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RATIONAL USE OF WATER AND ENERGY RESOURCES BY BUTTERNUT SQUASH CROPS IN THE SOUTH OF UKRAINE

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The article examines the problem of rational use of water and energy resources in the technology of growing butternut pumpkin under the agroclimatic conditions of Southern Ukraine. Special attention is paid to assessing the effectiveness of different irrigation methods and parameters of plant spatial arrangement as important factors influencing crop yield formation and the level of energy consumption.

The aim of the study was to establish the patterns of productivity formation of butternut pumpkin depending on water supply regimes and row spacing, as well as to assess the efficiency of water and energy resource use under different technological cultivation options. The research was conducted in 2025 under the conditions of the Inhulets Irrigation System in a field experiment, where the experimental design included variants without irrigation, sprinkler irrigation, and drip irrigation combined with different row spacings.

The results showed that under natural moisture conditions the total water consumption was about 650 m³/ha, which ensured low crop yield and a high-water consumption coefficient. The application of sprinkler irrigation significantly increased crop yield to more than 30 t/ha and considerably improved water use productivity. The highest yield in the experiment was obtained under drip irrigation with a row spacing of 140 cm, where the indicator reached 37.9 t/ha, indicating the high efficiency of localized water supply to plants.

Energy analysis showed that without irrigation, the production of butternut pumpkin is characterized by low energy efficiency. The use of irrigation significantly changes the structure of the energy balance of the agrophytocenosis, ensuring that the energy input from the yield exceeds energy expenditures. The highest energy coefficient was formed under the combination of sprinkler irrigation with a row spacing of 210 cm, indicating an optimal ratio between energy inputs and obtained production.

Correlation and regression analysis revealed a very strong positive relationship between total water consumption and yield (r ≈ 0.99), confirming the dominant role of water supply in the formation of crop productivity. The obtained mathematical models make it possible to predict butternut pumpkin yield depending on the level of moisture supply under the arid climatic conditions of Southern Ukraine.

Key words: *butternut pumpkin, irrigation conditions and methods, drip irrigation, sprinkler irrigation, yield, water consumption, energy efficiency.*

Шепель А.В. Раціональність використання водних та енергетичних ресурсів посівами гарбуза мускатного на півдні України

У статті розглянуто проблему раціонального використання водних та енергетичних ресурсів у технології вирощування гарбуза мускатного в агрокліматичних умовах Півдня України. Особливу увагу приділено оцінці ефективності різних способів зволоження та параметрів просторового розміщення рослин як важливих чинників формування врожайності культури та рівня енерговитрат. Метою нашого дослідження було встановлення закономірностей формування продуктивності гарбуза мускатного залежно від режимів вологозабезпечення та ширини міжряддя, а також оцінка ефективності використання водних і енергетичних ресурсів за різних технологічних варіантів вирощування. Дослідження проводилися у 2025 р. в умовах Інгулецької зрошуваної системи в польовому досліді, в схемі *якого вивчалися варіанти без зрошення, дощування та краплинного зрошення у поєднанні з різною шириною міжрядь. За результатами досліджень встановлено, що в умовах природного зволоження сумарне водоспоживання становило близько 650 м³/га, що забезпечило низьку врожайність і високий коефіцієнт водоспоживання. Застосування дощування сприяло суттєвому зростанню врожайності культури до понад 30 т/га та значному підвищенню продуктивності використання води. Найвищу врожайність у досліді отримано за краплинного зрошення при ширині міжряддя 140 см, де показник досяг 37,9 т/га, що свідчить про високу ефективність локального водопостачання рослин. Енергетичний аналіз показав, що без зрошення виробництво гарбуза мускатного характеризується низькою енергетичною віддачою. Використання зрошення суттєво змінює структуру енергетичного балансу агрофітоценозу, забезпечуючи перевищення енергетичного приходу з урожаєм над витратами. Найвищий енергетичний коефіцієнт сформувався за поєднання дощування із шириною міжряддя 210 см, що свідчить про оптимальне співвідношення витрат енергії та отриманої продукції. Кореляційно-регресійний аналіз засвідчив дуже тісний прямий зв'язок між сумарним водоспоживанням і врожайністю (r≈0,99), що підтверджує домінуючу роль вологозабезпечення у формуванні продуктивності культури. Отримані математичні моделі дозволяють прогнозувати врожайність гарбуза мускатного залежно від рівня вологозабезпеченості в умовах посушливого клімату Півдня України.*

Ключові слова: *гарбуз мускатний, умови та способи зволоження, краплинне зрошення, дощування, врожайність, водоспоживання, енергетична ефективність.*

Relevance of the research topic. It is known that pumpkin is a heat-loving and light-demanding plant, while butternut squash (Cucurbita moschata) is a record holder in terms of heat tolerance [1]. In addition, butternut squash is widely distributed in most regions of the world, and its fruits are rich in carotenoids, vitamins, and minerals. It is known that this crop has potential antidiabetic, antibacterial, and anticancer properties [2, p. 171]. As a valuable vegetable crop with a high biological productivity potential, butternut squash has significant prospects for expanding cultivation areas in the region [3, p. 99]. At the same time, the formation of its yield in the conditions of Southern Ukraine is largely determined by the level of water supply and energy costs for the implementation of technological processes [4, p. 13].

In the studies of Tunisian scientists Solsen Drine, Mohamed Bazes, and Tebra Triki on butternut squash, 14 flavonoids and 10 phenolic acids were identified in its fruits. The following phenolic acids and flavonoids predominate in the fruit pulp: quinic acid, p-coumaric acid, cirsiliol, and luteolin. In general, the obtained data indicate that Cucurbita moschata is a rich source of compounds with high nutritional value and beneficial biological properties. The presence of such substances in butternut squash makes it an excellent material for both industrial and therapeutic applications [5, p. 166]. Among cucurbit crops, pumpkin is the most moisture-demanding: its powerful aboveground mass, particularly the leaves, continuously grows and evaporates a large amount of water. Therefore, the absence of rainfall or irrigation often negatively affects yield formation [1]. Interesting research results on pumpkin seed oil were presented in the Scientific International Journal of Chemistry and Materials Science (SIJCMS). To obtain oil from butternut squash seeds, the following methods were used: Soxhlet chemical extraction, cold solvent extraction, and mechanical pressing. The oil yield was 35.5%, 30.2%, and 26.0%, respectively. The fatty acid composition of the oil was analyzed using gas chromatography–mass spectrometry (GC-MS). The results showed that the oil contains about 22.57% saturated fatty acids and 73.21% unsaturated fatty acids. The authors conducted these in-depth studies in order to assess the possibility of using butternut squash seed oil for biodiesel production [6, p. 56].

Thus, there is a growing need to study the patterns of yield formation of Cucurbita moschata depending on water supply conditions and the level of energy inputs, as well as to develop scientifically grounded recommendations for improving the rational use of water and energy resources in irrigated agriculture in Southern Ukraine.

Problem statement. The issue of rational use of water and energy resources in agriculture is becoming increasingly relevant at the present stage under the conditions of climate change, growing freshwater scarcity, and rising energy costs. For the agricultural sector of Southern Ukraine, which is characterized by an arid climate, high temperature stress during the growing season, and unstable moisture supply, the optimization of water consumption and energy expenditures in vegetable crop production technologies is of strategic importance. Under these conditions, the efficiency of irrigated agriculture directly depends on scientifically grounded approaches to irrigation scheduling, the selection of appropriate irrigation methods, and the minimization of energy costs for water supply and technological operations.

Analysis of recent research and publications. Previous studies conducted by Semen O. T. demonstrated that the feeding area of butternut squash plants significantly affects the yield level of their fruits. In particular, for both varieties, the maximum fruit yield (16.8 t/ha) was obtained in the treatment with a plant feeding area of 5 m² (average across fertilization backgrounds); the yield increase amounted to 2.0–12.6% compared with other treatments. The high yield of pumpkin fruits in this treatment is primarily explained by the biological characteristics of the root system, the physiologically active part of which is mainly located on the roots of the second and third orders, whose length reaches 1.5–2.5 m. Therefore, widening row spacing ensures more complete plant nutrition and does not cause competition among plants. With increased plant density, the crop yield decreased by 0.3–1.8 t/ha**.** The lowest yield was obtained when growing butternut squash plants with a feeding area of 2 m²-15.0 t/ha on average across varieties and fertilization backgrounds, which corresponds to the highest plant density within the rows [7, p. 117].

Professor Belova T. of the Poltava State Agrarian University and Zavertalyuk V., Director of the Dnipropetrovsk Experimental Station of the Institute of Vegetable and Melon Growing, recommend sowing long-vine pumpkin varieties according to a spacing scheme of 2.1 × 2.1 m, medium-vine varieties 2.1 × 1.4 m, and short-vine varieties 1.4 × 0.7 m [8]. Regarding yield, among the large-fruited pumpkins the best results in the studies reported by Avranchuk A. [1] were obtained for the variety Poliovychka, with a yield of standard fruits of 29.4 t/ha and a marketable fruit share of 89.6%. As for butternut pumpkins, the best results were obtained with the variety Dyvo, which produced 33.1 t/ha with a marketable fruit share of 91%.

In order to obtain the most accurate results, a study was conducted on the effect of plant spacing on the formation of fruit quality and the yield of marketable fruits. The standard planting scheme selected was 1.4 × 1.4 m with a sowing density ranging from 3.5 to 9.0 thousand plants per hectare. For this experiment, the varieties Zhdana and Dolya were selected. The highest yield of the Zhdana variety was obtained with a planting scheme of 1.4 × 1.4 m and a density of 5.1 thousand plants per hectare, resulting in a yield of 31.9 t/ha. For the Dolya variety, the optimal scheme was identical, although the yield was slightly higher, reaching 34.3 t/ha. According to the biochemical composition analysis, it was established that increasing plant density leads to a decrease in biochemical indicators. For more efficient use of the plant nutrition area and obtaining a marketable yield of large-fruited and butternut pumpkin at the level of 32–34 t/ha, sowing should be carried out according to the schemes 1.4 × 1.1 m and 1.4 × 1.4 m. Farmers are particularly interested in the profitability of cultivating specific varieties. Thus, according to research results, the use of the varieties Yuvilei and Dyvo is the most economically advantageous, as their profitability levels reach 109% and 151%, respectively [1].

According to the results of studies conducted by Khareba O. and Kokoiko V. [9, p. 78; 10, p. 77], the varieties Dolya and Dyvo of butternut pumpkin proved to be valuable, as they were characterized by high adaptability and total fruit yield at the level of 34.5–37.3 t/ha. In addition, these varieties were distinguished by a high content of total sugars in the fruit pulp - 7.3% and 6.4%, respectively. The varieties Dolya and Dyvo were also valuable due to their high content of provitamin A, amounting to 8.3 and 10.7 mg/100 g, respectively.

In studies conducted on butternut squash (Cucurbita moschata) by Colombian scientists R. Restrepo, M. Restrepo, S. Grisales, and G. Hermann, the influence of different levels of soil moisture during crop cultivation was investigated [11]. Different soil moisture levels were determined by the evapotranspiration rate of the crop, ranging from 0.4 ET0 to 1.2 ET0. The maximum biometric parameters-biomass, leaf area, number of stomata, and root length-were obtained in the treatment with the highest soil moisture level (1.2 ET0). In contrast, under moisture deficit conditions (ET0 evapotranspiration = 0.4), a significant decrease in the macromolecular composition of the leaf blade was observed, including soluble protein, soluble carbohydrates, chlorophyll a and b, and carotenoids. In addition, moisture deficiency stimulated the formation of hydrogen peroxide (H_2O_2), to which the plants responded by producing enzymes that protect the photosynthetic process.

Scientists from Sudan, Nahid Tajelsir Khieri and Ashraf Izzeldin Abdalla, conducted studies on butternut squash in which two sowing methods were examined: single-row sowing and two-row strip sowing [12, p. 289]. As expected, the single-row sowing method significantly exceeded the strip sowing method in terms of yield. According to the results of a study conducted in Malaysia [13, p. 33] on butternut squash, no statistically significant differences were observed in leaf area among treatments with 20 cm, 40 cm, and 60 cm spacing between plants within the row. Accordingly, there were no significant differences among these treatments in fruit weight, length, or width. Nevertheless, fruit size at the 60 cm spacing was larger compared with other plant spacing distances. In the study by Averchev O. V. and Avercheva N. O., it is noted that increasing the efficiency of land resource use in farming enterprises is achieved through the implementation of scientifically grounded crop cultivation technologies, rational use of natural resources, and optimization of production costs [14, p. 18].

Despite the availability of scientific studies on technologies for cultivating cucurbit crops, the issues of comprehensive assessment of the relationship between water consumption, energy inputs, and productivity of butternut squash crops under the specific soil and climatic conditions of Southern Ukraine remain insufficiently systematized. The lack of integrated approaches to determining energy efficiency indicators, taking into account different irrigation methods and plant placement parameters, necessitates a deeper scientific substantiation of optimal technological solutions.

Materials and methods of research. The research was conducted under the agro-climatic conditions of Southern Ukraine within the Ingulets irrigation system, using the technology for cultivating butternut squash that is typical for the region. The object of the study was Cucurbita moschata Duchesne ex Poir., which is characterized by high plasticity in water consumption and a significant biological productivity potential. The field experiment was established according to a two-factor design and included the following treatments: Factor A – moisture conditions and irrigation methods: without irrigation, sprinkler irrigation, and drip irrigation; Factor B – row spacing: 140 cm and 210 cm. In the experiment, the Dyvo variety was sown. In our research, field, statistical, and calculation–comparative methods were used. The field experiment was conducted with four replications, and the treatments were arranged sequentially. The total (sowing) area of the experimental plot was 420 m², while the accounting area depended on the row spacing. Thus, for treatments with a 2.1 m row spacing, the accounting area of the plot was 210 m², whereas for treatments with a 1.4 m row spacing it was 280 m².

The predecessor of butternut squash was winter wheat, with an average yield of 4.56 t/ha. The system of primary soil tillage was carried out according to a semi-fallow type. Weather conditions during the 2025 growing season were characterized as very dry and hot. In particular, during the period from harvesting the predecessor crop to sowing butternut squash, only 86 mm of precipitation fell in the farm area (according to data from the farm's own meteorological station), which is critically low. As a result, according to our calculations, the productive moisture reserve in the one-meter soil layer of southern chernozem at the time of sowing amounted to 421 m³/ha. During the crop growing season (May–September 2025), the total precipitation amounted to 73 mm, which is also critically low and consequently affected the yield of the crop under non-irrigated conditions in the control treatment.

Plant water supply was assessed based on the total volume of water used for irrigation, the amount of effective precipitation during the growing season of butternut squash, soil moisture indicators at different stages of crop development, as well as the water consumption coefficient, defined as the ratio of crop yield to the total water consumption of the crop. The energy analysis was based on calculations of specific energy inputs per unit area, taking into account all components of the technological cycle, including soil preparation, sowing, inter-row cultivation, irrigation, and harvesting. At the same time, an essential component was the determination of the actual energy costs for supplying water to the irrigation system, considering the technical parameters of the pumping equipment, which made it possible to evaluate the energy efficiency of each treatment.

Presentation of the main research material. In Southern Ukraine, large-scale irrigation systems such as the Ingulets, North Crimean, and Kakhovka systems were constructed 50-60 years ago, which made it possible to achieve guaranteed yields of agricultural crops under the planned economy model. In the current conditions of a market economy, the main goal of agricultural production is to obtain products at minimal cost and with optimal resource use, including mineral fertilizers, fuel, irrigation water, and so on. In our field experiment, based on the calculated values of the components of total water consumption, the water consumption coefficient of the crop was determined (Table 1).

The analysis of the data in Table 1 indicates a significant influence of moisture conditions and irrigation methods, as well as row spacing, on the values of water consumption and yield of butternut pumpkin. In the absence of irrigation, the total water consumption of crops amounted to 650 m³/ha regardless of row spacing, which is explained by the use of only soil moisture and effective precipitation during the crop growing season. At the same time, the yield at a row spacing of 210 cm (6.8 t/ha) exceeded the corresponding indicator at 140 cm (5.5 t/ha), which resulted in a decrease in the water consumption coefficient to 95.6 m³/t compared with 118.2 m³/t. This indicates a more efficient use of natural moisture under an optimized spatial arrangement of crops.

Sprinkler irrigation significantly increased the total water consumption of the crop to 1852–1848 m³/ha due to the irrigation rate of 1200 m³/ha. Under these conditions, a sharp increase in yield was observed, reaching 27.6 t/ha at a row spacing of 140 cm and 32.3 t/ha at 210 cm. Accordingly, the water consumption coefficient decreased to 67.1 and 57.2 m³/t, respectively, indicating improved efficiency in the use of water resources. The highest yield in the experiment was achieved with the combination of sprinkler irrigation and a row spacing of 210 cm, which indicates a synergistic effect of agrotechnical factors.

Table 1

Water consumption by butternut squash crops depending on irrigation conditions, methods, and row spacing, 2025

Moisture conditions and irrigation methods – Factor A	Row spacing, cm – Factor B	Components of total water consumption, m³/ha.				Yield, t/ha	Water consumption coefficient, m³/t
		Soil moisture	Effective preci-pitation	Irrigation rate	Total		
No irrigation	140	213	438	-	650	5.5	118.2
	210	212	438	-	650	6.8	95.6
Sprinkler irrigation	140	214	438	1200	1852	27.6	67.1
	210	210	438	1200	1848	32.3	57.2
Drip irrigation	140	208	438	1550	2196	37.9	57.9
	210	211	438	1550	2199	34.0	64.7
LSD 05, t/ha factor A						1.81	
LSD 05, t/ha factor B						1.70	

*Source: Author's own research.

Drip irrigation was characterized by the highest level of total water consumption – 2196-2199 m³/ha with an irrigation rate of 1550 m³/ha. At a row spacing of 140 cm, the yield reached 37.9 t/ha, which is the highest value in the study, whereas at a row spacing of 210 cm it amounted to 34.0 t/ha. The water consumption coefficient was 57.9 and 64.7 m³/t, respectively. The obtained results indicate that under drip irrigation, a denser plant arrangement (140 cm) contributes to increasing the productivity of the agrophytocenosis and ensures a more efficient conversion of water resources into yield.

In general, a clear trend can be observed: the application of irrigation significantly increases the yield of butternut pumpkin and reduces the water consumption coefficient compared with rainfed conditions. Cultivation without irrigation is the least efficient in terms of moisture use, whereas the most productive is the application of drip irrigation with a row spacing of 140 cm. At the same time, sprinkler irrigation with a row spacing of 210 cm ensures an optimal ratio between water consumption and yield.

Correlation analysis revealed a very strong positive relationship between total water consumption and crop yield ($r = 0.9897$), indicating an almost functional dependence of yield formation on the level of moisture supply. Similarly, a strong positive correlation was observed between the irrigation rate and yield ($r = 0.9900$). At the same time, the water consumption coefficient has a strong inverse relationship with yield ($r = –0.9505$) and with total water consumption ($r = –0.9257$), confirming an increase in water use efficiency with increasing productivity of the agrocenosis. Row spacing demonstrates a weak correlation with yield ($r = 0.027$), indicating the secondary nature of its influence compared with the irrigation factor within the presented dataset.

As a result of the single-factor regression analysis (yield as a function of total water consumption), the following equation was obtained:

$$Y = –6.3606 + 0.0194X$$

where Y is yield, t/ha; X is total water consumption, m³/ha.

The coefficient of determination $R^2 = 0.9796$, which explains 97.96% of the variation in yield by the water consumption factor. An increase in total water consumption by 100 m³/ha ensures an average increase in yield of 1.94 t/ha.

The multifactor regression model (taking into account row spacing) has the following form:

$$Y = -8.1270 + 0.0194X_1 + 0.0101X_2$$

where X_1 is total water consumption, m³/ha; X_2 is row spacing, cm.

The coefficient of determination $R^2 = 0.9803$, which only slightly exceeds the value of the single-factor model. This indicates that the main determining factor in yield formation is the level of moisture supply, whereas row spacing within the range of 140–210 cm has a relatively weak additional influence. Thus, the statistical analysis confirms the dominant role of irrigation in the formation of butternut pumpkin productivity. Increasing the irrigation rate significantly increases yield and simultaneously reduces the water consumption coefficient of butternut pumpkin, indicating an increase in the water-use efficiency of the agrophytocenosis. The obtained models can be used to predict yield under different parameters of water supply and to optimize irrigation regimes in order to achieve maximum economic and resource efficiency. Under modern farming conditions, the main factor in the development of production is the availability of energy sources. In this regard, an essential element in evaluating the technology of crop cultivation should be the analysis of energy efficiency (Table 2).

Table 2

Energy efficiency of muscat pumpkin cultivation depending on moisture conditions, irrigation methods, and row spacing, 2025

Moisture conditions and irrigation methods	Row spacing, cm	Energy balance components, MJ/ha		Energy efficiency coefficient	Yield, t/ha
		Total energy inputs	Energy output with the yield		
No irrigation	140	19.51	5.75	0.29	5.5
	210	20.16	7.11	0.35	6.8
Sprinkler irrigation	140	21.85	28.87	1.32	27.6
	210	22.34	33.79	1.51	32.3
Drip irrigation	140	28.62	39.64	1.39	37.9
	210	26.17	35.56	1.36	34.0

*Source: Author's own research.

The analysis of the indicators of energy efficiency in butternut pumpkin cultivation indicates a significant influence of moisture conditions and irrigation methods, as well as row spacing, on the formation of the energy balance of the agrophytocenosis. Under rainfed conditions, the level of total energy costs was the lowest and amounted to 19.51–20.16 MJ/ha, which is explained by the absence of additional energy expenditures for water supply and distribution. However, the low energy input with the yield (5.75–7.11 MJ/ha) resulted in the formation of a minimum energy coefficient of 0.29–0.35, indicating the energy inefficiency of production under non-irrigated conditions. Increasing row spacing to 210 cm contributed to an increase in yield from 5.5 to 6.8 t/ha and a corresponding rise in the energy coefficient; however, the overall level of energy return remained critically low.

The use of sprinkler irrigation was accompanied by a moderate increase in total energy costs to 21.85–22.34 MJ/ha, but the increase in yield to 27.6–32.3 t/ha ensured a significant rise in energy input with the harvested products, up to 28.87–33.79 MJ/ha.

As a result, the energy coefficient increased to 1.32–1.51, indicating that energy output exceeded energy inputs and a positive energy balance was formed. The highest value of the energy coefficient (1.51) was obtained with the combination of sprinkler irrigation and a row spacing of 210 cm, which indicates an optimal ratio between crop structure and moisture conditions from the standpoint of energy efficiency.

Drip irrigation was characterized by the highest total energy expenditures – 26.17–28.62 MJ/ha, which is associated with the energy intensity of the water supply system and its technical maintenance. At the same time, this method of irrigation ensured the maximum energy input with the yield - 35.56–39.64 MJ/ha and the highest yield (37.9 t/ha at a row spacing of 140 cm). The energy coefficient ranged from 1.36 to 1.39, which is slightly lower than the best variant with sprinkler irrigation at 210 cm, but significantly higher than the indicators without irrigation.

Generalization of the results shows that the introduction of irrigation fundamentally changes the energy structure of butternut pumpkin production, transforming the system from an energy-deficient one into an energy-profitable one. The most energy-efficient option proved to be the combination of sprinkler irrigation with a row spacing of 210 cm, whereas the maximum biological productivity was achieved with drip irrigation at 140 cm. Therefore, the choice of a technological option should be based on a balance between maximizing yield and optimizing energy costs.

Based on the data in Table 2, a correlation and regression analysis was conducted to determine the relationship between the indicators of energy efficiency in butternut pumpkin cultivation and the crop yield depending on moisture conditions and row spacing. The calculation results indicate the presence of a strong direct statistical relationship between the energy coefficient and yield. The value of the pair correlation coefficient is $r = 0.97$, which characterizes a very high level of positive correlation between the studied indicators. This means that with an increase in the energy efficiency of the cultivation technology, a consistent increase in crop yield is observed. The coefficient of determination $R^2 = 0.95$ indicates that about 95% of the yield variation is explained by changes in the energy coefficient, while only a small share depends on other factors.

Regression analysis made it possible to establish a linear regression equation describing the dependence of yield on the energy coefficient:

$$Y = -1.67 + 24.78X,$$

where Y is the yield of butternut pumpkin, t/ha; X is the energy coefficient of the cultivation technology. The obtained equation shows that an increase in the energy coefficient by one unit is accompanied by an increase in yield by approximately 24.8 t/ha, which confirms the high efficiency of energy-saving and intensive technological solutions in the crop cultivation system. The highest values of yield and energy return were observed when drip irrigation and the optimal row spacing were used, ensuring more efficient utilization of energy resources and increased productivity of the agrocenosis.

Thus, the results of the correlation and regression analysis confirm the existence of a close functional relationship between the energy efficiency of the cultivation technology and the yield of butternut pumpkin. An increase in the energy coefficient, achieved through the rational application of irrigation and optimization of agrotechnical parameters, contributes to a significant increase in crop productivity. This indicates the feasibility of implementing energy-efficient cultivation technologies as an important factor in improving the economic and production efficiency of vegetable growing.

Conclusions and prospects for further research. It was established that the efficiency of water resource use is largely determined not only by the irrigation rate, but also by row spacing and the irrigation method. The optimal variant of our field experiment, in which the minimum water consumption for the formation of 1 t of butternut pumpkin fruits (57.2 m^3) and the maximum energy coefficient (1.51) were obtained, was the following: crop sowing with a row spacing of 210 cm combined with sprinkler irrigation.

The results of the correlation and regression analysis indicate the presence of a close relationship between total water consumption, energy expenditures, and yield, which makes it possible to predict the efficiency of resource use under different technological options. The prospects for further research involve a comprehensive study of the influence of various technological schemes of butternut pumpkin cultivation on water and energy efficiency in combination with economic and environmental indicators.

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