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Performance Indicators of the Improved Technology of Soilless Growth the Tomato in the PreAral Sea Region

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Abstract: This scientific work is a continuation of the research on the effectiveness of the use of soilless technology for growing tomatoes in the PreAral Sea region, conducted on the basis of the greenhouse of the Korkyt Ata Kyzylorda University. In previous studies, the technological parameters of culture management were separately studied and their optimal values for regional conditions were established, some of which differed from the parameters in the previously used technology proposed by OLDS College (Canada). Based on the results obtained, an improved technology of soilless growth the tomato was developed, the study of the effectiveness of which was the purpose of these studies. The studies were carried out on hybrid tomatoes Lilos F1 (RZ Netherlands), which was grown on a composite substrate of sawdust and rice husk in conditions of extended turnover. The research results showed that the use of improved technology of groundless tomato cultivation contributed to the creation of the most favorable conditions for the growth and development of tomato hybrid plants, increased productivity and product quality. The period before flowering was reduced by 4 days, and before fruiting-by 6 days, the first flower cluster was laid earlier (by 1 leaf), and the first three clusters formed a larger number of fruits (by 1.6). The early yield of tomatoes increased by 2.12 kg/m^2, and the total-by 3.74 kg/m^2. Due to the formation of larger fruits, the average weight of which was higher by 14.7 g, the yield of standard products increased by 2.4%. The qualitative characteristics of tomato fruits did not show significant differences, and their taste qualities remained at a high level.

Keywords: Product Quality, Productivity, Soilless Technology, Substrate, Tomato

Introduction

The soilless cultivation system is increasingly being used as the main technological component in the modern greenhouse industry. Its main advantage is the independence of culture from the soil, which, as a natural environment, is heterogeneous, contains pathogens, tends to decompose in monoculture systems, and can be infertile and saline.

Over the past decade, the most widespread in the world has been a soilless small-volume technology for cultivating vegetables using various substrates and drip irrigation and fertigation system. This technology is one of the best ways to overcome local water shortages, as well as to obtain high-quality products, even in areas with low fertile soils and severe climatic conditions (Baeza and Kacira, 2015).

Technologies for soilless cultivation of eco-friendly vegetable products in small-volume hydroponic modules are the fruit of many years of fundamental and applied research by several foreign companies and Russian scholars. To date, a lot has been done to increase the productivity and efficiency of soilless technology for the cultivation of various crops, including the development of soilless nutrient media with optimal physical and chemical properties (Asaduzzaman, 2015).

But, despite the multifaceted study of the issue of the effectiveness of greenhouse vegetable cultivating in a market economy, the territorial specificity of the production process of greenhouse production has not been fully studied. When creating a standard technology project, the researchers did not have the physical ability to adapt it to the conditions of specific regions, since this study can only be done on-site and it has a long-term nature (Lutsenko, 2005). Research on the mineral nutrition of plants is also inadequate and various technological systems are being introduced without prior study and adaptation to local conditions (Pfanenstil, 2004).

As a result, when using these technologies in practice, several problems arise, the main one of which is its adaptation to regional conditions. The fact that all the currently available recommendations for small-volume cultivation in substrates in a greenhouse are generalized and require the technology to be improved taking into account production and climatic factors, noted in this study by many foreign scientists (Schwarz *et al*., 2014; Poorter *et al*., 2012; Salazar *et al*., 2013).

An analysis of the directions used in practice for the development of greenhouse vegetable growing in the Republic of Kazakhstan showed that for increase the efficiency of the industry requires the elaboration and improvement of the technology for the cultivation of vegetable crops.

Tomato (*Solanum lycopersicum* L.) is one of the most popular vegetable crops grown in the world due to its fruit quality-taste, color, flavor, and nutritional content (Ofori *et al*., 2022). In the Republic of Kazakhstan, tomato plantings occupy 44% of all greenhouse areas.

However, experience shows that the efficient production of greenhouse tomatoes is possible primarily due to the use of improved growing technology, improved conditions of the region, and the characteristics of the crop and variety.

Since 2004, based on the greenhouse facility of Koryt Ata Kyzylorda University, created within the framework of an international project (Sida, Canada), research has been carried out on the cultivation of vegetable crops on soilless substrates. As part of the project, the technology for cultivating tomatoes on a sawdust substrate, developed by scientists from olds college (Canada), was introduced in the greenhouse. Further research was aimed at adapting the technology proposed by researchers from the old college to the natural and climatic conditions of the region.

To determine the adaptive capacity, various tests of hybrids from the group of indeterminate tomatoes of the leading breeding companies in the Netherlands, Israel, the USA, and Russia were carried out and the most promising ones were identified for further cultivation in the greenhouses of region. Substrate compositions based on sawdust and rice hull, wastes from regional processing industries (AMCTRHSVV, 2016; AMCTSSVV, 2016), as well as various technological parameters, such as sowing and planting dates, the density of standing plants and others, were studied to determine their optimal values.

Therefore, this research aimed to study the efficiency of the soilless technology of cultivation of tomatoes in small volume hydroponic modules with a substrate of sawdust and rice hull, adapted to the natural and climatic factors of the Kazakhstan Prenatal Sea region, with a view to its further implementation in the farms of the region.

Materials and Methods

Cultivation Environment

The research was done in the greenhouse of the Korkyt Ata Kyzylorda University, covered with a double polymer film. The greenhouse area is 270 m^2.

The hybrid Lilos F1 (RZ, Netherlands) was selected for the research, which showed high and stable productivity results in previous experiments (24.45-24.70 kg/m^2).

The control sample for comparing the efficiency of the improved soilless technology of small volume tomato cultivation was the technology of olds college (Canada) with the following technological parameters: The crop turnover-extended; seed sowing date-July 15; the composition of the substrate-sawdust; the density of plant placement-2.3 pcs/m^2; the formation of plant-one stem stacked on racks; the composition of the nutrient mixture (ppm)-before fructification: N-107, P-114, K-114, Ca-38, Mg-20, Fe-0.25, Cu-0.018, Mo-0.004, Mn-0.15, Zn-0.012, B-0.034; during fructification: N-200, P-55, K-300, Ca-200, Mg-55, Fe-3.0, Cu-0.5, Mo-0.12, Mn-0.125, Zn-0.2, B-0.9; the concentration of the nutrient solution-1.7-3.0 ms/cm^2; pH-5.5-6.5.

In the proposed improved technology of growing tomato hybrid Lilos F1 in an extended turnover, some technological parameters were changed in accordance with the results of previous tests, in which the highest yield of this hybrid was obtained (24.70 kg/m^2), namely: The date of sowing seeds August 1, the composition of the substrate-sawdust (75%) and rice husk (25%), the density of plant placement 2.5 pcs/m^2, nutrient solution concentration-0.7-2.7 ms/cm.

Growing Procedure

For experimental studies, tomato seedlings were previously grown on peat moss. The seeds of the tomato hybrid were first sown in cassettes and after 2 weeks, the plants in the phase of the 1st real leaf were transplanted into pots with a volume of 0.5 dm^3 (Fig. 1). Then pots were exposed in a room for growing seedlings of 28 pieces per 1 m^2. The high level of solar radiation intensity during this period of time allowed seedlings to be grown without additional lighting, but to create better lighting conditions, starting from the 5th week after transplantation, the density of plant placement was reduced by 30%, a week later by another 25% and in the next 2 weeks by 15%.

During the growing of seedlings, fertilizing was carried out with a solution of mineral fertilizers N:P: K (10:52:10; 14:11:25), $Ca(NO_3)_2$, biofertilizers (sodium humate), as well as preventive treatments against a complex of diseases and pests.

Fig. 1: Tomato seedlings after prickling out

Before planting seedlings, the greenhouse room was thoroughly disinfected. The structures and the greenhouse coating were washed with water with the addition of a washing agent, then the structures were treated with a 3% hypochlorite solution (at the rate of 10 m^3/ha). The greenhouse was hermetically sealed, kept for 1 day, and then well ventilated. After disinfection in the greenhouse, the drip irrigation system was installed, on the trellis hooks with a rope for tying up plants were hung, and on racks bags with the substrate with a volume of 30 liters were placed. In each bag 4 landing holes were cut, into which drip tubes were installed.

The seedlings were placed in the greenhouse 1.5 months after sowing. At the same time, the pots were not connected to the substrate, but placed on bags next to the holes and connected to a drip irrigation system in order to effectively regulate the generative and vegetative development of young plants.

Before growing, the bags with the substrate were moistened using the drip irrigation system with a nutrient solution with a concentration of 3.0-3.5 ms/cm^2. After full saturation, drain holes were made on the long side of the bag (2 for each bag).

A week before planting in the substrate, the plants are tied to a vertical twine. The plants were transferred to the substrate when 9-10 leaves were formed on them and the flowering of the 2^{nd} flower brush began.

Tomato plants were formed into one stem. To do this, as the plants grew, all the lateral shoots (stepchildren) were removed, as well as the lower leaves up to a brush with green fruits that reached the maximum size (but no more than 3 leaves per week).

After planting the plants for 3 days, the temperature in the greenhouse was maintained at 180°C during the day and 16°C-at night. Then every day the temperature was increased by 10 C until it reached the optimum for growing plants: During the day 24-26°C, and at night 17-18°C. The humidity was maintained at 65-70%.

Watering and fertilizing of plants were carried out by drip method every hour from 7.00 am till 5.00 pm and the total volume of drainage per day was at least 25%. The concentration of the nutrient solution was established by electrical conductivity depending on the phase of plant development from 1.7 to 2.7, and the desired pH level of 5.5 to 6.0 of the solution was maintained using a nitric acid solution.

Phytomonitoring Studies

The regime of irrigation and nutrition was monitored daily by measuring of following parameters of nutrient and drainage solution: Volume (mL), Electrical Conductivity (EC), and acidity (pH). Based on the measurement results, corrections were made in the operation of the automatic elements of the system of drip: On the fertilizer injector and timer of irrigation.

Phenological and Biometric Observations

During the phenological observations, the dates of the onset of the main phases of growth and development of tomato plants were noted: Seedlings, flowering, and fruiting. The beginning of the phase was recorded at its onset in 10% of plants and the full onset when 75% of plants entered this phase. According to the method of conducting experiments with vegetable crops, the date of sowing and planting of seedlings was necessarily marked and the duration (length) of the growing season was counted not from the date of sowing, but from the date of emergence. The duration of flowering and fruiting periods was also calculated.

Biometric measurements were performed according to the development phases on 10 fixed plants in each repeatability and were determined: The height of the first cluster set up, the amount of fruit on the first 3 brushes, the number of leaves and clusters on the plant, the fruit weight, the shape and size of the fruit by the largest transverse diameter, the degree of maturity and taste qualities of the fruit.

Harvesting and Recording

Tomato crop yields were recorded at each harvest. Harvesting was carried out three times a week when the tomatoes reached brown and pink maturity. Tomato fruits were divided into commercial and non-commercial and the quality of the crop was assessed by organoleptic indicators in accordance with the requirements of GOST (GOST 1725-85, 1985).

The firmness of tomatoes was determined using the methods of squeezing and cutting by the Durofe level (more than 75% hard, 60-70% medium-hard, less than 60% soft) in fruits in brown, pink, and red degrees of maturity.

The total yield was calculated by summing each crop. The harvest of the Lilos F1 hybrid is illustrated in Fig. 2.

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Fig. 2: Harvest of Lilos F1 hybrid

Biochemical Analysis

The biochemical composition of tomatoes was studied in the engineering laboratory of Korkyt Ata University. The following measurements were done: Dry matter content (GOST ISO 2173-2013, 2013), total sugar content (GOST 8756.13-87, 1987), titratable acid (GOST ISO 750-2013, 2013), ascorbic acid concentration (GOST 24556-89, 1989) and nitrate content (GOST 29270-95, 1995).

Mathematical Processing

Statistical analysis of experimental data was carried out by the method of variance analysis for a one-factor experiment using the Microsoft office excel program of the windows host operating system (Dospechov, 1979).

Results

Phenological and biometric observations showed that the cultivation of tomato plants according to the improved technology contributed to the intensification of growth and development of tomatoes.

Thus, the flowering period began 4 days earlier and the fruiting period-6 days earlier. As a result, when planted 15 days later, the harvest period of tomatoes was reduced by only 4 days (Fig. 3).

The research results showed that when applying the adapted technology, the setting up of the 1st brush on the Lilos F1 hybrid plants occurred earlier after the 8th leaf (in previous tests after the 9th leaf), and on the first 3 brushes the number of fruits increased from 8 up to 9.6. This contributed to the fact that even with the late start of fruiting, the early yield of products increased by 15,3%.

The entire harvest analysis showed that on 1 plant of the Lilos F1 hybrid, on average, 7 fewer fruits were formed, but their average weight was higher by 13.7%. As a result, due to the formation of larger fruits, the mass of standard products increased by 2.4%. The productivity of the tomato hybrid Lilos F1 when applying the improved technology increased by 15.6% and amounted to 28.16 kg/m^2 (Table 1).

To test the statistical null hypothesis H_0 about the presence of significant differences in the productivity of the tomato hybrid Lilos F1 depending on the used technology and to confirm the reliability of the results, an analysis of variance was carried out on the results of their productivity. The results of mathematical processing showed the presence of significant differences between the options at the 5% level only in terms of overall yield capacity ($F_f > F_{05} = 69.30 > 7.71$). There were no significant differences in early yield capacity ($F_f > F_{05} = 5.59 < 7.71$).

The results of the dynamics of crop receipts showed that the receipt of products with improved technology began later, but the result in November was 15.6% higher than when grown using Olds College technology (control) for the period October-November. In the rest of the period, the same trend was observed in the dynamics of crop receipts for both technologies: The lowest output fell in the period from February to March, the largest starting from April until the end of the culture. It should be noted that the receipt of products with the use of improved technology was higher in all periods: In December by 11.1%, January by 6.2%, February by 13.0%, March by 9.4%, April by 45.4%, May by 10.1% and June from 5.8% (Fig. 4).

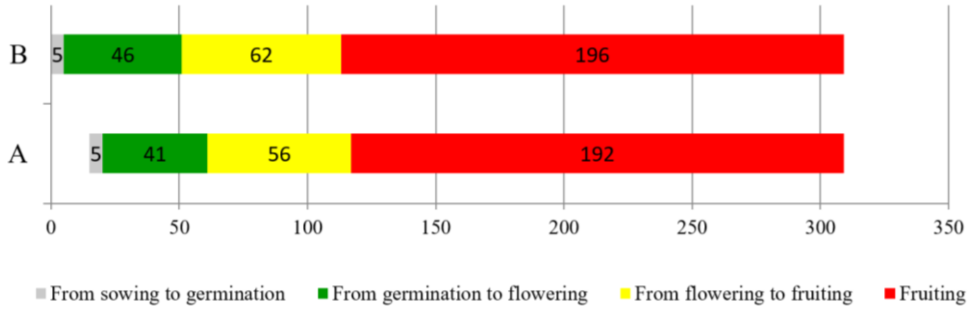

Fig. 3: Influence of the improved technology of soilless cultivation of tomato on the intensity of growth and development of plants (A) improved technology, (B) technology of olds college, Canada)

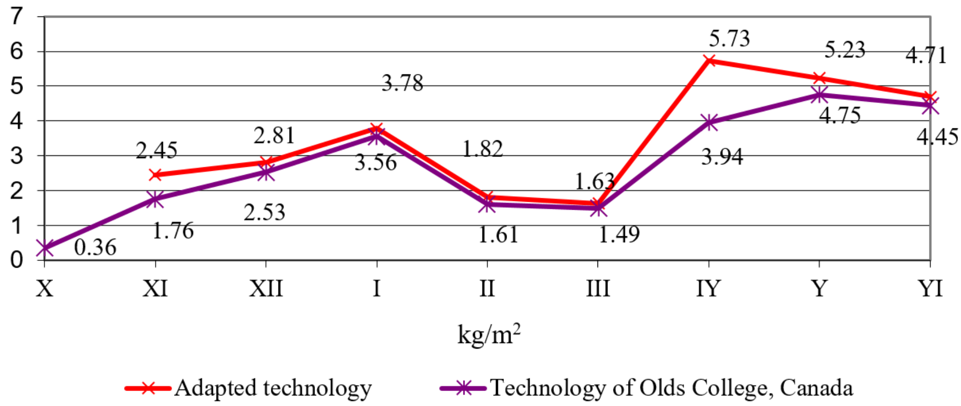

Fig. 4: Influence of the improved technology of soilless tomato cultivation on crop yield

Table 1: Indicators of the effectiveness of the improved technology of soilless cultivation of the tomato hybrid Lilos F1

Option	Number of leaves before the first blossom, piece	The average amount of fruit on 1-3 inflorescence, piece	Yield, kg/m^2 Early	Total	Standard	Number of fruits per plant	Fruit weight, g
Olds college technology, (control)	After the 9th leaf	8.0	2.12	24.45	96.8	103.0	103.2
Improved technology	After the 8th leaf	9.6	2.45	28.16	99.2	96.0	117.3
+ by control		1.6	0.33	3.74	2.4	-7.0	14.1
% by control			15.60	15.30	2,5.0	- 6.8	13.7
LED_{05}	-	-	0.06	0.20	-	-	-

Table 2: Biochemical composition of the Lilos F1 hybrid fruits

Option	Dry matter, %	Total sugar, %	Ascorbic acid, mg/100 g	Titratable acidity, %	Nitrate (NO_3^-), mg/kg
Olds college technology, (control)	6,20	2,91	15,38	0,59	84,60
Improved technology	6,04	2,83	15,30	0,54	93,50
LED_{05}	0,15	0,11	0,02	0,002	7,63

The results of organoleptic indicators of the quality of tomato fruits showed that they fully met the requirements of GOST: In appearance, the fruits were fresh, whole, clean, healthy, not damaged by pests, dense, unripe, with a typical hybrid shape, with a peduncle, without mechanical damage and sunburn, taste, and smell met the criteria, peculiar to this hybrid. The content of fruits with the permissible smallest transverse diameter (at least 4 cm) did not exceed the permissible limit of 5% and was 0.8% when using the improved technology, in the control version (old college technology) 3.2%.

The hardness of tomato fruits according to the Durofe level was in the control variant (OLDC college technology) in fruits with brown degrees of maturity 93%, pink 89%, and red 83%; in the experimental one (improved technology) 83 and 73% accordingly.

The characteristics of the biochemical quality of Lilos F1 tomato fruits (Table 2) did not show major differences at the 5% level, since, according to the results of the analysis of variance, F_f for all indicators, except for the content of nitrate ions, was lower than F_{05}.

Discussion

As a result of the use of improved groundless cultivation technology, more favorable conditions were created for the growth and development of plants of the Lilos F1 tomato hybrid, which contributed to increasing their productivity and the quality of products.

The change in the date for the start of tomato cultivation in the greenhouse to 2 weeks later was done to avoid extremely high temperatures (up to 48-54°C) of the region's environment from mid-July to mid-August, which negatively affect the growth and development of greenhouse tomatoes. They note that exposure to sub-high temperatures in any period from flower bud differentiation to fruit ripening harms the entire further process of cultivating greenhouse tomatoes and poses a serious threat to yield and fruit quality (Gruda, 2005, Zhang *et al*., 2005; Hussain *et al*., 2001).

The research results showed that the change in the planting time in the adapted technology for cultivating the Lilos F1 hybrid tomato contributed to the intensification of the processes of plant growth and development and the earlier setup of the first flower cluster after the 8th leaf. As a result, the duration of the period before the start of flowering was reduced by 4 days and before the start of fruiting by 6 days. The earlier onset of the flowering and fruiting phases contributed to the fact that the harvest period was shorter by only 4 days, despite the fact that tomato culture was started 15 days later. The formation of more vegetatively strong young tomato plants contributed to an increase in the number of fruits on the first 3 racemes from 8 to 9.6.

For the entire fruiting period, 96 fruits were formed on the plants of the tomato hybrid Lilos F1, which is on average 7 fruits less than in the control variant. At the same time, the mass of fruits was 14.1 g more. The formation of fruits of greater mass increased the yield of standard products increased by 2.4%.

The number of fruits formed on plants and their mass is indicators that determine the productivity of the variety (hybrid) and directly depend on both the growing conditions (Zdravković *et al*., 2011).

The formation of larger fruits was facilitated by: A more favorable temperature regime and a decrease in the concentration of the nutrient solution. The effect of these factors on tomato fruit size is consistent with the findings (Adams *et al*., 2001; Sawhney and Polowick, 2011; Mpelasoka and Nichols, 2003).

The intensification of growth and development of plants with the application of the adapted technology had a direct impact on their productivity. The increase in the crop yield of early products amounted to 15,6%, a total of 15,3%.

In the dynamics of crop formation during the entire fruiting period, the same trend was observed for both technologies. Since no additional lighting was used when growing tomatoes, the determining factor of their productivity in February and March was the intensity of solar radiation. During this period, the lowest yield was due to the fact that the flowering period and the beginning of the formation of the harvest of this period fell on December and January the months with the lowest duration of daylight and low intensity of solar radiation. The largest output of products began in April and lasted until the end of the growing season, so from mid-February, the light factor ceased to be limiting.

For a full assessment of the effectiveness of the applied tomato production technology, along with the level of their productivity, such criteria as external attractiveness, taste qualities, and ecological purity of fruits are of no small importance. Therefore, the analysis of organoleptic and biochemical indicators of crop quality was carried out. The results of the organoleptic evaluation of the quality indicators of tomato fruits showed that they fully met the requirements of GOST in appearance and degree of maturity. The number of non-standard products was 0.8% with an allowable value of 5%.

The hardness of fruits is a very important indicator of their commercial quality since it minimizes mechanical damage during harvesting, packaging, and transportation. Indicators of the hardness of tomato fruits have shown that they can be harvested at later stages of maturity when they have a better taste.

Taste is one of the most important properties of tomatoes that determine their consumer demand. The main factors of tomato taste are the content of sugars and organic acids. Higher, but balanced, levels of sugars and organic acids improve the quality of tomatoes (Agius *et al*., 2018; Zdravković *et al*., 2011).

In the biochemical quality parameters of tomato fruits cultivated in the conditions of the adapted technology, there were slight differences in the direction of reduction. This is because the improved technology used a nutrient solution with a lower concentration and higher concentrations of solutions contribute to an increase in the content of soluble solids, titratable acidity, and ascorbic acid in tomato fruits (Vesseur, 1990; Davies *et al*., 1981).

In addition, tomatoes planted at a lower planting density according to the old college technology (Canada) received more solar radiation, which also increases the dry matter in fruits and the content of soluble sugars and ascorbic acid (Baldwin *et al*., 2015).

Since, in terms of biochemical quality parameters, the fruits cultivated with the adapted technology did not have significant differences, their taste qualities were kept at a high level and the content of nitrate ions, was significantly less than the Maximum Permissible Concentration (MPC) for fruits of greenhouse tomatoes -300 mg/kg, making it possible to maintain the ecological friendliness of tomatoes.

Conclusion

This research is another confirmation that in order to increase the efficiency of greenhouse tomato production, the proposed standard technologies require refinement taking into account the conditions of a particular region of their cultivation and the requirements of the genotype of a particular variety (hybrid). According to the research results, the use of the improved technology contributed to an increase in the degree of interaction of the genetic characteristics of the tomato hybrid Lilos F1 with technological parameters and its environmental adaptability. When using the developed technology, the most favorable conditions were created for the growth and development of tomato hybrid plants, which contributed to an increase in its productivity: Early-by 15.6%, total by 15.3%. The taste qualities were maintained at a high level, and the output of standard products increased by 2.4%.

The research carried out is of an applied nature and has practical significance for regional producers of greenhouse vegetable products. The use of improved technology will help entrepreneurs in the region to increase the efficiency of greenhouse tomato production.

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Author’s Contributions

Rakhym Iskendirovich Kudiyarov: The author of the idea, head of the of the research work, interpretation of research results, conclusions, 25%.

Elina Bakhtiyarovna Dyamurshayeva: Head of the of the research work, interpretation of research results, conclusions, 20%.

Gulsim Zikiriyevna Sauytbayeva: Performer, conducted biochemical research, generalization and analysis of the results obtained, 15%.

Dyamurshayeva Galina Evgenievna: Responsible executor, conducted phenological and biometric observations in experimental studies, preparation of the manuscript, 25%.

Mariya Abdikhalikovna Taiteli and Zhaxybay Tuleubayev: Contractor, conducted experimental research, 15%.

Ethics

All the principles of scientific ethics have been observed during the research work, there is no conflict of interest.

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