OBTAINING BALSAMIC POPLAR BUD ESSENTIAL OIL BY THE BAROTHERMAL METHOD AND STUDYING THE EFFECT OF ITS AQUEOUS EMULSIONS ON SEED GERMINATION AND GROWTH OF TOMATO PLANTS

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In recent years, there has been a persistent search for new methods and technologies for cultivating specific crops to increase their productivity and improve product quality. The aim of the study was to obtain essential oil from poplar buds by the barothermal method, to standardize the obtained essential oil, to study the effect of an aqueous emulsion of poplar oil on the growth and development of tomato seeds. For obtaining the maximum yield of balsam poplar essential oil, the optimum pressure, input of raw material, and processing time were investigated. The essential poplar oil was standardized according to organoleptic and physico-chemical parameters. The study found that the use of an aqueous emulsion of poplar bud oil had a significant impact on the morphogenesis, physiological and biochemical parameters of tomato seeds.

Keywords: *Populus balsamifera*, essential oil, poplar buds, tomato seeds, physiological activity

INTRODUCTION

Balsam poplar (*Populus balsamifera* L.), a species of deciduous trees from the poplar genus (*Populus*) of the willow family (*Salicaceae*), has been found promising in terms of development and implementation in practical healthcare of highly effective herbal remedies. The plant is widely distributed in the European part of Russia, as well as in Western Europe and Asia. In Kazakhstan, it is found in urban plantings in Karaganda and Semipalatinsk, Northern Kazakhstan.[1]

A number of publications have been devoted to the study of the chemical composition of poplars, their biologically active compounds, and the possibility of obtaining drugs based on them. The works of Polyakov V.V.,[2] Adekenov S. M.,[3] Braslavsky V.B. and Kurkina V.A.,[4,5] Roshchina V.I.,[6] Fuksman I.L.[7] and others have shown that tree greens, and in particular poplar buds, can serve as a raw material to produce antibacterial drugs. Poplar essential oil has valuable aromatic, antimicrobial and medicinal properties.

This product is able to conquer the consumer market and diversify the range of flavors. The main production waste is the solid residue of the vegetative part of poplar, which has in its composition a complex of substances with a wide range of biological activities.[8] The results of a study of the chemical composition of poplar buds showed that polysaccharides account for 17%, of which more than 50% is cellulose.[9] About 30% of the mass of dry raw material represent substances of phenolic nature. With the complex use of plant materials, in addition to the basic structural components of the cell, extractive substances are of great importance, which, from a physiological point of view, are substances of very diverse significance.

The share of extractive substances in poplar buds accounts for 40 to 54% of the mass of raw materials, depending on the phase of development.[10]

In the composition of lipid fatty acids, acids of significant biological value have been identified. It has been established that the content of linoleic and linolenic acids in the buds of balsamic poplar can be up to 50%, arachidonic acids – up to 5% of the total fatty acids.[11] These fatty acids are indispensable. They have a number of valuable biological properties: they prevent the development of many skin diseases, atherosclerosis, converting cholesterol into a readily soluble compound, lower blood clotting and reduce the possibility of thrombosis; have an antiarrhythmic effect, *etc*., that is, they play an important role in the metabolic processes of living organisms.[12]

In connection with the use of poplar buds as a new technological raw material, it became necessary to study the content of its main biogenic elements. It has been established that their composition the following macro- and microelements, in mg/kg: sulfur – 1.17; nitrogen – 6.7; phosphorus – 2.03; sodium – 0.82; potassium – 6.40; calcium – 10.16; magnesium – 2.52; iron – 2.58; copper – 1.25; zinc – 3.75 mg/kg. The presence of nickel and iron enhances the nutritional value of the solid residue, since their presence, even in small quantities, significantly activates vital activity of microorganisms.[13] The content of heavy metals was also assessed considering that poplar is widely used for planting greenery in cities. As a result, it was found that the content of harmful substances of this group of chemical elements (lead – 0.33 mg/kg; cadmium – 0.03 mg/kg; arsenic – not detected) does not exceed the maximum permissible concentrations given in the "Medical and biological requirements and sanitary standards for the quality of food raw materials and food products" No. 5061-89.[14]

The favorable chemical composition of the starting material makes it possible to use poplar buds as a cheap and environmentally friendly raw material for the production of biological preparations. The main group of compounds in the essential oil of balsam poplar buds are sesquiterpene hydrocarbons, which account for an average of 94.4% of the total oil produced per year, in which the main components are α,β,γ-eudesmol, α,β-bisabolol, 2-phenyl-ethyl 2-methylbutanoate.[15]

There are many methods to obtain biologically active substances (steam distillation, extraction with organic solvents, hydrodistillation method, barothermal method, *etc*.). The choice of processing method depends on the properties of the raw material, the type of essential oil containers, the composition of the essential oil and the properties of its components, the nature of the connection between the essential oil and the raw material. When choosing a method, one of the main conditions is to ensure the highest yield and the best product quality.

The advantages of steam distillation include such indicators as low temperature and high economic performance of production. However, there is deterioration in the quality of essential oils due to chemical changes in the components, especially such as terpene alcohols and their esters, as well as the loss of valuable aromatic substances that are not volatile with water vapor.[16]

By extraction, they are extracted from raw materials with low-boiling solvents (ether, methyl chloride), as well as liquefied gas (propane, butane). The solvent is easily removed, the residue is purified, but valuable components are decomposed.[17] Pressing (squeezing) is an economically profitable process used to obtain essential oils from raw materials, where it is contained in large receptacles and in large quantities.[18]

The barothermal method includes such advantages as product safety, no need for flammable expensive solvents, high labor productivity, fire safety, installation reliability and cost-effectiveness. Importantly, the resulting poplar bud residues can be used as feed additive for cattle nutrition.[19] This method of obtaining essential oil allows, unlike the extraction method, to obtain valuable substances without the use of organic solvents. This method consists in extracting essential oil from poplar buds that have opened under the influence of high temperature and high pressure, with superheated water vapor, which is then cooled, condensed, and collected in a receiver.

This method is cost-effective, as it eliminates the use of expensive flammable solvents, significantly reduces the extraction time of poplar oil, because it eliminates 4 technological operations (preparation of the extractant, extraction, settling, evaporation) and reduces the number of devices employed in the operation.[20]

In addition, the final product does not contain residual solvents that contaminate it and increase its toxicity.

On the other hand, increasing the germination of seeds is one of the main problems of agriculture. Under the influence of unfavorable factors, the germination of seeds is reduced, which leads to irrational use of seed material and a decrease in yield. Currently, it has been reported in the literature that physiological processes and germination can be influenced by substances, such as phytohormones, biostimulants and vitamins.[21] While the data on the effects of natural and synthetic stimulants on the sowing quality of seeds are contradictory, the high content of fatty acids (stearic, oleic, palmitic, myristic), organic acids (oxalic, succinic, citric, ketaglutaric) and trace elements in poplar buds oils recommends their use as a plant growth biostimulant.[22]

The leading group of biologically active compounds (BAC) in poplar buds are flavonoids (about 30%), among which, the flavanones pinocembrin and pinostrobin dominate.[23] Also in poplar buds, phenyl compounds were found in large quantities (representatives of 30 cinnamic acids: caffeic, p-coumaric, ferulic and cinnamic), being the second group of active compounds in poplar buds.[24] One of the most important functions of phenolic substances is their participation in the process of respiration due to reversible oxidation and reduction; in addition, these compounds also perform protective functions in plants associated with exposure to adverse environmental conditions.[25] Phenolic compounds are involved in the process of plant growth, acting as stimulants, and are formed most intensively in young, vigorously growing tissues, which include plant buds.[26,27]

The purpose of the present study has been to obtain essential oil from poplar buds by the barothermal method and to study the effect of an aqueous emulsion of poplar oil on the growth and development of tomato seedlings.

EXPERIMENTAL

Materials

Balsam poplar buds were collected in March 2022 in the vicinity of the village of Zarechny, North Kazakhstan region, Republic of Kazakhstan. Seeds of tomato varieties Excellent 176, Minsky Early, Carlson and September were used in the study. For seed treatment, water emulsions of essential oil of balsamic poplar buds of 0.03% concentration were used.

Methods

Obtaining poplar essential oil by barothermal method

Unground poplar buds were treated with steam at a temperature of 140 °C at a pressure of 1.9 atm in a horizontal medical autoclave.

Standardization of the finished product of poplar bud essential oil

The essential oil was produced according to the technological instructions and recipe specified in related standard procedure[28] for essential oils, in compliance with the prescribed sanitary norms. Also, the obtained essential oil must comply with technical specifications,[28] in terms of organoleptic parameters, as well as physical and chemical properties.

Organoleptic parameters

The appearance and color of essential oils was determined as follows: an amount of 30-550 mL of essential oil sample was placed in a colorless glass beaker with the capacity of 100 mL, 45 mm in diameter and 90 mm high. The beaker was placed on a sheet of white paper, and the color of the oil was examined in transmitted or reflected daylight at 20±1 °C.[29]

The smell of the essential oil was determined for strips of thick paper measuring 10 x 160 mm, which were moistened to 1/6 of the length in the tested liquid. The smell of solid and crystalline substances was determined in a similar way, after preparing from them 10% solutions in double rectified alcohol. The smell must correspond to the smell of the raw material from which the oil is obtained. Extraneous shades of smell are not allowed.[29]

The taste was determined for a mixture of one drop of oil and 1 g of powdered sugar.[29]

Physical and chemical parameters

Solubility – essential oils are slightly soluble, very slightly soluble or practically insoluble in water, soluble in alcohol, ether and other organic solvents. Solubility was determined using 90% ethanol. 1 mL of oil was placed in a test tube, and the corresponding water-alcohol solution was poured from the burette. The temperature of the initial liquids was 20 °C. Alcohol was added in small portions, shaking the mixture and maintaining the temperature at 20 °C by introducing the test tube into a water bath.[30]

Density was determined using a pycnometer. The pycnometer with distilled water was kept in a water bath at 20 °C for 20 min. Then, using filter paper, the water level was brought to the mark and, after an additional 10-minute exposure at 20 °C, it was weighed. Then, water was removed from the pycnometer and it was rinsed successively with ethyl alcohol and ether, and then filled with essential oil, and the same operations were carried out as with distilled water.[31]

Density ρ was calculated by the following formula:

$$\rho = 0.9982\ (m_2 - m) / (m_1 - m) \quad (1)$$

where 0.9982 is the density of water at 20 °C; while m, m_1 and m_2 are the mass of an empty pycnometer, then filled with water and with essential oil, respectively.

Refractive index was determined in a refractometer. Before the measurement, 1-2 drops of liquid were applied to the lower prism of the refractometer, after which the upper prism was lowered and pressed tightly. A beam of light was directed with a mirror into the upper window of the prism. The refractive index was read on the left scale with an accuracy of four decimal places.[32]

Acid value – a sample of 1.5-2.0 g of essential oil, taken with an accuracy of 0.01 g, was dissolved in 5 mL of 95% ethyl alcohol, previously neutralized with 0.1N NaOH and a few drops of phenolphthalein. 1 mL of phenolphthalein solution was added and titrated with constant stirring with 0.1N NaOH until a pink color appears and is maintained for 30 s. 1 mL of 0.1N NaOH corresponds to 5.61 mg KOH.[33] The acid value was calculated by the formula:

$$acid\ number = \frac{V \cdot 5{,}61}{m} \quad (2)$$

where V is the volume of 0.1N NaOH consumed for titration (mL), m – weight of essential oil sample (g).

Ester value was determined in the solution obtained after determining the acid value. To this solution, 20 mL of 0.5N KOH alcoholic solution was added and heated on a water bath in a flask with an air cooler (tube diameter 1 cm, length 100 cm) for 1 h, counting from the moment of boiling. At the end of saponification, the solution was diluted with 100 mL of water and the excess of KOH was titrated with 0.5N H_2SO_4 (phenolphthalein was used as indicator).[34]

The ester value X was calculated by the formula:

$$X = \frac{28{,}05V}{m} \quad (3)$$

where V is the volume of 0.5N KOH used for saponification of esters (mL); m is the weight of the oil sample, g; 28.05 – mass of KOH (mg) contained in 1 mL of its 0.5N alcoholic solution.

Determining impurities in essential oil

Alcohol admixture – 1 mL of the test oil was poured into a test tube, closed with a loose lump of cotton wool, in the middle of which a fuchsin crystal was placed, heated to a boil; in the presence of alcohol, its vapor dissolves fuchsin, staining cotton wool red.

Fatty and mineral oils – 1 mL of essential oil was shaken in a test tube with 10 mL of alcohol; there should be no turbidity and drops of fatty oil.

Water – qualitative determination with petroleum ether, used for most liquid essential oils. 0.5 mL of the test oil was introduced into a test tube, 10 mL of anhydrous petroleum ether was added and mixed thoroughly. The appearance of turbidity indicates the presence of moisture. The determination was carried out at 20° ± 0.5 °C.

Effects of balsamic poplar bud essential oil on tomato seed germination and growth of seedlings

Tomato seeds (100 seeds of each variety) were germinated in Petri dishes on filter paper in 0.03% solutions of the studied emulsions, in the dark at a constant temperature of 20 °C for 10 days. Distilled water was used as a control. According to GOST 12038-84, germinated seeds were counted in the experiment on days 3 and 7, using a 4-fold repetition.[35]

On the 8th day of the experiment, the morphometric parameters of tomato seedlings were assessed (with accuracy of 0.1 cm). Then, the arithmetic means of the results were calculated and analyzed.

Also, the content of macro- and microelements in the plantlets was determined according to generally accepted methods. For an in-depth analysis of the supply with nutrients of the plants, leaf diagnostics was used. The leaves of one tier were used as an indicator organ, in which the content of nutrients was determined.[36]

Balsamic poplar bud oil was used in the form of aqueous emulsions of 0.03% concentration for treatment of seeds and seedlings, as well as for foliar application for young plants during flowering and the beginning of fruiting.

Then, the effects of the balsamic poplar bud essential oil biostimulant on the amount of sugars and vitamin C in the produced tomatoes were determined. The content of sugars in tomatoes was determined according to GOST 8756.13-8,[37] and that of vitamin C was determined according to the Tilsman method.[38]

Statistical analysis of the results was carried out by calculating the arithmetic mean and standard deviation. The data were processed using a computer.

RESULTS AND DISCUSSION

Optimization of essential oil yield

Poplar essential oil was obtained using a standard horizontal medical autoclave by the barothermic method. To determine the optimal operating conditions of the installation for achieving the maximum yield of essential oil, a series of experiments were carried out. Thus, the experiments aimed to determine the effects of the pressure applied, raw material input (height of the layer), and varying treatment time.

Effect of pressure variation

When extracting essential oil from balsamic poplar buds, the pressure in the apparatus was varied within the following limits – from 0.5 to 2 atm. It is not advisable to use a higher pressure because of the high temperature, which would affect negatively the quality of the resulting essential oil, and cause increased safety risks. To obtain reliable results, the experiment was carried out in five runs, and the results differed slightly. The dependence of the essential oil yield on the applied pressure was presented graphically in Figure 1.

Effect of raw material input

Experiments were conducted to determine the optimum input of raw material to achieve the maximum yield of essential oil. To this end, the height of the raw material layer was varied from 1 cm to 10 cm, and the dependence of the yield of essential oil on this indicator was studied. With an initial increase in the height of the layer of poplar buds, due to greater contact of the steam with the raw material and, consequently, greater saturation, the yield increases. However, when the layer height exceeded 7 cm, a decrease in the yield was observed. This could be a consequence of the compaction of the raw material, which forms lumps, which make it difficult for steam to penetrate uniformly through the raw material (Fig. 2).

Effect of extraction time

During the experiments, observations were made regarding the dependence of the product yield on the extraction time. As may be noted in Figure 3, with an increase in the processing time of the poplar buds, the yield of the essential oil increases, the maximum being reached around 100-120 minutes. After this time, the product yield began declining sharply, which indicates that a longer extraction time would be inappropriate (Fig. 3).

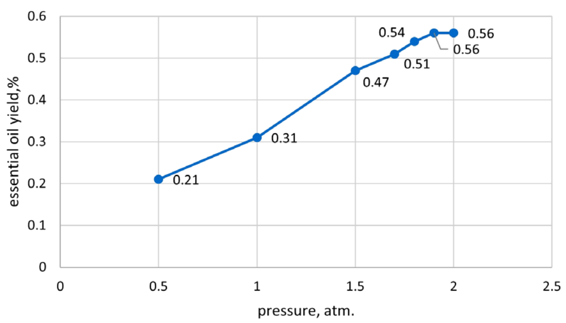

Figure 1: Effect of pressure variation on essential oil yield

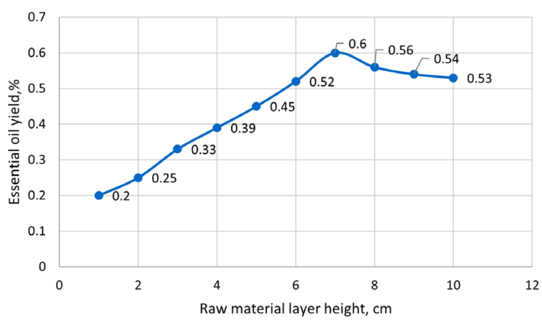

Figure 2: Effect of varying input of the raw material on essential oil yield

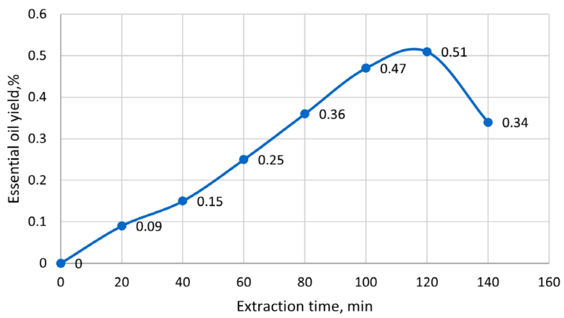

Figure 3: Effect of extraction time variation on essential oil yield

To conclude, the optimal conditions for obtaining the maximum yield of essential oil were determined as follows: pressure of 1.9 atm, input of raw materials – a layer height up to 7 cm, processing time of raw materials – not more than 2 hours.

As a result of processing the balsamic poplar buds in the autoclave, we obtained an aqueous emulsion of essential oil. Thus, the problem arises of isolating pure essential oil from the given aqueous emulsion. Since the essential oil has a lower density (ρ essential oil = 0.914) than that of water, it becomes possible to separate the essential oil and water using a separating funnel. A layer of essential oil gradually accumulates on the surface of the water, which can be easily removed by first draining the water.

Standardization of the finished product

Organoleptic evaluation of poplar bud essential oil

The conformity of the essential oil in terms of appearance and physical and chemical properties was evaluated. First, its appearance and smell were evaluated organoleptically, these serving as important criteria for confirming its authenticity. The obtained balsamic poplar essential oil presented a yellow-green mobile liquid, with a specific odor. In terms of organoleptic properties, the essential oil must meet the requirements specified in Table 1. After evaluation, it was concluded that the resulting essential oil corresponded to standard requirements in terms of organoleptic parameters.

Physical and chemical properties of poplar bud essential oil

The evaluation of physical and chemical properties of the essential oil of poplar buds revealed that the obtained essential oil was soluble in 90% alcohol, and had the density ρ^{20} = 0.8911. The refractive index of the essential oil of poplar buds was n^{20} = 1.478. It had an acid value of 4.5, and an ester value of 10.03. No impurities were found in the composition of the oil. In terms of physical and chemical parameters, it can be concluded that the obtained poplar bud essential oil meets the standard requirements specified in Table 2.

Table 1
Organoleptic parameters of *Populus balzamifera* essential oil

Indicator	Characteristic
Appearance	Oily liquid, without sediment
Taste and smell	With a specific smell characteristic of raw materials used, without foreign taste or smell
Color	Straw yellow

Table 2
Physical and chemical properties of *Populus balzamifera* essential oil

Property	Standard range
Density, g/cm^3, at 20 °C	0.887 – 0.892
Refractive index, at 20 °C	1.470 – 1.495
Acid value	2.01 – 10.50
Ester value	8.02 – 14.10

Effects of poplar bud essential oil on seed germination, seedling growth and chemical composition of tomato fruits

To assess the effects of the balsamic poplar essential oil on seed germination, its aqueous emulsion of 0.03% concentration was applied on filter paper and tomato seeds of different varieties were placed on the filter paper in Petri dishes, under controlled conditions, and their germination was observed. As can be seen from the data in Table 3, the pre-sowing seed treatment with an aqueous emulsion of balsamic poplar oil of 0.03% led to a significant increase in germination energy, resulting in a tendency of accelerating the rate of seed germination. So, already after three days, under the experimental conditions, 11, 3, 25, 22% of tomato seeds germinated (varieties Excellent 176, Minsky Early, Carlson, September, respectively). Also, after 7 days, 61, 66, 87, 82% of the seeds germinated for each variety, respectively, while only 27, 31, 42, 43% germinated in the control of the same varieties.

Observing the morphometric parameters of the tomato seedlings of different varieties allows evaluating the physiological activity of the essential oil and the effect of the applications of balsamic poplar oil emulsion on the growth characteristics of seedlings and the length of the main root (Table 4). The results listed in Table 4 indicate that the treatment using the balsamic poplar emulsion contributed to an increase in the length of the seedlings and of their roots in the studied tomato varieties, compared to the corresponding control. The greatest effect was recorded for the varieties Carlson and September. The differences in the root length reached 200-208%, and in the length of the stem (seedling) – 161-186%. Also, significant differences have been recorded in the accumulation of biomass in the experimental variants of the studied tomato varieties, determined for both the wet and the dry weight of the plants (Table 5).

Table 3
Effect of balsamic poplar oil emulsion on germination of tomato seeds

Tomato variety		Excellent 176		Minsky Early		Carlson		September	
Day		Control	Treated sample	Control	Treated sample	Control	Treated sample	Control	Treated sample
Number of germinated seeds, %	1	-	-	-	-	-	-	-	-
	2	-	-	-	1	-	1	-	-
	3	1	11	-	3	3	25	2	22
	4	4	18	15	28	5	32	4	32
	5	10	31	18	34	10	46	12	44
	6	19	41	21	45	21	69	28	68
	7	27	61	31	66	42	87	43	82
	8	54	75	52	71	60	100	56	100
	9	72	83	77	87	74	100	76	100
	10	78	89	81	90	79	100	78	100
Energy of seed germination, %		19	41	21	45	21	69	28	68
Germination energy in relation to control, %		100.0	215.8	100.0	214.3	100.0	330.0	100.0	242.8
Seed germination, %		78	89	81	90	79	100	78	100
Seed germination in relation to control, %		100.0	114.1	100.0	111.1	100.0	126.6	100.0	128.2

Table 4
Changes in seedling length and roots after the treatment with balsamic poplar oil emulsion

Tomato variety	Excellent 176		Minsky Early		Carlson		September	
	Control	Treated sample	Control	Treated sample	Control	Treated sample	Control	Treated sample
Seedling length, cm	2.9	3.8	2.7	3.5	2.0	3.5	2.1	3.9
Relation to control, %	100	131.7	100	130.4	100	161	100	186
Root length, cm	2.1	4.3	2.2	4.3	2.3	4.8	2.6	5.2
Relation to control, %	100	205	100	195.5	100	208	100	200

Table 5
Effect of poplar oil emulsion treatment on seedling biomass accumulation

Tomato variety	Excellent 176		Minsk Early		Carlson		September	
	Control	Treated sample	Control	Treated sample	Control	Treated sample	Control	Treated sample
Wet weight, mg	202.0	358.0	207.0	362.0	210.0	365.0	220.0	382.0
Relation to control, %	100.0	177.2	100.0	174.9	100.0	173.8	100.0	173.6
Dry weight, mg	19.0	37.0	21.0	35.4	19.0	38.0	23.0	40.1
Relation to control, %	100.0	194.7	100.0	168.6	100.0	200	100.0	174.3

Moreover, the data in Table 6 indicate that the application of balsamic poplar oil emulsion during seedling growth and development had a significant effect on the content of macro- and microelements in the tomato leaves. Thus, the balsamic poplar oil emulsion can serve as a biological additive that contributes to the accumulation of the main nutrients in the plants, which are necessary during their development phases, thus, reducing the need or the doses of mineral additives to be applied.

Further, to determine the effectiveness of the treatment, the quality of the crop was analyzed in terms of the major indicators, such as the contents of dry matter, vitamin C, sugars and nitrates. Table 7 shows the effects of the treatments applied on the chemical composition of tomato fruits.

Table 6
Contents of macro- and microelements in tomato leaves of Carlson variety

Experimental stage	Nutrients, % on dry matter mg/kg						
	Ca	Mg	N	P_2O_5	K_2O	Cu	Mn
Plant development phase: flowering							
Control	1.3	0.3	4.0	0.5	5.5	1.4	19.3
Seed treatment	1.4	0.3	4.5	0.5	6.0	1.6	29.5
Seedling feeding	1.4	0.4	4.8	0.6	6.7	1.5	32.9
Plant nutrition	1.6	0.5	5.2	0.8	7.4	1.7	33.6
Plant development phase: fruiting							
Control	1.3	0.3	4.2	0.5	5.5	1.3	24.6
Seed treatment	1.4	0.3	4.6	0.6	7.1	1.4	29.5
Seedling feeding	1.6	0.4	4.8	0.7	7.6	1.5	33.2
Plant nutrition	1.8	0.4	5.4	0.7	8.0	1.6	32.9

Table 7
Major indicators of the chemical composition of tomato fruits

Experimental stage	Nutrients, % on dry matter mg/kg							Dry matter, %	Vitamin C, mg %	Sugars, %	Nitrates, mg/kg
	Ca	Mg	N	P_2O_5	K_2O	Cu	Mn				
Variety Carlson											
Control	0.17	0.14	3.0	0.32	4.8	3.74	3.9	5.0	20.6	1.27	92.0
Seed treatment	0.15	0.14	3.1	0.33	5.1	2.3	3.8	5.1	21.3	1.29	91.9
Seedling feeding	0.13	0.13	3.1	0.32	4.1	2.5	4.3	5.7	21.2	1.34	91.9
Plant nutrition	0.16	0.13	3.2	0.34	5.1	2.4	4.1	5.7	21.9	1.34	87.8
Variety September											
Control	0.13	0.14	3.0	0.37	5.1	4.0	4.0	4.9	21.3	1.18	91.0
Seed treatment	0.15	0.14	3.2	0.33	5.4	2.0	3.6	5.1	20.6	1.11	91.9
Seedling feeding	0.17	0.14	3.1	0.34	5.5	2.4	3.6	5.4	21.9	1.26	87.7
Plant nutrition	0.16	0.14	3.1	0.35	5.5	2.2	3.9	5.7	22.1	1.31	87.1

An increase in the contents of solids, vitamin C, carbohydrates, and a decrease in nitrates in the fruits are important indicators of the effectiveness of the plant treatments applied. The findings of our research are in agreement with the results of other scientists found in the literature. Many research works have reported previously significant biological stimulation of plants by the action of phytohormones, biostimulants and vitamins. The use of brown algae as biostimulator for crop growth has been studied and it was stated that brown algae aqueous extracts are rich in various micro- and macroelements necessary for plant life, as well as vitamins, various polysaccharides, including fucoidan and alginic acids.[39] Therefore, it has been suggested that these algae can be used as an alternative source of potassium supplements and growth promoters for terrestrial plants.[40] Also, extracts obtained from balsam poplar leaves and buds (leaf water-soluble substances, bud essential oil and bud alcoholic extract) have been reported as efficient growth regulators. Thus, the results of experimental treatments showed that they influenced the initial growth and field germination, as well as the crop yields of spring soft wheat variety Omskaya 580.[15] Other studies have shown that a 0.05% extract of chamomile contributed to a significant increase in the germination of spring rapeseeds by 13.0%, and a 0.5% extract increased the germination of soybean seeds by 10.0%.[41] The 0.05% chamomile extract caused an increase in the length of seedlings and roots by 71.2 and 22.9%, respectively, in spring rapeseed, and by 53.0 and 49.9%, respectively, in winter wheat, while an extract of 0.5% concentrations increased the length of seedlings and roots by 64.2 and 41.5%, respectively, in soybeans.[41]

CONCLUSION

Populus balsamifera essential oil was obtained using a standard horizontal autoclave. The optimal conditions for obtaining the maximum yield of essential oil were determined as: pressure of 1.9 atm, raw material input in a layer height up to 7 cm, and processing time of raw materials – up to 2 hours. Standardization of the obtained essential oil according to organoleptic and physico-chemical parameters was carried out. The essential oil extracted from balsamic poplar represented an oily liquid, without sediment, with a specific odor characteristic of the raw material used, without foreign taste and smell, of straw yellow color. The essential oil of poplar buds was found soluble in 90% alcohol, had a density of ρ^{20} = 0.8911, a refractive index of n^{20} = 1.478, acid value of 4.5, and ester value of 10.03.

An aqueous emulsion of balsamic poplar oil of 0.03% concentration was applied as a presowing seed treatment, and a significant increase in germination energy was observed – up to 87.82%, while in the control, the maximum value was 43%. The maximum seed germination in relation to the control was 128%.

The treatment was further used as foliar application during seedling growth and major plant development stages: flowering and the beginning of fruiting. The results indicated that the treatment with the balsamic poplar emulsion caused an increase in the length of the seedlings, their roots, biomass weight in the studied tomato varieties, compared to the control. The greatest effect was obtained in the seeds of Carlson and September varieties, as the length of the seedlings reached 161 and 186%, respectively, in relation to the control, and the length of the roots reached 200-208% in relation to the control. The treatment with the balsamic poplar emulsion also had a positive effect on the contents of macro- and microelements, as well as of dry matter, in the tomato fruits of the studied varieties, compared to the control.

Thus, the findings of this work indicate that using balsamic poplar oil extract as an emulsion of 0.03% concentration for presowing treatment of tomato seeds, as well as for foliar application during plant development, has a stimulating effect on the seeds, increasing their germination rates, promotes plant growth, and, ultimately, increases the nutritional value of tomato fruits.

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