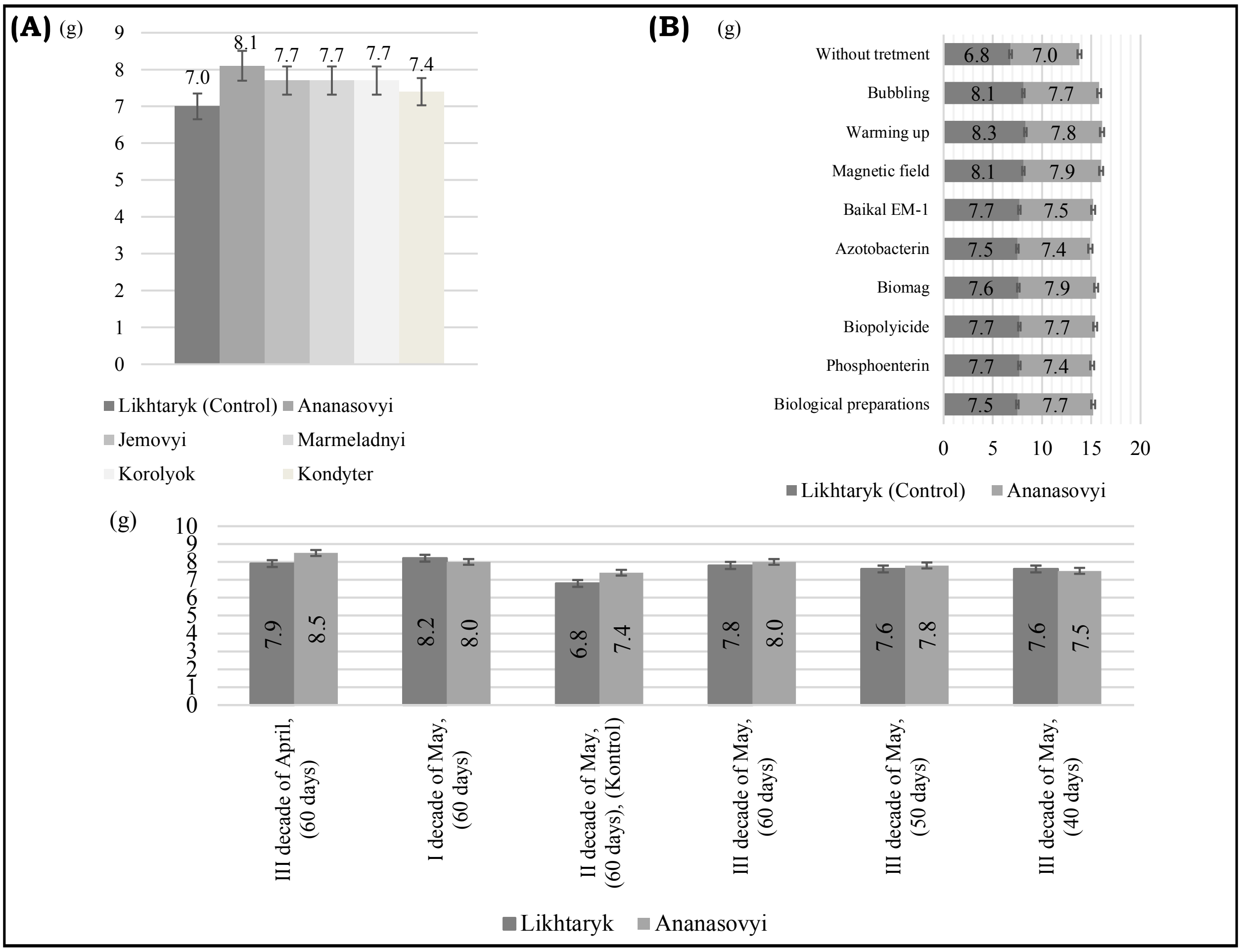

Fig. 3. Weight (g) of tomatillo fruit as influenced by varietal characteristics, pre-sowing seed treatment, time of planting and age of seedlings (average of 2016, 2017 and 2018).

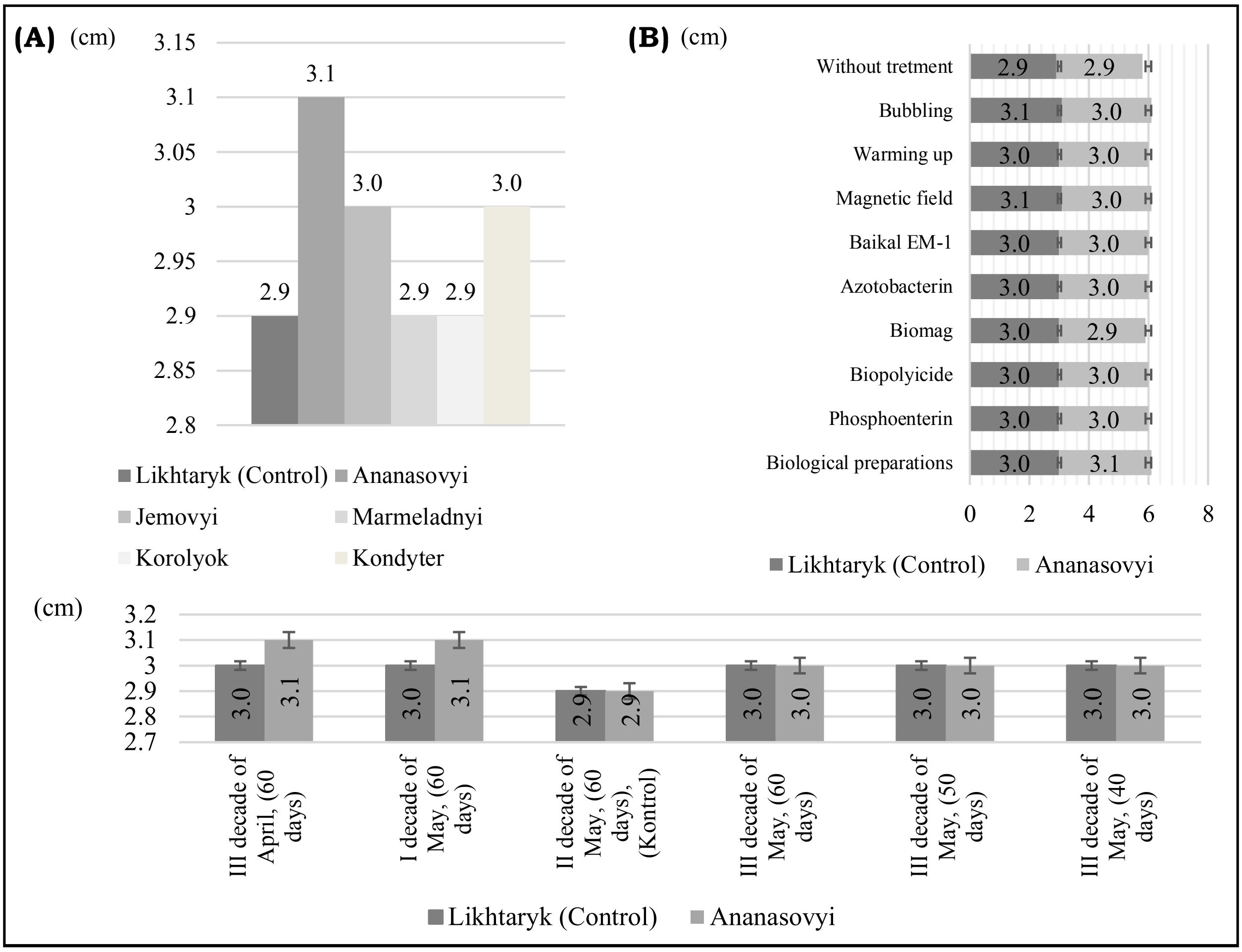

Fig. 4. Fruit diameter (cm) of tomatillo as affected by varietal characteristics, pre-sowing seed treatment, time of planting and age of seedlings (average of 2016, 2017 and 2018).

and fruit number (r=0.97), between yield and leaf area (r=0.98), and between yield and fruit diameter (r=0.99). At the same time, it was determined that there was an average direct correlation between the number of fruits and dry matter in the leaves (r=0.32), and between the diameter of the fruit and its weight (r=0.43) (Table 4).

Analysis of the individual indicators of biochemical composition of the fruits revealed a higher dry matter content in the fruits of the Korolyok variety – 10.7 %, and of the Kondyter one – 9.0 %, which exceeded the control Likhtaryk variety by 2.4 and 0.7 %,

Table 2. Total yield of tomatillo as influenced by the varieties

Varieties	Productivity (t/ha) Year			Average	± Compared to the control		Lewis stability factor (K_{sfn})
	2016	2017	2018		(t/ha)	(%)	
Likhtaryk (C)*	21.2	27.0	36.1	28.1	0	0	1.7
Ananasovyi	23.0	31.7	41.3	32.0	+3.9	+13.9	1.8
Jemovyi	22.5	28.0	40.4	30.3	+2.2	+7.8	1.8
Marmeladnyi	22.0	29.5	41.0	30.8	+2.7	+9.6	1.9
Korolyok	23.1	30.6	38.1	30.6	+2.5	+8.9	1.6
Kondyter	22.2	27.1	38.0	29.1	+1.0	+3.6	1.7
$LSD_{0.05}$	1.7	2.4	3.0				

*: Control.

respectively. The lower content of dry matter in the fruits was characteristic of the Ananasovyi, Jemovyi, Marmeladnyi varieties. The highest protein content was found in the Korolyok variety – 1.6, smaller – in the Ananasovyi and Jemovyi varieties. Higher content of ash elements was characteristic of the Korolyok variety – 1.0 % (Fig. 5).

As a result of field production of tomatillo in Ukraine, the Ananasovyi, Jamovyi, Marmeladnyi and Kondyter varieties exceeded the Likhtaryk variety of Ukrainian selection in terms of ash content only by 0.1 %. The highest content of sugar in the fruits was observed in the Jemovyi (3.3%), Marmeladnyi (3.2 %), and Korolyok (4.3 %) varieties. These varieties exceeded the Likhtaryk one by 0.4-1.5 %.

Significant success in obtaining a high yield depended on conditioned and quality seeds. In the experiment, tomatillo seeds were characterized by a significant supply of nutrients, which in turn provided friendly plant germination, timely use of nutrients and formation of a vegetative mass in the seedling period and in open ground. This tendency to influence the quality of seeds on these indicators of the plant and the yield is confirmed in the work of (Vitanova and Solonenko, 2007). At the same time, many researchers studied the process of passing important phases of growth and development of the plant. Some of them, however, observed that the beginning and duration of the phases of growth and development depends on the composition of the soil mixture, seed quality and growing conditions (Berry, 2003; Nehayyan, 2007; Gil *et al.*, 2008; Lykhatsky, 2012; Shulgina, 2015). Some researchers emphasize that the beginning and duration of the phases depend on varietal characteristics, seedling age and fertilization regime (Hernandez, 2016; Kosok-Pokorny and Stein, 2016; Mierzejewski, 2016). In our studies, the beginning and duration of the growth and development phases of the tomatillo plant depended on the age of the seedlings: the older the seedlings, the more true leaves were formed, due to the accumulation of dry matter in the leaves and the corresponding nutrient and temperature regime, confirming (Berry, 2003; Nehayyan, 2007; Sabluk, *et al.*, 2010; Shulgina, 2015; Chernishenko *et al.*, 2017).

However, the varietal characteristics of the plant and their impact on the size and quality of the yield need not be rejected. We can recommend both domestic and foreign varieties for the conditions of Eastern Europe. In field production, varieties of foreign selection – Ananasovyi and Korolyok and domestic variety – Likhtaryk were characterized by higher yields, which amounted to 30.6-32.0 t/ha. However, for other regions of the world, other varieties may be

Table 3. Total tomatillo yield as affected by time of planting and seedling age

Varieties (A)	Time of planting and seedling age (B)	Yield (t/ha) Year				Lewis stability factor (K_{sfn})
		(2016)	(2017)	(2018)	Average	
Likhtaryk	III decade of April, (60 days)	23.5	33.0	40.5	32.3	1.7
	I decade of May, (60 days)	29.2	31.0	40.0	33.4	1.4
	II decade of May, (60 days), (C)*	19.4	27.2	36.5	27.7	1.9
	III decade of May, (60 days)	25.8	30.3	37.9	31.3	1.5
	III decade of May, (50 days)	24.2	29.4	38.7	30.8	1.6
	III decade of May, (40 days)	22.7	28.7	38.5	30.0	1.7
Ananasovyi	III decade of April, (60 days)	23.2	32.6	42.6	32.8	1.8
	I decade of May, (60 days)	22.9	31.3	41.5	31.9	1.8
	II decade of May, (60 days), (C)*	21.5	29.7	38.5	29.9	1.8
	III decade of May, (60 days)	24.0	31.1	40.6	31.9	1.7
	III decade of May, (50 days)	23.1	30.5	40.3	31.3	1.7
	III decade of May, (40 days)	23.3	29.9	39.2	30.8	1.7
LSD (P=0.05) : A	1.1	1.1	1.0			
	B	1.9	1.9	1.7		
	A x B	2.7	2.7	2.4		

*: Control.

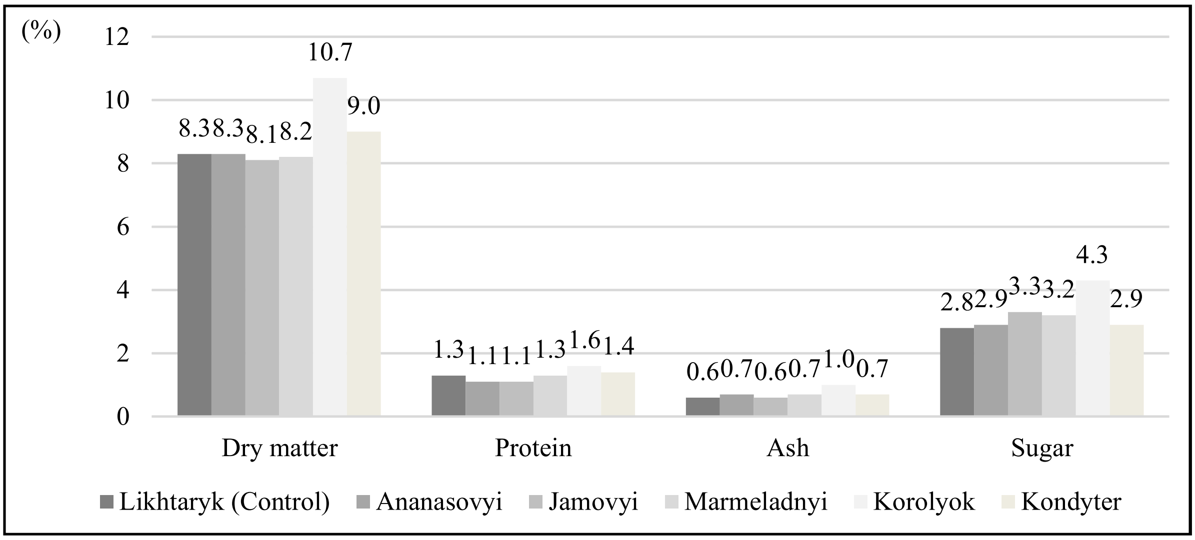

Fig. 5. Biochemical composition (%) of the tomatillo in natural value depending on the varietal characteristics (average of 2016, 2017 and 2018).

Table 4. Correlation matric of the tomatillo variety (average of 2016, 2017 and 2018)

Indicators	Indicators							
	Plant diameter (cm)	Plant height (cm)	Leaves area (thousand m²/ ha)	Leaves dry matter content (%)	Fruits number (pcs/ plant	Fruit diameter (g)	Fruit diameter (cm)	Productivity (t/ha)
Plant height (cm)	0.99							
Leaves area (thousand m²/ha)	0.85	0.77						
Leaves dry content (%)	-0.87	-0.93	0.88					
Number of fruits (pcs per plant)	1.00	0.99	0.85	0.32				
Fruit weight (g)	-0.14	0.13	0.76	-0.11	-0.40			
Fruit diameter (cm)	1.00	0.99	0.85	-0.02	1.00	0.43		
Productivity (t/ha)	0.97	0.92	1.00	0.97	0.91	0.99	1.00	

recommended as emphasized by Bell *et al.* (2015) and Hernandez (2016). According to them, Randidor and Randidor meiorad should be considered high-yielding varieties for the conditions of Mexico and Guatemala.

Based on previous research, the plant yield depends on the correct pre-sowing treatment of seeds, which can increase the yield of vegetables by 5-10 %. Such a pattern in increasing yields is inherent in almost all vegetable plants (Cumali Ozaslan *et al.*, 2017; Naumova *et al.*, 2019). However, our research has shown that the total yield of tomatillo can increase to 23.6 %, which is a more effective way in modern technology, namely: heating the seeds at 40°C for 4 hrs or treatment of seeds with a 50 E magnetic field for 12 hrs or 1.0 l/t Baikal EM-1 solution. The use of such pre-sowing seed treatment helps the plants to reach the height of 91.3-93.7 cm, while fruit weight increases to 7.9-8.3 g, and yield – to 33.0 t/ha (Strelets, 2015).

Berry (2003) and Nehayyan (2007) emphasized the technology of tomatillo cultivation directly through the sowing of seeds in the soil without using the seedling method of growing and fertilizing the plant. However, such cultivation is possible in Mexico only, where there are different temperatures. In our opinion, it is economically advantageous to grow this plant only using the seedling method, because the air and soil temperature when growing seedlings in the open ground does not correspond to the biological requirements of the plant (Pashkovsky, 2014; Shulgina, 2015; Chernyshenko *et al.*, 2017; Ulyanich, 2018).

Therefore, specialized farms in Ukraine can use only the seedling method of growing tomatillo, where the plant yield can be increased from 27.7 to 33.4 t/ha.

However, according to Berry (2003), tomatillo can also be grown by seedling method in Mexico. The scholar recommends for these conditions to grow seedlings of plants aged 50-60 days, which will have a height of 30 cm, the number of true leaves 3-4, a well-developed root system, and get a satisfactory harvest. In the conditions of Ukraine, such age of seedling is quite corresponding that is confirmed by our researchers. However, we believe that for field production, the seedling age should be 60 days and the seedlings should be planted in open ground in the third decade of April or the first decade of May under temporary film tunnel protection, or the age of seedlings should be 50-60 days, followed by hardening and planting in the open ground. This scheme of growing seedlings will help to obtain a total yield of up to 33.4 t/ha. At the same time, the timing of planting seedlings significantly affects the biometrics of the plant. The biometrics of the tomatillo plant in our studies do not contradict the results of studies Bell *et al.* (2015) and Kutovenko and Mikhalina (2012) in terms of the timing of planting seedlings, but do not fully confirm the data of Barabash *et al.* (2008). Thus, there are different views and recommendations in the elements of technology for growing tomatillo. Therefore, the growing area, environmental factors and biological characteristics of the plant should be taken into account before their cultivation.

CONCLUSIONS

On the basis of the present study it can be concluded that (i) the increase in biometric parameters of the tomatillo plant depends on the treatment of seeds with a magnetic field intensity of 50 E for 12 hr or a solution of Baikal EM-1 @ 1.0 l/tonne, (ii) in order to increase the yield to 31.8 to 33.0 t/ha, it is recommended to apply the action of a magnetic field on seeds with an intensity of 50 E for 12 hr or to heat the seeds at a temperature of 40°C for 4 hr and (iii) varieties - Likhtaryk and Ananasovyi are able to form early fruit yields if planting of 60 days old seedlings is done in the third week of April or in the first week of May under temporary tunnel shelters, where yields increase upto 33.4 t/ha.

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