SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 25(11), 51-62

UDC 635.4: 635.7 (477.46)
DOI: 10.48077/scihor.25(11).2022.51-62

Efficiency of the Sowing Date of Spinach in the Southern Steppe Conditions of Ukraine

Olena Ulianych[1*], Vitaliy Fedorenko[2], Liudmila Riabovol[1], Kostiantyn Shevchuk[1], Liliia Voievoda[1]

[1]Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine

[2]Institute of Plant Protection National Academy of Agrarian Sciences of Ukraine
03022, 33 Vasylkivska Str., Kyiv, Ukraine

Article's History:
Received: 09/14/2022
Revised: 10/28/2022
Accepted: 11/21/2022

Suggested Citation:
Ulianych, O., Fedorenko, V., Riabovol, L., Shevchuk, K., & Voievoda, L. (2022). Efficiency of the sowing date of spinach in the Southern steppe conditions of Ukraine. *Scientific Horizons*, 25(11), 51-62.

Abstract. The population of Ukraine should receive fresh greens from early spring to autumn from open field production and the period of growing spinach will ensure the supply of fresh greens. The purpose of the research was to study the possibility of extending the period of fresh greens supplying from the open field due to the extension of the seed sowing period in the open field. The research was conducted in 2019-2021 in the conditions of the Southern Steppe of Ukraine. For the research, field, statistical, calculation-analytical and laboratory methods were used. The varieties Fantaziia and Malakhit were studied. The behaviour of plants after six sowing dates was examined. The control variant was the variety Fantaziia for sowing in the 1st decade of April. It was found that plants of both varieties of spinach had a larger leaf surface (114.2-127.7 cm^2) in the early sowing period. Plants which were sown in August had a smaller leaf surface – 86.0-106.2 cm^2. The highest yield of marketable green mass was obtained for sowing in the 3rd decade of April and 2nd decade of May. The variety Fantasia provided 22.9-23.0 t/ha, and the variety Malakhit provided 23.3-23.9 t/ha. The sowing date had a significant influence on the main chemical parameters of spinach of the Fantaziia and Malakhit varieties. The higher indicators were the sowing dates in the third decade of April and the second decade of May, when the brix reached the level of 6.4-6.8%, the sugars content – 2.3-2.4% and the content of vitamin C – 58-70 mg/100 g. It was established that the soil and climatic conditions of the Southern Steppe of Ukraine were suitable for sowing spinach in six dates and would ensure an uninterrupted supply of products from the 3rd decade of April to the end of September inclusive, and in years with favourable weather conditions in the 2nd to 3rd decades September to mid-October. Such approach will solve the problem of seasonality in the consumption of fresh vegetables. The sowing dates are recommended to agricultural producers of spinach in order to extend the period of receiving fresh greens from the 3rd decade of April to the end of September and in some years to the middle of October

Keywords: total leaves surface, leaves number, plant height, weight of the plant, beginning of rosette growth, technical maturity

*Corresponding author

INTRODUCTION

Establishment of optimal sowing dates for uninterrupted supply of marketable greens and consumption during the spring-summer-autumn period in fresh form, correlation between plant growth and productivity, determines the relevance of this study. It is known from research of Hospodarenko *et al.* (2008) that from early to late sowing, the accumulation of dry matters and brix consistently decreases. The intensity of the processes of plant and stem death during the spring-summer vegetation period decreases. According to the research of Ulianych *et al.* (2018), at the optimal sowing date plants are programmed for high yield, but their productivity decreases both at early and at late sowing date. In the first case, the plant forms a larger vegetative mass and, because of overgrowth, intensively uses reserve substances and becomes less resistant to adverse conditions. In addition, the plant of the early sowing is more damaged by pests, diseases, and is often weedier. Because weeds, by their biological characteristics, are more competitive with plants, they outgrow and shade them, take more nutrients and moisture. All this leads to slowdown in the growth of cultivated plants, thinning of crops and a decrease in yield founded by Korniyenko *et al.* (2015).

Plants of the late sowing grow and develop more slowly, do not have time to form a full-fledged rosette and sufficient above-ground mass and secondary root system shown in research of Ulianych *et al.* (2015).

The study of the dependence of the sowing date on soil fertility of Galla *et al.* (2013) and Barcelos *et al.* (2017) showed that it was necessary to sow earlier on poor soils, and later fertile ones, so that the plants did not overgrow. The optimal sowing date on fertilized fields is shifted 10-15 days later, compared to sowing on a less fertilized field mentioned in research of Guttierrez-Rodriguez *et al.* (2013). Positive impact on yield has organic fertilizers and sea weed extractions mentioned in researches of Kim *et al.* (2018), Xu & Leskovar (2015) and Fan *et al.* (2013). Using of bio stimulants, besides regular fertilizing has positive impact on yield and leaves quality was found in research of Fiorentino *et al.* (2018) and Kulkarni *et al.* (2019).

Sowing date is important as environmental temperature influencing on plants. In autumn, and spring the effect of the maximum, minimum and average temperature was dominant, but in summer, only the average and maximum temperature seemed significant concluded in research of Zuska *et al.* (2019). The sowing date varies depending on the biological characteristics of the variety, and for classic varieties, the interval of the optimal sowing period is longer. Studies of Khareba *et al.* (2012) are recommending calendar dates for sowing 6-12 days later, compared to previously grown varieties, which is due to the biological features of the modern variety. And this is a shortened epicotyl, faster passage of the interphase period, more intense formation of plastic substances and formation of above-ground mass.

The results of observations of the growth and development of plants in the autumn period showed by research of Golubkina *et al.* (2017). It showed that the degree of plant development, especially the accumulation of dry matter, was not directly related to the level of adaptive characteristics. They are formed higher during optimal and late sowing. Plants of different ages do not equally consume water from the soil. Van Treuren *et al.* (2012) shows then crops of early sowing, as they are more physiologically old, use less water than plants of optimal and late sowing.

For vegetables, in particular of spinach, the sowing date is important, because the optimal sowing date will help to increase the yield due to the full growth and development of the plant mentioned by M. Pollock (2012). Therefore, in order to obtain a high yield of green mass several times during the growing season in the Southern Steppe of Ukraine, research was conducted to study the effectiveness of the sowing date for growing spinach. As a result of the conducted experimental study, new elements of the technology of growing spinach were investigated. For the first time, in the study of by Panda *et al.* (2017), the biological ability of new varieties of spinach to form a high yield of marketable green mass and their actual productivity has been theoretically substantiated and experimentally proven.

The aim of the current research was to find the optimal timing of sowing spinach seeds and obtaining high yields.

MATERIALS AND METHODS

The research on determining the optimal sowing date of spinach in the Southern Steppe of Ukraine was conducted in 2019-2021 in open field conditions on a field with drip irrigation. The influence of the sowing date on the growth, development and yield of spinach varieties Fantaziia and Malakhit was determined. The methodical recommendations of Bondarenko and Yakovenko (2001) were used.

In order to ensure a constant supply of fresh products during the period from spring to autumn, the following six sowing dates were studied: the 1st and 3rd decades of April, the 2nd decade of May, the 2nd decade of June, and the 1st and 3rd decades of August. The control variant was drilled in first decade of April. The research was conducted on light sandy chornozems. The humus horizon in the 0-20 cm soil layer contained 1% of humus, and 0,6% of humus in the 20-40 cm soil layer. Chemical characteristics of the soil: organic carbon – 2.1%, pH 6.9-7.4, P – 92 mg/kg-1, K – 101 mg/kg-1, N–NO_3 – 17 mg/kg-1. The electrical conductivity (EC) of the soil was measured by using a conductometer. P, K were determined by the AB-DTPA method according to Ryan *et al.* (2001). The sowing conducted by the density of 150 000 seeds per hectare. The total acreage for the experiment was 360 m^2, for the single plot it was 60 m^2.

The experiment was designed as a Full Randomized with four replications.

Biometric research. The length and width of the leaf, the surface of the leaf plate and the total leaf surface of the plant were determined. The height of the plant and the number of leaves on the plant were count. The sowing dates of spinach, plant productivity, vitamin C were studied. All analyses were performed in four repetitions.

Plant material. Spinach (*Spinacea oleraceae* L.) varieties Fantaziia and Malakhit.

The analysis of vitamin C was held as follows: Lyophilized samples of leaves (0.2 g) were crushed and adding to 30 ml of a 3% metaphosphoric acid solution with followed homogenized at 11,000 rpm for 2 min by using a homogenizer (T25 basic ULTRA-TURRAX – IKAWerke GmbH. & Co. KG, Staufen, Germany). The volume was adjusted to 50 ml with a 3% solution of metaphosphoric acid. The 2 ml of extract was centrifuged at 12000 rpm for 3 min. The supernatant was filtered through polyvinylidene difluoride membrane filter of 0.45 μm (Whatman International Ltd., Maidstone, UK). The fresh samples were analysed by using an HPLC system equipped with a PU (pump 2089), MD (2010 UV), AS (autoinjector 2057) variable wavelength detector (JASCO Corp., Tokyo, Japan). The separation made on a Crest Pak C18S column (15094.6 mm, inner diameter, 5 μm, JASCO Corp.). The peak was reading at 254 nm using a UV detector. The quantification was determining by external calibration with the ascorbic acid.

Weather conditions during the research years. According to the data of the Nova Kakhovka hydrometeorological station (n.d.), the hydrometeorological conditions of 2019 were characterized as a slightly lower amount of precipitation compared to the average long-term indicators. The amount of precipitation for this period in 2020 was significantly higher than in 2019. 2021 was the rainiest year. The most precipitation fell in June, which allowed for better forming of leaf mass the plants. The air temperature in 2019-2021 at the sowing time was slightly higher than the perennial one, which had a positive effect on the development of spinach plants.

Statistical analysis. The nutritional and chemical compositions were analysed in four replications. Results were expressed as averages. Chemical composition was analysed using analysis of variance with $P \leq 0.05$ for yield, plant weight and productive moisture storage by using the program of statistical analysis (SAS) v. 9.1.3.

RESULTS AND DISCUSSION

The sowing of the spinach at different dates shows a positive effect on the results of farming and allowed obtaining reliable data on the plasticity of the crop in terms of growing conditions. The assessment of the influence of the date of the seeds sowing on the growth and development of the spinach under the conditions of growing in open field was conducted based on the fixation of the duration of the phenological phases of plant growth, their development and other indicators. The analysis of the data obtained as a result of research on the growth of the spinach plants and their development in the Southern Steppe of Ukraine showed that the duration of the periods from the germination to the onset of the main phenological phases was the shortest for sowing seeds in the I and II decades of August, regardless of the studied variety. The mass germination appeared on the 8th day in the control variety and on the 7th day in the Malakhit variety due to sowing seeds in the I decade of April. The mass germination of both researched varieties was noted for 6 days due to sowing seeds in the III decade of April and II decade of May, as well as in the Fantasia variety due to sowing in the II decade of June. During the August sowing dates, mass germination was recorded at 5th day, regardless of the studied variety, which can be associated with the influence of high environmental temperatures.

The phase of the appearance of the first true leaf in spinach was recorded after 10-17 days, depending on the variant of the experiment, and it was noted after 12-17 days for the Fantasia variety, and 10-15 days for the Malakhit variety. The plants reached the technical phase of maturity on the 40th day after the appearance of germination in both studied varieties due to sowing seeds in the III decade of April and on the 41st day due to sowing seeds in the II decade of May. The summer sowing date showed that the onset of the technical maturity phase did not depend on the variety and occurred on the 37th and 38th day.

The study of the effect of the variety and date of sowing seeds on the duration of the growth phases proves that for all sowing dates the advantage is observed in plants of the Malakhit variety - the phase of technical maturity came 1-4 days earlier than in the Fantaziia variety. In its turn, studies showed that the difference in the speed of passage of phenological phases by spinach plants was more pronounced depending on the date of sowing than on the variety.

The influence of the sowing date of spinach and the variety is characterized by differences in biometric indicators. The evaluation of the plants of the Fantaziia and Malakhit varieties in the phase of the beginning of rosette growth shows that plants had height of 6.3-7.3 cm due to the sowing in the III decade of April and in the II decade of May and were taller compared to the plants of later sowing. This fact can be explained by the fact that at lower temperatures the growing season is longer. An exception to this pattern can be considered the sowing period in the I decades of April, when at the beginning of the growing season, low temperatures, on the contrary, slowed down the growth and development of spinach plants (Table 1).

***Table 1**. The height of the spinach plant depends on the variety, cm*

Variety	Sowing date	Beginning of rosette growth				Technical maturity			
		2019	2020	2021	2019-2021	2019	2020	2021	2019-2021
Fantaziia	April I decade*	4.8	5.4	5.1	5.1	24.4	23.8	26.2	24.8
	April III decade	6.8	7.4	7.1	7.1	30.5	25.4	30.8	28.9
	May II decade	6.8	7.3	6.7	6.9	27.5	26.3	26.1	26.6
	June II decade	6.7	6.3	6.5	6.5	19.3	19.7	19.2	19.4
	August I decade	5.3	5.4	4.9	5.2	16.2	15.9	15.7	15.9
	August III decade	5.4	5.6	7.1	6.0	17.4	16.7	16.9	17.0
Malakhit	April I decade	5.8	5.5	5.1	5.5	29.4	24.8	30.4	28.2
	April III decade	7.4	7.2	7.2	7.3	25.5	26.4	25.2	25.7
	May II decade	5.7	7.1	6.2	6.3	24.8	28.5	26.3	26.5
	June II decade	4.8	5.4	5.1	5.1	21.1	22.8	18.6	20.8
	August I decade	5.3	5.7	5.4	5.5	17.8	16.9	18.1	17.6
	August III decade	6.2	5.8	5.1	5.7	16.9	17.8	17.5	17.4
	$LSD_{0.5}$	0.4	0.3	0.5		1.4	1.2	0.8	

***Note:** * – control variant*
***Source:** compiled by the authors*

It was noted that the height of spinach plants depended to a considerable extent on the sowing date and not on the variety. On average, over the years of research, the height of city spinach plants in the phase of green technical maturity, was 24.8-28.2 cm, depending on the variety due to sowing in the I decade of April. The research indexes differed and in the Fantaziia variety they increased to 26.6-28.9 cm, while in the Malakhit variety, on the contrary, they decreased to 25.7-26.5 cm due to the sowing of spinach in the III decade of April and in the II decade of May. The indexes of both studied varieties exceeded the control by 1.8-4.1 cm and 0.9-1.7 cm, respectively. It has been established that in spinach the number of leaves per plant determines the potential value of the yield, therefore, in the conducted observations, attached great importance to this index (Fig. 1).

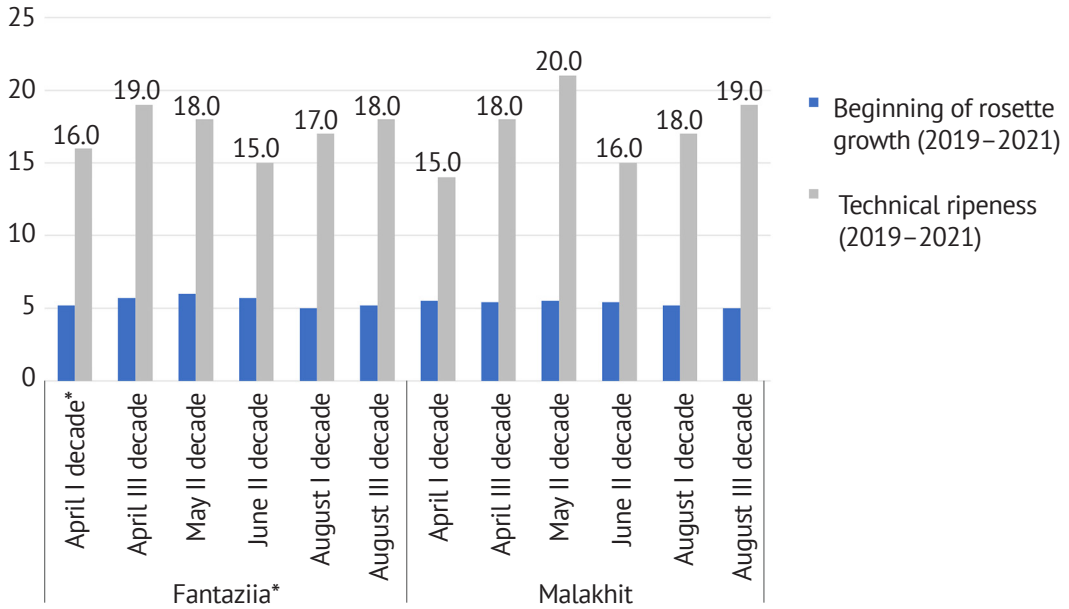

***Figure 1**. The dynamics of the leaves number increase of the spinach in different periods of growth and development depending on the variety and sowing date (2019-2021)*
***Source:** compiled by the authors*

In the phase of the beginning of plant rosette growth the number of leaves was, depending on the investigated variety, from 5.0 to 6.0 pcs/plant. Observations of 2019-2021 showed us that early sowing

dates, especially the III decade of April, the II decade of May and the II decade of June, were more conducive for the Fantaziia variety, as one plant formed a larger number of leaves from 5.7 to 6.0 cs/plant. At the time when a significantly lower number of leaves from 5.0 to 5.2 pcs/plant was observed due to late sowing and sowing in the I decade of April. In its turn, in the Malakhit variety, the number of leaves varied slightly regardless of different sowing dates and ranged from 5.0 to 5.4 leaves per plant.

It was noted that the studied varieties had different numbers of leaves at the phase of the beginning of the rosette growth. High variability of the index was noted in the Fantaziia variety with the highest index due to the sowing in the II decade of May. During the studies of the influence of the variety and sowing date on the number of leaves and their growth throughout the growing season, it should be noted that at the harvesting date the number of leaves increased by 2.5-3.5 times, from 5.0-6.0 to 14-21 pcs/plant. One of the important indexes of spinach plant growth, which determines their value as a green plant, is the leaf surface and the total leaves surface. The determination of these indexes depending on the date of sowing was conducted at the beginning of the rosette growth and in the phase of technical maturity of the greenery before the bolting (Table 2).

***Table 2**. The spinach leaf surface in different mode of growth and development depending on the variety and sowing date, cm^2*

Variety	Sowing date	Beginning of rosette growth				Technical maturity			
		2019	2020	2021	2019-2021	2019	2020	2021	2019-2021
Fantaziia	April I decade*	18.8	17.7	18.5	18.3	110.3	108.3	107.2	108.6
	April III decade	20.4	21.7	23.8	22.0	122.4	120.6	122.0	121.7
	May II decade	21.5	20.8	19.9	20.7	128.5	128.7	125.9	127.7
	June II decade	21.8	20.9	20.5	21.1	105.8	107.8	111.4	108.3
	August I decade	17.4	16.7	17.1	17.1	96.4	86.3	76.2	86.3
	August III decade	18.4	18.1	18.5	18.3	84.6	88.4	85.1	86.0
Malakhit	April I decade	24.1	21.3	21.7	22.4	120.1	110.6	115.2	115.3
	April III decade	25.7	22.1	22.9	23.6	130.1	121.4	124.7	125.4
	May II decade	22.3	21.5	22.2	22.0	115.7	110.5	116.5	114.2
	June II decade	21.7	20.7	22.5	21.6	114.4	117.7	118.0	116.7
	August I decade	19.4	18.3	18.8	18.8	111.5	101.5	105.6	106.2
	August III decade	19.1	18.1	18.3	18.5	109.9	102.2	104.1	105.4
	$LSD_{0.5}$	0.5	0.2	0.3		4.3	3.9	2.8	

***Note:** * – control variant*
***Source:** compiled by the authors*

It was established that plants of the Fantaziia variety had a larger leaf surface due to sowing in the I decade of April – 22.0 cm^2. The smallest leaf surface in the Fantaziia variety was found due to sowing seeds in the I decade of August – 17.1 cm^2. At the same time, in the Malakhit variety, the smallest leaf surface was observed due to sowing in the last term – 18.5 cm^2, and the largest due to the III decade of April – 23.6 cm^2. The study of the influence of sowing dates on the leaf surface index proves that it is larger at the beginning of growth due to sowing in the III decade of April and the II decade of May, regardless of the variety.

At the phase of technical maturity, before harvesting the spinach plant in both researched varieties, a smaller leaf surface was observed in the August sowing dates and was from 86.3 to 86.0 cm^2 due to the Fantaziia variety and from 106.2 to 105.4 cm^2 due to the Malakhit variety. At the technical maturity mode, plants of the Fantaziia variety of spinach had a larger leaf surface due to sowing in the III decade of April and II decade of May – 121.7 and 127.7 cm^2, respectively, and in the Malakhit variety due to sowing in the III decade of April – 125.4 cm^2. The study of the influence of the sowing date on this index proves that the surface of the leaf plate in spinach plants had bigger values at the beginning of growth in the early dates, apart from the first one.

During 2019-2021, the dynamics of the growth of the leaf surface depending on the date of sowing were studied in detail, and data were obtained and factors that could influence the increase in the leaves surface during the growing season and on the eve of harvesting, depending on the variety and the date of sowing in open field were analysed. The data received shows that the leaves surface of the spinach plants in 2019-2021 at the beginning of growth was found to have a larger the leaves surface of Fantaziia spinach plants that were sown in the II decade of May – 1.72 thousand m^2/ha, which exceeded the control by 0.40 thousand m^2/ha. In the Malakhit variety, during the three early sowings, the index almost did not vary and was in the range from

1.71 to 1.73 thousand m²/ha, which exceeded the control by 0.39-0.41 thousand m²/ha. A smaller leaves surface was obtained in the summer sowing dates in both studied varieties of spinach.

It was established that the August sowing dates did not contribute to obtaining a large leaves surface, and for sowing in the I and III decades of August it amounted to 1.21-1.29 thousand m²/ha in the Fantaziia variety, according to the sowing date, which was lower than control by 0.11-0.03 thousand m²/ha. In plants of the Malakhit variety, this index in August was 1.34 and 1.25 thousand m²/ha, respectively. At the technical maturity mode, the leaf surface reached the value of 25.6 thousand m²/ha of Fantaziia variety due to sowing in the I decade of April. In the Malakhit variety during the early sowing date the leaf surface was 23.9 thousand m²/ha, which is lower than the control by 1.7 thousand m²/ha.

The larger leaves surface was formed by spinach varieties Fantaziia and Malakhit due to the seeds sowing in the III decade of April – 30.8-33.4 thousand m²/ha, according to the variety, which exceeded the control by 5.2-7.8 thousand m²/ha. In the second decade of May plants had a leaf surface in this phase of 31.1-32.3 thousand m²/ha, according to the variety, which exceeded the control by 5.5-6.7 thousand m²/ha. The leaves surface largely depended on the weather conditions of the year. Thus, plants grown in 2020 had the smallest leaf surface, which is explained by the unfavourable weather conditions of the year, especially the lack of moisture during the period of intensive plant growth and development.

Observation of the growth and development of plants showed that in the first period of growth, spinach grows slowly and forms an insignificant leaf mass, but during the period of technical maturity the plant significantly increases in size. In the phase of intensive growth, plants sown in the open field in the III decade of April had a larger leaves surface, regardless to the variety. At the time of the plant density forming the leaf surface was from 28.9 to 32.9 thousand m²/ha (Figs. 2; 3).

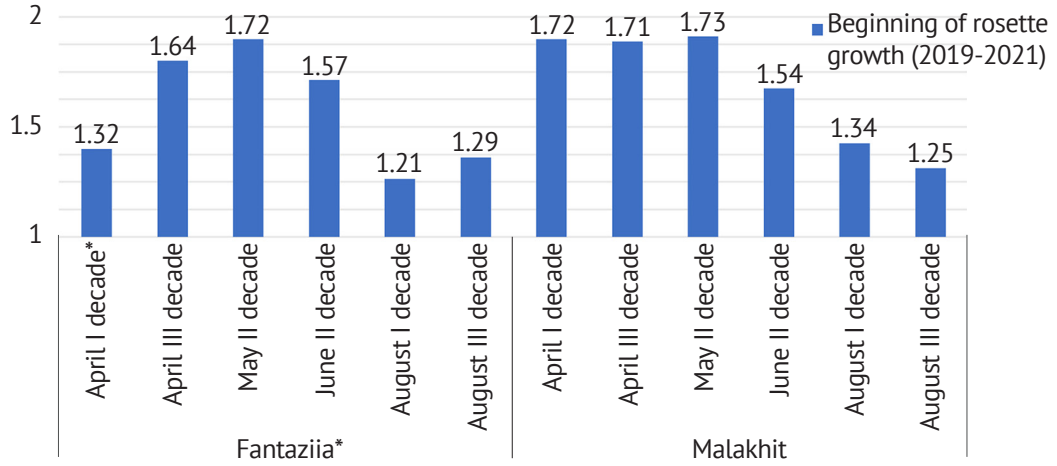

***Figure 2**. The dynamics of the leaves surface increase on the beginning of rosette growth of spinach varieties Fantaziia and Malakhit depending on the sowing date (2019-2021), thousand m²/ha*

***Source:** compiled by the authors*

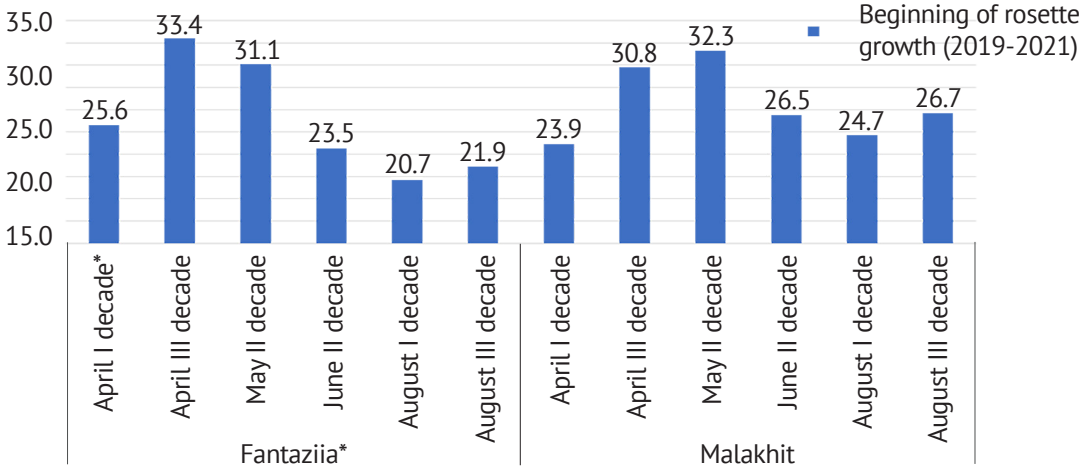

***Figure 3**. The dynamics of the leaves surface increase on the technical maturity phase of spinach varieties Fantaziia and Malakhit depending on the sowing date (2019-2021), thousand m²/ha*

***Source:** compiled by the authors*

The tendency of the leaves surface decreasing with each next sowing in the variety Fantaziia was observed. Thus, the leaves surface reached 33.4 thousand m^2/ha due to second sowing date in the III decade of April. It decreased to 31.1 thousand m^2/ha due to II decade of May and to 23.5 thousand m^2/ha due to II decade of June. In the late summer sowing dates, the leaf surface had a minimum value and amounted to 20.7 thousand m^2/ha due to sowing in the I decade of August, and 21.9 thousand m^2/ha due to III decade, which was caused by high temperature conditions of growth.

In spinach varieties Fantaziia and Malakhit before harvesting the green mass, the plants had the largest leaves surface after sowing in the III decade of April – 33.4-30.8 thousand m^2/ha and 31.1-32.3 thousand m^2/ha in the II decade of May. Plants of the Fantaziia variety sown in the II decade of May had a smaller leaves surface on the plant – 31.1 thousand m^2/ha. In the late summer sowing dates, the leaves surface of Fantasia variety was minimal and was 20.7 thousand m^2/ha during sowing in the II decade of August, and 21.9 thousand m^2/ha in the III decade, which was caused by high temperature conditions.

An index of the efficiency of varieties and growing periods of spinach in the open field is the output from one plant and from a unit of acreage. The results of the conducted research show that the variety and sowing date have a significant effect on the weight of the plant since the connection between the yield of commercial greens and the weight of one plant is quite high. It has been proven that the largest weight of a spinach plant was obtained by using early sowing dates and when sowing spinach in the I decade of April. At the beginning of the rosette growth the mass of the Fantaziia variety over the years of research reached 2.0 g, in the III decade of April – in the II decade of May – 2.5-2.8 g.

In the Malakhit variety, in the I decade of April at the beginning of rosette growth, the weight of the plant reached 2.5 g. In the III decade of April and the II decade of May it reached from 2.7 to 2.8 g, respectively. Next years the weight of the plant was on the level from 2.3 to 2.8 g in accordance to sowing date. With the use of early sowing dates for sowing of spinach in the I decade of April in the phase of technical maturity, the mass of the Fantaziia plant over the years of research reached 57.5 g, in the III decade of April – II decade of May – from 66.4 to 70.0 g. At the next years the plant weight index was smaller and amounted to 60.5-65.0 g, depending on the sowing date. In the Malakhit variety, in the I decade of April in the phase of technical maturity, the weight of the plant reached 57.0 g, in the III decade of April and the II decade of May was from 62.4 to 67.3 g, respectively.

Therefore, later sowing dates in the Southern Steppe of Ukraine coincide with high temperatures during the growth of plants. It has a detrimental effect on plants, and therefore, in later sowing dates, especially in late summer, they were smaller in weight. The main assessment of the level of influence of the variety and sowing date on the growth and development of spinach plants of the Fantaziia and Malakhit varieties is conducted based on the results of the analysis of the productivity of marketable green mass (Table 3).

***Table 3**. The yield of spinach depending on the variety and sowing date, t/ha*

Variety	Sowing date	2019	2020	2021	2019-2021	± to control
Fantaziia	April I decade*	19.6	20.5	18.9	19.7	0
	April III decade	20.9	24.7	23.3	23.0	3.3
	May II decade	21.7	23.8	23.2	22.9	3.2
	June II decade	21.3	22.2	21.9	21.8	2.1
	August I decade	19.9	21.8	21.5	21.1	1.4
	August III decade	20.6	22.7	21.9	21.7	2.1
Malakhit	April I decade	19.8	22.8	19.6	20.7	1.1
	April III decade	22.5	25.5	23.6	23.9	4.2
	May II decade	20.4	24.7	24.9	23.3	3.7
	June II decade	20.8	22.8	22.7	22.1	2.4
	August I decade	19.9	20.2	21.6	20.6	0.9
	August III decade	20.6	21.6	22.8	21.7	2.0
LSD_{05}	*Factor A*	*0.3*	*0.4*	*0.2*		
	Factor B	*0.7*	*0.6*	*0.5*		
	Interaction AB	*1.4*	*1.3*	*1.1*		

***Note:** * - control variant*

***Source:** compiled by the authors*

According to the table data, it is possible to trace the change in yield index of spinach depending on the variety and date of sowing in open field and the year of research, when the weather conditions were not the same

and mostly dry in 2019. Accordingly, the yield analysis shows that it was lower in 2019 by 19.6-22.5 t/ha, which is explained by unfavourable weather conditions during the growing season. The years 2020 and 2021 were characterized by more favourable conditions, in which the yield of marketable green mass was higher and during the early sowing dates it reached the level of 23.2-24.7 t/ha in spinach of the Fantaziia variety and 23.6-25.5 t/ha in the Malakhit variety. It was received significant yield growth at level from 3.3 to 6,0 t/ha. At the next sowing dates in the II decade of June and I and II decades of August, the productivity of the Fantaziia variety was 21.5-22.7 t/ha and Malakhit 20.2-22.8 t/ha respectively.

On average, over the years of research, the highest yield, depending on the variety, was obtained for sowing in the III decade of April and the II decade of May in the Fantaziia variety – from 22.9 to 23.0 t/ha, in the Malakhit variety – from 23,3 to 23.9 t/ha, which is higher than the control by 3.3-4.2 t/ha. A low yield was obtained from plants sown in the I decade of April and in summertime. So, when sowing spinach varieties Fantaziia and Malakhit in the I decade of April, the yield was only 18.9 and 19.6 t/ha, respectively, according to the studied variety. In the II decade of June, the yield of both varieties decreased to the level of 21.8-22.1 t/ha, which was higher than the control by 2.1-2.4 t/ha. During the late summer sowing dates in August, the yield of commercial greens was 20.6-21.7 t/ha, which is higher than the control by 0.9-2.1 t/ha.

The $LSD_{0.5}$ in quantitative terms, according to factors A and B for spinach yield was 0.2-0.7 t/ha, which indicates reliable values between their replications and variants. Three factors together (year – 49%, genetical potential of variety – 34%, sowing date – 8%) form 91% of the spinach yield in the conditions of the Southern Steppe of Ukraine (Fig. 4).

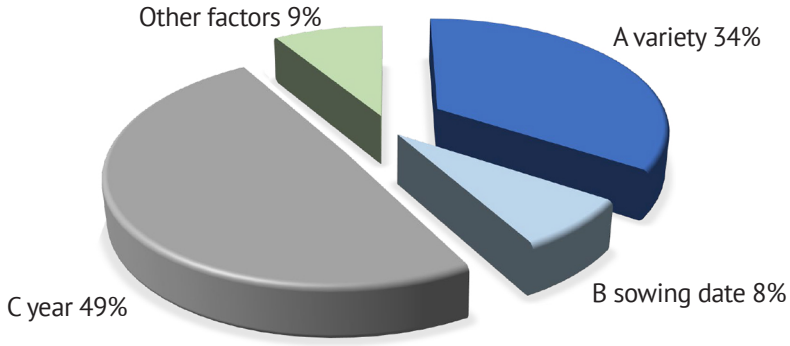

***Figure 3**. The dynamics of the leaves surface increase on the technical maturity phase of spinach varieties Fantaziia and Malakhit depending on the sowing date (2019-2021), thousand m^2/ha*

***Source:** compiled by the authors*

As a result of the conducted research, there was a need to establish important characteristics for spinach, which was conducted on the basis of calculations of correlations between biometric and productive indexes (Table 4).

***Table 4**. Matrix of correlation analysis of biometric and productive indexes of the spinach (2019-2021)*

Index	Plant height, cm	The leaves number, pcs/plant	Plant weight, g
Plant height, cm	–	–	–
The leaves number, pcs/plant	0.23	–	–
Plant weight, g	0.33	0.98	–
Yield, t/ha	0.57	0.75	0.91

***Source:** compiled by the authors*

It was found that there is a strong positive correlation between plant weight and the number of leaves (r=0.98), the yield of spinach and the plant weight (r=0.91). In parallel with the study of productivity, an assessment of the quality of products of spinach varieties was conducted according to chemical parameters in commercial products before harvesting, depending on the variety and date of sowing in open field (Table 5). The analysis of the obtained data showed that the variety and sowing date influenced the main indexes of the chemical composition of the green mass of the spinach varieties Fantaziia and Malakhit. The higher content of chlorophyll (a+b) – 0.445 ml/l was observed in plants that were sown in the III decade of April. The content of nitrates in spinach plants was at a low level in the range from 48 to 55 mg/kg and did not exceed the MAC for green leaves of spinach.

***Table 5**. Indexes of the chemical composition of spinach in different periods of growth and development depending on the variety and date of sowing (2019-2021)*

Variety	Sowing date	Brix, %	Chlorophyll (a+b), ml/l	Nitrates, mg/kg	Sugar, %	Vitamin C, mg/100 g
Fantaziia	April I decade*	6.3	0.449	51	2.2	55
	April III decade	6.7	0.449	52	2.3	61
	May II decade	6.4	0.442	49	2.3	59
	June II decade	6.4	0.429	53	2.2	55
	August I decade	5.4	0.429	52	2.1	54
	August III decade	5.8	0.408	54	2.1	54
Malakhit	April I decade	6.1	0.440	47	2.1	53
	April III decade	6.2	0.442	51	2.2	57
	May II decade	5.2	0.421	52	2.3	59
	June II decade	5.3	0.422	52	2.2	55
	August I decade	5.3	0.420	52	2.1	54
	August III decade	5.5	0.421	53	2.1	55

***Note:** * – control variant*
***Source:** compiled by the authors*

The brix in spinach leaves of varieties Fantaziia and Malakhit was at the level of 5.1-6.8% and was higher than sowing in the III decade of April and II decade of May – 6.4-6.8%, which exceeded the control by 0.3-0.7%. The mass share of sugars, depending on the variety and date of sowing in open field, fluctuated between 2.1-2.4% and was almost at the same level. Plants grown during the early sowing dates were characterized by a higher sugar content. The content of vitamin C was in the range of 52-70 mg/100 g, depending on the date of sowing. Moreover, the vitamin C content was dominated by the sowing dates in the I and III decade of April – 50-60 mg/100 g and II decade of May – 58-70 mg/100 g. So, the date of sowing had a significant influence on the main chemical parameters of the spinach varieties Fantaziia and Malakhit, and in the leaves, the higher parameters were noted for the dates of sowing in the III decade of April and the II decade of May, where the brix reached the level of 6.4-6.8%, sugars content – 2.3-2.4%, vitamin C content – 58-70 mg/100 g.

The sowing date has quite significant influence on the plant's phenotype. It was proved by conducted research. The leaf surface and total leaves surface were under attention in research as direct influencer on productivity and result production in general. The leaf surface depended on growing conditions and variety. The general tendency was observed then due to mile temperature conditions plants have more time for forming big leaves and higher number of them. On the other hand, increasing of temperatures of environment make growing period shorter and leaves size smaller. The research of Mudau *et al.* (2018) confirms than term of growing is directly influencing on leaf size and as resalt on biomass production itself. Longer growing time is showing significant difference in leaf size and biomass production. It needs to indicate than by research of Conte *et al.* (2008) was proved than climatic conditions slightly influenced visual quality of spinach leaves.

A. Bottino *et al.* (2009) and Gutiérrez-Rodríguez *et al.* (2013) conclude that dry matter is a direct indicator of leaves quality and their storage ability. The dry maters were in scope of the conducted research. The study showed that the degree of plant development, especially the accumulation of dry matter, was not directly related to the level of adaptive characteristics. The influence of the sowing date on the dry matter content was observed. It was found decreasing of their content at latest sowing dates. The highest content was found at Spring sowing and partly during Summer growing at hot climatic conditions. It a bit contradictory with research of V. Chernyshenko *et al.* (2017). The plants are forming higher content of dry matter during optimal sowing. Dry matter was depended on research variety as well in research of Alessa *et al.* (2017). It was shown in current research than varieties differently react on growing conditions and general tendence was not observed.

The sowing date still under attention of Ukrainian scientists and foreigners as well. The sowing date is quite important because it can determine growing result can has significant impact on spinach plants' productivity. The tendency of increasing of plant habitus and prolongation of the growing terms due to mild growing conditions observed. Similar tendency was shown by research of Polish scientist by E. Kunicki *et al.* (2010) which was conducted in two sowing dates only. However, instead of sowing at Spring and Autumn were investigated late Spring and Summer sowing dates for prolong possibility to obtain fresh greens during whole open field season. It was risky to grow spinach at hot conditions because yield can by decreased by 30% and more what was found by research of Tai *et al.* (2020). Conducted research partly confirmed such tendency.

The decreasing of yield was observed with growth of the day temperatures during the growing period for summer sowing dates. But decreasing was on the level not mote then 10-14%. The higher impact on yield had cold weather and wet soil at the earliest sowing date. It was observed decreasing of yield more than 15% compere to the best variant of research. Flood and water stress was studies by C. Pereira *et al.* (2019) and M. Seymen (2021) and reported than overwatered soil has negative effect on the spinach plans' characteristic and yield itself.

Studying the timing of sowing garden spinach, we believe that in the conditions of the Steppe of Ukraine, these issues are quite relevant because spring and autumn allow to extend the timing of production and obtain high yields.

CONCLUSIONS

The study of the influence of the sowing date on the leaves number revealed that when sowing of spinach varieties Fantaziia and Malakhit in the 3rd decade of April and the 2nd decade of May formed a higher number of leaves. The Fantaziia variety had 18-19 pcs/plant and Malakhit – 18-20 pcs/plant. More favourable conditions in 2020 made it possible to obtain an additional 2-4 leaves per plant. Spinach plants of both varieties had a larger leaf surface at the beginning of rosette growth during the early sowing dates - 114.2-127.7 cm^2. Plants sown in August had a smaller leaf surface – 86.0-106.2 cm^2.

Depending on the variety, the highest yield of marketable green mass was obtained for sowing in the 3rd decade of April and the 2nd decade of May in the Fantaziia variety – 22.9-23.0 t/ha, in the Malakhit variety – 23.3-23.9 t/ha, which was higher compared to control by 3.2-4.2 t/ha. The $LSD_{0.5}$ in quantitative expression according to factors A and B for spinach yield was 0.2-0.7, which indicates reliable values between their reps and variants. Three factors together (year, variety and sowing date) form 91.3% of the spinach yield.

It was established that the climatic and soil conditions of the Southern Steppe of Ukraine were suitable for sowing spinach in six sowing dates. The conveyor growing will ensure an uninterrupted supply of green products from the third decade of April to the end of September. In some years until mid-October. It will partially solve the problem of overcoming seasonality in the consumption of fresh green vegetables. The date of sowing had a significant influence on the main chemical parameters of spinach varieties. The higher indexes were noted for the dates of sowing in the 3rd decade of April and the 2nd decade of May, where the brix reached the level of 6.4-6.8%, sugars content – 2.3-2.4%, vitamin C content – 58-70 mg/100 g.

Taking into consideration the importance of fresh greens consumption during full year and positive impact on health, prospect research may be based on extension of terms of receipt of the fresh greens on account of using temporary tunnels in early spring and fixed tunnels and greenhouse in autumn-winter growing seasons.

REFERENCES

[1] Alessa, O., Najla, S., & Murshed, R. (2017). Improvement of yield and quality of two *Spinacia oleracea* L. varieties by using different fertilizing approaches. *Physiology and Molecular Biology of Plants*, 23(3), 693-702. doi: 10.1007/s12298-017-0453-8.

[2] Barcelos, C., Machado, R.M.A., Alves-Pereira, I., Ferreira, R., & Bryla, D.R. (2017). Effects of substrate type on plant growth and nitrogen and nitrate concentration in spinach. *International Journal of Plant Biology*, 7, 44-47. doi: 10.4081/pb.2016.6325.

[3] Bondarenko, H.L., & Yakovenko, K.I. (2001). *Methodology of experimental work in vegetable and melon*. Kharkiv: Osnova.

[4] Bottino, A., Degl'Innocenti, E., Guidi, L., Graziani, G., & Fogliano, V. (2009). Bioactive compounds during storage of fresh-cut spinach: The role of endogenous ascorbic acid in the improvement of product quality. *Journal of Agricultural and Food Chemistry*, 57, 2925-2931. doi: 10.1021/jf803740q.

[5] Chernyshenko, V., Pashkovsky, A., & Kyriy, P. (2017). *Modern technologies of open field vegetable growing*. Zhytomyr: Ruta.

[6] Conte, A., Conversa, G., Scrocco, C., Brescia, I., Laverse, J., Elia, A., & Del Nobile, M.A. (2008). Influence of growing periods on the quality of baby spinach leaves at harvest and during storage as minimally processed produce. *Postharvest Biology and Technology*, 50(2), 190-196. doi: 10.1016/j.postharvbio.2008.04.003.

[7] Fan, D., Hodges, D.M., Critchley, A.T., & Prithiviraj, B. (2013). A commercial extract of brown macroalga (*Ascophyllum nodosum*) affects yield and the nutritional quality of spinach in vitro. *Communications in Soil Science and Plant Analysis*, 44, 1873-1884. doi: 10.1080/00103624.2013.790404.

[8] Fan, D., Hodges, D.M., Zhang, J., Kirby, C.W., Ji, X., Locke, S.J., Critchley, A.T., & Prithiviraj, B. (2011). Commercial extract of the brown seaweed *Ascophyllum nodosum* enhances phenolic antioxidant content of spinach (*Spinacia oleracea* L.) which protects *Caenorhabditis elegans* against oxidative and thermal stress. *Food Chemistry*, 124, 195-202. doi: 10.1016/j.foodchem.2010.06.008.

[9] Fiorentino, N., Ventorino, V., Woo, S.L., Pepe, O., De Rosa, A., Gioia, L., Romano, I., Lombardi, N., Napolitano, M., Colla, G., & Rouphael, Yu. (2018). Trichoderma-based biostimulants modulate rhizosphere microbial populations and improve N uptake efficiency, yield, and nutritional quality of leafy vegetables. *Frontiers in Plant Science*, 9, 1-15. doi: 10.3389/fpls.2018.00743.

[10] Galla, N.R., Pamidighantam, P.R., Karakala, B., Gurusiddaiah, M.R., & Akula, S. (2016). Nutritional, textural and sensory quality of biscuits supplemented with spinach (*Spinacia oleracea* L.). *International Journal of Gastronomy and Food Science*, 7, 20-26. doi: 10.1016/j.ijgfs.2016.12.003.
[11] Golubkina, N.A., Kosheleva, O.V., Krivenkov, L.V., Dobrutskaya, H.G., Nadezhkin, S., & Caruso, G. (2017). Intersexual differences in plant growth, yield, mineral composition and antioxidants of spinach (*Spinacia oleracea* L.) as affected by selenium form. *Scientia Horticulturae*, 225, 350-358. doi: 10.1016/j.scienta.2017.07.001.
[12] Gutiérrez-Rodríguez, E., Lieth, H.J., Jernstedt, J.A., Labavitch, J.M., Suslow, T.V., & Cantwell, M.I. (2013). Texture, composition and anatomy of spinach leaves in relation to nitrogen fertilization. *Journal of the Science of Food and Agriculture*, 93, 227-237. doi: 10.1002/jsfa.5780.
[13] Hospodarenko, H., Yeschenko, V., & Poltorets'kyy, S. (2008). *The technology systems in crop production*. Uman: Sochinsky.
[14] Khareba, V., Korniyenko, S., Khaveba, O., Podoliak, O., & Unuchko, O. (2012). *Unusual vegetable crops*. Kharkiv: Pleiada.
[15] Kim, M.J., Shim, C.K., Kim, Y.K., Ko, B.G., Park, J.H., Hwang, S.G., & Kim, B.H. (2018). Effect of biostimulator *Chlorella fusca* on improving growth and qualities of chinese chives and spinach in organic farm. *The Plant Pathology Journal*, 34, 567-574. doi: 10.5423/PPJ.FT.11.2018.0254.
[16] Korniyenko, S.I., Khareba, V.V., Khareba, O.V., & Pozniak, O.V. (2015). *Features of the technology of growing non-traditional vegetable crops*. Vinnytsia: Nilan-LTD.
[17] Kulkarni, M.G., Rengasamy, K.R.R., Pendota, S.C., Gruz, J., Plačková, L., Novák, O., Doležal, K., & Van Staden, J. (2019). Bioactive molecules derived from smoke and seaweed *Ecklonia maxima* showing phytohormone-like activity in *Spinacia oleracea* L. *New Biotechnology*, 48, 83-89. doi: 10.1016/j.nbt.2018.08.004.
[18] Kunicki, E., Grabowska, A., Sękara, A., & Wojciechowska, R. (2010). The effect of cultivar type, time of cultivation, and biostimulant treatment on the yield of spinach (*Spinacia oleracea* L.). *Folia Horticulturae,* 22(2), 9-13. doi: 10.2478/fhort-2013-0153.
[19] Mudau, A.R., Araya, H.T., & Mudau, F.N. (2018). The quality of baby spinach as affected by developmental stage as well as postharvest storage conditions. *Acta Agriculturae Scandinavica*, 69(1), 26-35. doi: 10.1080/09064710.2018.1492009.
[20] Nova Kakhovka Hydrometeorological Station. (n.d.). Retrieved from https://www.wunderground.com/weather/ua/nova-kakhovka.
[21] Panda, V., Mistry, K., Sudhamani, S., Nandave, M., & Ojha, S.K. (2017). Amelioration of abnormalities associated with the metabolic syndrome by *Spinacia oleracea* (Spinach) consumption and aerobic exercise in rats. *Oxidative Medicine and Cellular Longevity*, article number 2359389. doi: 10.1155/2017/2359389.
[22] Pereira, C., Dias, M.I., Petropoulos, S.A., Plexida, S., Chrysargyris, A., Tzortzakis, N., Calhelha, R.C., Ivanov, M., Stojković, D., Soković, M., Barros, L., & Ferreira, I.C.F.R. (2019). The effects of biostimulants, biofertilizers and water-stress on nutritional value and chemical composition of two spinach genotypes (*Spinacia oleracea* L.). *Molecules*, 24(24), 44-94. doi: 10.3390/molecules 24244494.
[23] Pollock, M. (2012). *Fruit and vegetable gardening*. London: Dorling Kindersley Limited.
[24] Ryan, J., Estefan, G., & Rashid, A. (2001). *Soil and plant analysis laboratory manual*. Aleppo: International Center for Agricultural Research in the Dry Areas.
[25] Seymen, M. (2021). How does the flooding stress occurring in different harvest times affect the morpho-physiological and biochemical characteristics of spinach? *Scientia Horticulturae*, 275, article number 109713. doi: 10.1016/j.scienta.2020.109713.
[26] Tai, Ch., Sawada, Yu., Masuda, J., & Fukao, Yo. (2021). Cultivation of spinach in hot seasons using a micro-mist-based temperature-control system. *Scientia Horticulturae*, 273, article number 109603. doi: 10.1016/j.scienta.2020.109603.
[27] Ulianych, O., Khareba, V., Kovtuniuk, Z., Kets'kalo, Khaveba, O., & Filonova, O. (2015). *Unusual vegetable plants*. Kyiv: Agrarian science.
[28] Ulianych, O., Vdovenko, S., Kovtuniuk, Z., Kets'kalo, V., Slobodianyk, H., Vorobiova, N., Soroka, L., Didenko, I., & Kravchenko, V. (2018). *Biological features and growth of unusual vegetables*. Uman: Vizavi.
[29] Van Treuren, R., Coquin, P., & Lohwasser, U. (2012). Collections of leafy vegetables (lettuce, spinach, chicory, artichoke, asparagus, lamb's lettuce, rhubarb and rocket salad): Composition and gaps. *Genetic Resources and Crop Evolution*, 59(6), 981-997. doi: 10.1007/s10722-011-9738-x.
[30] Xu, C., & Leskovar, D.I. (2015). Effects of *A. nodosum* seaweed extracts on spinach growth, physiology and nutrition value under drought stress. *Scientia Horticulturae*, 183, 39-47. doi: 10.1016/j.scienta.2014.12.004.
[31] Zuśka, Z., Kopcińska, J., Dacewicz, E., Skowera, B., & Wojkowski, J. (2019). Application of the principal component analysis (PCA) method to assess the impact of meteorological elements on concentrations of particulate matter (PM10). *Sustainability*, 11(23), 27-40. doi: 10.3390/su11236740.

Ефективність строків сівби шпинату в умовах південного Степу України

Олена Іванівна Улянич[1], Віталій Петрович Федоренко[2], Людмила Олегівна Рябовол[1], Костянтин Миколайович Шевчук[1], Лілія Ігорівна Воєвода[1]

[1]Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна

[2]Інститут захисту рослин Національної академії аграрних наук України
03022, вул. Васильківська, 33, м. Київ, Україна

Анотація. Населення України повинно отримувати свіжу зелень від ранньої весни до осені з відкритого ґрунту і строки вирощування шпинату забезпечать постачання свіжої зелені. Метою досліджень було вивчення можливості подовження періоду надходження свіжої зелені шпинату з відкритого ґрунту за рахунок розширення строків висівання насіння у відкритому ґрунті. Дослідження проводились у 2019–2021 рр. в умовах Південного Степу України. У дослідженні було використано польові, статистичні, розрахунково-аналітичні та лабораторні методи. Досліджувалися сорти Фантазія та Малахіт. Вивчали поведінку рослин залежно від шести строків сівби. Контрольним варіантом був сорт Фантазія за строком сівби І декада квітня. Виявлено, що рослини обох сортів шпинату мали більшу листкову поверхню за ранніх строків сівби 114,2–127,7 см^2. Рослини, які висівали в серпні, мали меншу площу листкової поверхні – 86,0-106,2 см^2. Найбільший урожай товарної зеленої маси отримано за сівби у ІІІ декаді квітня та ІІ декаді травня і сорт Фантазія забезпечив 22,9–23,0 т/га, а сорт Малахіт – 23,3–23,9 т/га. Строк сівби мав значний вплив на основні хімічні показники шпинату городнього сортів Фантазія і Малахіт і вищими показниками відзначалися строки сівби у ІІІ-й декаді квітня та ІІ-й декаді травня, де вміст сухої розчинної речовини досягав рівня 6,4–6,8 %, масова частка цукрів – 2,3–2,4 %, вміст вітаміну С – 58–70 мг/100 г. Встановлено, що ґрунтово-кліматичні умови Південного Степу України придатні для сівби шпинату городнього у шість строків і забезпечать безперебійне надходження продукції з ІІІ-ї декади квітня до кінця вересня включно, а у роки з сприятливими погодними умовами у ІІ-й–ІІІ-й декадах вересня до середини жовтня, що вирішить проблему сезонності у споживанні свіжих овочів. Рекомендуємо сільгоспвиробникам досліджені строки сівби шпинату, щоб продовжити термін отримання свіжої зелені з третьої декади квітня до кінця вересня і в окремі роки до середини жовтня

Ключові слова: загальна площа листків, кількість листків, висота рослини, маса рослини, початок росту розетки, технічна стиглість