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Agroclimatic substantiation of common fennel cultivation in the Western Forest-Steppe

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Abstract. Common fennel, as a plant with a wide range of uses and a highly profitable crop, is of great interest to researchers and agricultural producers and determines the relevance of the study on the adaptation of the crop in the Western Forest-Steppe zone and the complex of technological factors in its cultivation. The purpose of the study was to identify the influence of active and effective temperatures, sowing time, row spacing width, and seeding rate on the productivity of common fennel. In the course of the study, general scientific, mathematical and statistical methods were used. In the conditions of the Western Forest-Steppe, the authors investigated the sums of active and effective temperatures in dynamics in the context of different weather conditions of the years of research and vegetation phases of common fennel plants. As a result of the conducted studies, the indicators of integral photosynthetic active radiation in the growing, generative, and

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vegetative periods of plant growth and development were analysed. The yield level of common fennel seeds, when grown on deep low-humus chernozems, was determined, depending on the sowing period and the seeding rate for row spacing under different weather conditions during the years of research. A correlation analysis was performed according to the indicators of the yield of common fennel seeds and total temperatures, which can be attributed to the main uncontrolled factors affecting the yield of agricultural crops in a particular growing zone. The expediency of growing common fennel in the conditions of the Western Forest-Steppe of Ukraine was proved in terms of the sum of active and effective temperatures during the growing season of fennel, which contributed to the generation of a sufficiently high seed yield, and the optimal sowing time, seeding rate, and row spacing for growing crops in specific soil and climatic conditions of the zone were established. The practical value of the study is conditioned by the development of recommendations for production for agricultural enterprises in the conditions of the Western Forest-Steppe on optimising the complex of technological factors in the cultivation of common fennel

Keywords: common fennel; active and effective temperatures; yield, sowing time; row spacing width; seed application rate

INTRODUCTION

The range of crop choices for cultivation depends on many factors: weather and climatic conditions, pharmaceutical production, the needs of the food and cosmetics industries, and prices for certain raw materials. One of the most valuable essential oil, medicinal, and spice crops is common fennel, the biological and technological aspects of which are practically not investigated in the Western Forest-Steppe, which indicates the relevance of choosing a research topic. Particularly relevant issues are the study of temperature compliance and improvement of such components of cultivation technology as sowing time, row spacing, seeding rate, top dressing, investigation of their impact on plant growth, development, yield, and quality indicators of seeds and their chemical composition.

In world agriculture and in European countries, common fennel is considered a crop with a wide range of uses. Common fennel plants are used completely, starting from the roots and ending with seeds, since the whole plant contains valuable biologically active substances that can serve as a component for medicines, seasoning for various dishes, flavouring, or oil for perfumes and cosmetics. The value of essential oils, in particular common fennel, as a seasoning is indicated by researchers from other countries (Xie & Finley, 2018; Sharangi & Acharya, 2018). Fennel inflorescences are a traditional culinary spice in Italy (Ferioli *et al.*, 2017). An important area of use of essential oil crops is the processing of essential oils to obtain natural food flavourings (Frolova & Ukrainets, 2010; Badgujar *et al.*, 2014). Due to the content of biologically active substances in plants, raw materials are used for medical needs as bactericidal, antiviral, anti-inflammatory, antispasmodic, sedative, and tonic agents (Zrira, 2017; Najjaa *et al.*, 2017). In addition, the plant is also characterised by carminative, secretolytic, and diuretic properties, helps to slow down the growth of tumour cells (Sarla, 2019; Granata *et al.*, 2022). The antibacterial properties of medicinal raw materials of such essential oils as coriander seed and common fennel are indicated (Lo Cantore *et al.*, 2004; Miguel *et al.*, 2010). The extract obtained on the basis of fennel is characterised by antioxidant and antimicrobial action (Mahdavi *et al.*, 2017).

Fennel essential oil consists of a number of substances, the ratio of which depends on many factors, both biological and technological. Global aspects of studying the chemical composition of common fennel are extremely relevant and substantial. The basis of research (Afifi *et al.*, 2021) is used to determine the chemical composition of essential oil in the context of substances by gas chromatography and mass spectrometry of 12 different types of fennel grown in different soil and climatic conditions. The anthelmintic effect of fennel oil (Wakabayashi *et al.*, 2015) and an extract of certain parts of the plant (Domínguez-Vigil *et al.*, 2022) have been established. Ukrainian researchers (Filipyuk & Vishnevska, 2022) have investigated the technological qualities of medicinal plant raw materials of common fennel fruits (extractives, degree of grinding, fractional composition, humidity, etc.).

Mirzoeva (2019) notes that the field of production of medicinal plants in general and essential oils in particular is very profitable and promising. At the same time, it is widely reported that medicinal crop production in Ukraine is a very narrow segment, in which demand now exceeds supply.

Issues of development and improvement of the technology of growing common fennel were studied in different zones of Ukraine. In the conditions of the Right-Bank Forest-Steppe (Vinnytsia Oblast), a study was carried out to determine the optimal timing of planting fennel seedlings, their influence on the formation of the green mass of the plant, and harvesting. Researchers (Knyaziuk *et al.*, 2019) found that increasing the width of row spacing up to 45 cm helps increase the individual productivity of common fennel. Regarding the timing of planting seedlings, the best was the early planting (April 20), which resulted in maximum seedling growth.

Studies conducted in Polissya are devoted to the investigation of the influence of sowing methods on

the yield of fennel. Researchers (Moisienko & Stotska, 2019; Stotska *et al.*, 2022) prove that in the conditions of the zone, it is advisable to sow common fennel with a row spacing of 60 cm, since this experiment option provided the optimal area of the leaf apparatus (24.2 to 25.5 thousand m^2/ha), photosynthetic potential of crops (1.512 to 1.685 mln m^2/ha*day), net photosynthetic productivity (3.39-3.65 g/m2 per day), seed yield (0.96 t/ha).

Early spring sowing with a row spacing of 45 cm is preferred by researchers in the South of Ukraine. According to (Makuha & Fedorchuk, 2016) for sowing common fennel in the third ten days of March against the background of $N_{60\text{-}90}$ were the most favourable conditions for the formation of sowing qualities and the accumulation of essential oil in seeds. Changing the row spacing width relative to 45 cm reduced seed yield by 0.08-0.17 t/ha, or by 7.3-15.5%.

Various terms of sowing common fennel have also been studied in the conditions of the Carpathian region. As a result of research (Dmytryk, 2019), the expediency of early sowing (the first ten days of April) was established, and the yield indicator for this period reached 1.58 t/ha. At medium and late sowing dates, the yield of fennel seeds decreased by 0.2 and 0.34 t/ha. In the conditions of the Western Forest-Steppe, this crop is poorly studied, so there was a need to improve technological measures for growing common fennel in the zone conditions.

The purpose of the study consisted in establishing the feasibility of growing common fennel in the conditions of the Western Forest-Steppe, considering active and effective temperatures and technological factors: the sowing period, the width of row spacing, and the seeding rate.

MATERIALS AND METHODS

The study uses general scientific methods for generalising research results, which are based on objectivity, evidence, reproduction, and mathematical and statistical methods for processing experimental data.

The research was conducted during 2015-2020 on the experimental field in the production conditions of the private enterprise "Prudivus S.M." in the Khmelnytska Oblast, Kamianets-Podilskyi district. According to the heat supply and degree of moisture during the growing season, the region belongs to a warm agroclimatic region. The main type of soil in the experimental field is deep low-humus chernozem on carbonate loessial loams, with a heavy loamy texture.

The experiment included the following factors: A – sowing period: 1st ten days of April (soil thermal regime – 6-8°C), 2nd ten days of April (soil thermal regime – 10-12°C); B – row spacing width: 15, 30, 45, and 60 cm, C – seeding rate: 1, 1.5, and 2 million germinated seeds/ha. The area of the accounting plot – 50 m^2. The repetition is fourfold. The sowing period was taken as the control – the first ten days of April, the seed application rate – 1.5 million germinated seeds/ha, and the row spacing – 60 cm.

In autumn, deep fall ploughing was carried out at 27 cm, under which $N_{45}P_{60}K_{60}$ was applied, and P_{10} was applied in the spring during sowing. When the plants were in the stemming phase, they were fertilised with $N_{30}P_{30}$. To establish the feasibility of growing common fennel in the conditions of the Western Forest-Steppe, the sums of active and effective temperatures in dynamics were determined by the phases of plant growth and development, and as the final result – the yield of the crop.

The sum of active temperatures was determined on an accrual basis by the growth and development phases of common fennel plants. The interval for sowing dates was one decade, but the generation of plant yields significantly depended on the sum of active and effective temperatures during the passage of plant growth and development phases.

To determine the yield of common fennel seeds, a Sampo-130 combine harvester was used to thresh each plot separately. Variance, correlation, and regression analyses using Excel 2003 and Statistica 6.0 programmes were used for mathematical processing of the obtained data.

RESULTS AND DISCUSSION

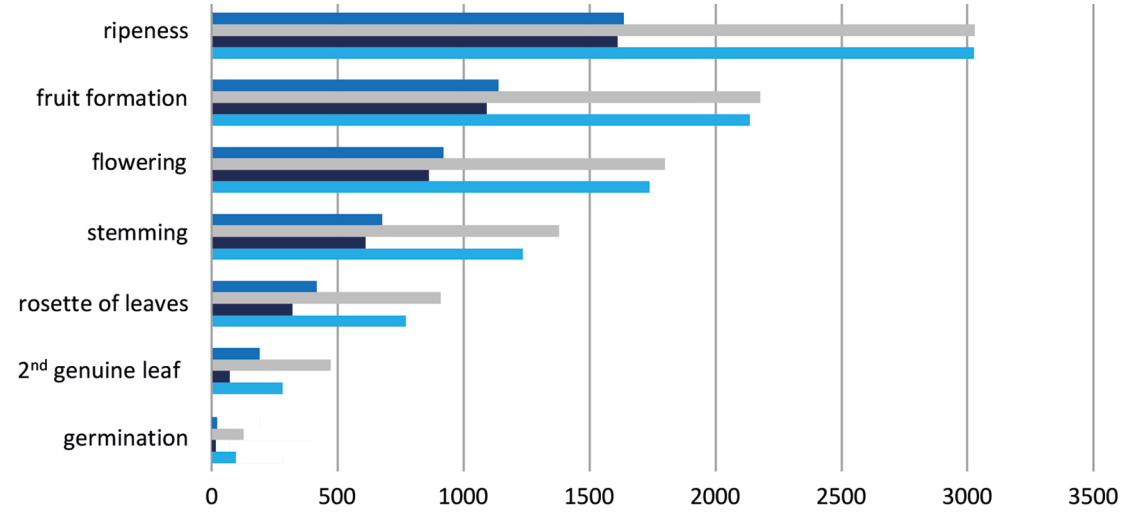
Active and effective temperatures during the growing season of common fennel were calculated in the context of years of research. The conditions in 2017 were the most favourable in terms of the accumulation of the sum of active and effective temperatures by the phases of growth and development of common fennel plants. In the ripeness phase, the sum of effective temperatures in the first sowing period was 1,611°C, in the second – 1,637°C, in the conditions of the year, optimal indicators of fennel seed yield were formed. The lowest total temperatures were characterised by 2018 and 2019. The sum of effective temperatures for the growing season and the sowing period was 1,516-1,518°C, for the second term – 1,527-1,529°C. With an increase in the sum of active and effective temperatures, the growing season of common fennel was shortened and the seed yield increased.

Under the conditions of 2017, the highest indicators of the sum of active and effective temperatures above 10°C (cumulative total) of the onset of the developmental stages of common fennel depending on the sowing dates were noted (Fig. 1).

In the context of the remaining five years of research, the following trend was observed:

In the conditions of 2015, the germination phase took place at the sum of active temperatures in the first period – 94°C, in the second – 115°C, effective respectively: 15 and 18°C. During the passage of subsequent phases of plant growth and development from the formation of the 2nd true leaf to fruit formation, the increase in both active and effective temperatures occurred quite quickly, especially during the passage of the stemming and flowering phases,

and the fruit formation and ripeness of fennel plants. The total amount of active and effective temperatures was higher in the second sowing period, active was 3,018°C, and effective – 1,629°C.



	germination	2nd genuine leaf	rosette of leaves	stemming	flowering	fruit formation	ripeness
2nd sowing period. Sum of effective temperatures		191	417	677	921	1138	1637
2nd sowing period. Sum of active temperatures		472	909	1380	1799	2179	3029
1st sowing period. Sum of effective temperatures		71	321	610	862	1092	1611
1st sowing period. Sum of active temperatures		282	772	1235	1739	2137	3025

***Figure 1**. Sums of active and effective temperatures above 10°C (cumulative total) of the onset of phases of development of common fennel depending on the time of sowing in 2017, °C*

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

In 2016, a similar trend was observed, but with slightly higher amounts of active and effective temperatures. Thus, in the growing season during the first sowing period, the sum of active temperatures was 3,015°C, effective – 1,606°C, for the second term, respectively: 3,021 and 1,632°C.

The sums of active and effective temperatures during the growth and development phases of fennel plants in 2018 and 2019 were the lowest in all the years of research. Notably, during the growing season of plants in the context of phases, the analysed indicators were very similar as well as the duration of interphase and growing seasons during these two years. A similar pattern was observed for the yield, which was the lowest in the conditions of 2018 and 2019. Thus, the growing season in the conditions of these years was the longest, if the difference in comparison with other years of research for the first period was 1-2 days, then for the second – 1-4 days, which turned out to have an impact on yield. According to the accumulation of the sum of active and effective temperatures for the growth and development phases of ordinary fennel plants, the conditions of 2020 were close to the conditions of 2016, the difference in values for the growing season was only 1-2°C. The maximum increase in temperatures was observed during the leaf rosette formation – fruit formation. In the fennel ripeness phase, the sum of active temperatures during the first sowing period was 3,013°C, second – 3,019°C, while the effective level was at the level of 1,605 and 1,630°C, respectively.

Correlation analysis performed on indicators of yield and total temperatures, which can be attributed to the main uncontrolled factors affecting the yield of agricultural crops in a particular growing zone, showed the dependence of the yield of common fennel on the sum of active temperatures ($R=0.89$, $F=8.39$, $p=0.03$). The equation obtained as a result of statistical analysis is as follows: $Yc=-199{,}059+0.218\ Sat-0{,}000\ Sat^2$. The dynamics of integral photosynthetic active radiation indicators in the cultivation of common fennel have changed over the years of research in a wide range (Table 1).

***Table 1**. Integral photosynthetic active radiation indicators ΣQ_f when growing common fennel*

Years of research	Plant vegetation periods					
	vegetative		generative		growing	
	million kcal/ha for the period	GJ for the period	million kcal/ha for the period	GJ for the period	million kcal/ha for the period	GJ for the period
2015	778.7	3,252.8	936.7	3,912.6	1,715.4	7,165.4
2016	845.4	3,531.1	887.2	3,706.1	1,732.6	7,237.2
2017	867.5	3,623.5	1,005.9	4,201.7	1,873.4	7,825.2
2018	772.4	3,226.7	934.0	3,901.3	1,706.4	7,128.0
2019	769.5	3,214.1	938.3	3,919.6	1,707.8	7,133.7
2020	845.4	3,531.3	872.6	3,644.8	1,718.0	7,176.1
V, %	10.9		6.2		7.6	

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

From the analysis of the obtained data, it can be concluded that with the values of the integral PAR indicator in the range of 1,715.4-1,873.4 million kcal/ha in the conditions of the Western Forest-Steppe, it is possible to obtain a yield of fennel seeds at the level of about 1.74-1.77 tonnes per hectare. Variational analysis proved that the lowest variability (V=6.2%) of the integral headlight indicators ΣQ_f when growing common fennel was during the generative period, and during the growing and vegetative period, an increase in variation in the years of research was recorded up to 7.6-10.9%.

Thus, the sums of active and effective temperatures during the passage of the phases of growth and development of common fennel in the conditions of the Western Forest-Steppe during the years of research were satisfactory for the full development of plants and the formation of a high yield of seeds of the crop. These indicators correlated with the duration of vegetative, generative, and growing periods of fennel and its yield. With a larger amount of active and effective temperatures, the duration of the growing season of plants decreased and seed yield increased.

The yield of fennel seeds in the experiments was very diverse, it varied depending on the conditions of the year, the sowing period of the crop, the width of row spacing, and the seeding rate. Considering all the factors of influence, the yield ranged from 0.4-1.77 t/ha (Table 2).

***Table 2**. Yield of common fennel seeds depending on the sowing period, row spacing, and seeding rate, t/ha (2015-2020)*

Row spacing width, cm (B)	Seeding rate, million germ. seeds/ha (C)	Year of research					
		2015	2016	2017	2018	2019	2020
1st sowing period (A)							
15	1	0.68	0.71	0.72	0.55	0.5	0.69
	1.5	0.87	0.9	0.91	0.66	0.6	0.89
	2	0.98	1.0	1.1	0.66	0.62	1.0
30	1	1.66	1.69	1.69	1.14	0.92	1.67
	1.5	1.38	1.42	1.44	0.97	0.94	1.12
	2	1.01	1.04	1.06	0.67	0.69	1.04
45	1	1.74	1.76	1.77	1.19	1.16	1.75
	1.5	1.28	1.32	1.36	0.9	0.88	1.77
	2	0.95	0.98	1.01	0.53	0.65	0.98
60	1	1.63	1.65	1.67	1.16	1.14	1.63
	1.5	1.09	1.12	1.14	0.86	0.83	1.1
	2	0.77	0.79	0.83	0.69	0.64	0.81
2nd sowing period (A)							
15	1	0.65	0.67	0.68	0.5	0.48	0.66
	1.5	0.81	0.85	0.9	0.4	0.56	0.84
	2	0.91	0.95	0.96	0.63	0.59	0.93

Table 2, Continued

Row spacing width, cm (B)	Seeding rate, million germ. seeds/ha (C)	Year of research					
		2015	2016	2017	2018	2019	2020
30	1	1.59	1.62	1.63	1.09	1.07	1.62
	1.5	1.32	1.36	1.38	0.92	0.9	1.35
	2	0.93	0.91	0.99	0.67	0.63	0.94
45	1	1.64	1.62	1.68	1.12	1.1	1.65
	1.5	1.17	1.18	1.22	0.82	0.78	0.78
	2	0.86	0.87	0.9	0.59	0.58	0.84
60	1	1.55	1.57	1.58	1.1	1.08	1.55
	1.5	1.04	1.05	1.08	0.83	0.79	1.05
	2	0.71	0.72	0.77	0.62	0.58	0.71
	LSD_{05}	*A-0.04* *B-0.06* *C-0.05*	*A-0.06* *B-0.09* *C-0.08*	*A-0.08* *B-0.12* *C-0.10*	*A-0.05* *B-0.06* *C-0.07*	*A-0.05* *B-0.07* *C-0.06*	*A-0.05* *B-0.07* *C-0.06*

Source: *compiled by the authors*

The lowest seed yield was in 2018 and 2019, the sum of active temperatures in these years was the lowest – in the range of 2,940-2,986°C, and effective – in the range of 1,516-1,529°C, and the growing season lasted several days longer compared to other years. The maximum yield values of 1.14-1.16 t/ha were formed by crops of the first sowing period with a row spacing of 45 cm with a seeding rate of 1 million germ. seeds/ha, the minimum – in the range of 0.4-0.5 t/ha when sowing in a continuous row for both periods.

Optimal yield indicators (on the best variants of 1.76-1.77 t/ha) were obtained in 2016 and 2017, which most corresponded to the biological characteristics of the crop by hydrothermal coefficient, the presence of sufficient precipitation for the sowing period and during flowering, the uniformity of precipitation distribution and temperature regime in the context of months. At the best variants of 2015 and 2020, the yield of fennel was 1.74 and 1.75, respectively, these are variants of the first sowing period with a row spacing of 45 cm and a seeding rate of 1 million germ. seeds/ha. Relative to the width of row spacing, the lowest yield in the context of all years of research (in the range of 0.4-1.1 t/ha) was obtained by sowing in a continuous row method, as well as wide-row methods with a seed application rate of 2 million germ. seeds/ha. That is, the yield decreased on more thickened crops. Fennel plants can form a significant aboveground part, and with a small feeding area, fewer productive shoots are formed, shading of plants occurs, i.e., the photosynthetic potential of such crops decreases and, as a result, the yield is not enough.

Based on the correlation and regression analysis of the yield data of common fennel and the data of the sum of active and effective temperatures for the growing season of the crop, the tightness of statistical relationships was determined through the indicators of multiple and paired correlation coefficients, total and partial determination coefficients, and regression coefficients were calculated (Fig. 2).

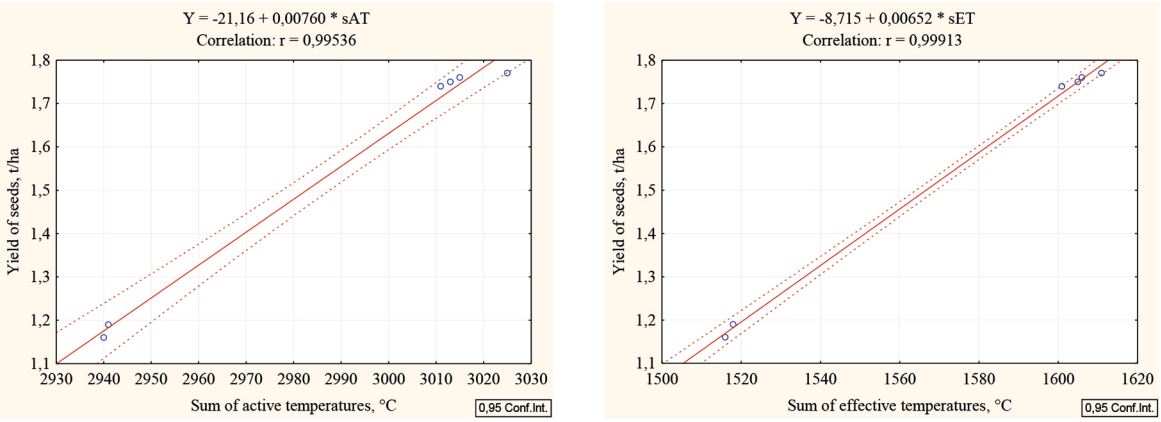


Figure 2*. Correlation and regression dependence of the yield of common fennel seeds on the sum of active and effective temperatures during the first sowing period (soil thermal regime – 6-8°C)*

Source: *compiled by the authors*

The sum of effective temperatures during the growing season of common fennel significantly affected the yield of seeds of the crop, as evidenced by the multiple correlation coefficient (R), which was equal to 0.9991. The coefficient of determination changed in the context of the studied factors in the same way as the correlation coefficient. To predict the seed productivity of fennel based on the results of statistical modelling, regression equations were developed for different sums of effective temperatures: Y=-8.71506+0.00652 sET.

Correlation and regression analysis of statistical relationships between the dependence of fennel yield on the sum of active and effective temperatures during the second sowing period (soil thermal regime – 10-8°C) showed that a similar trend was observed with the first term (Fig. 3).

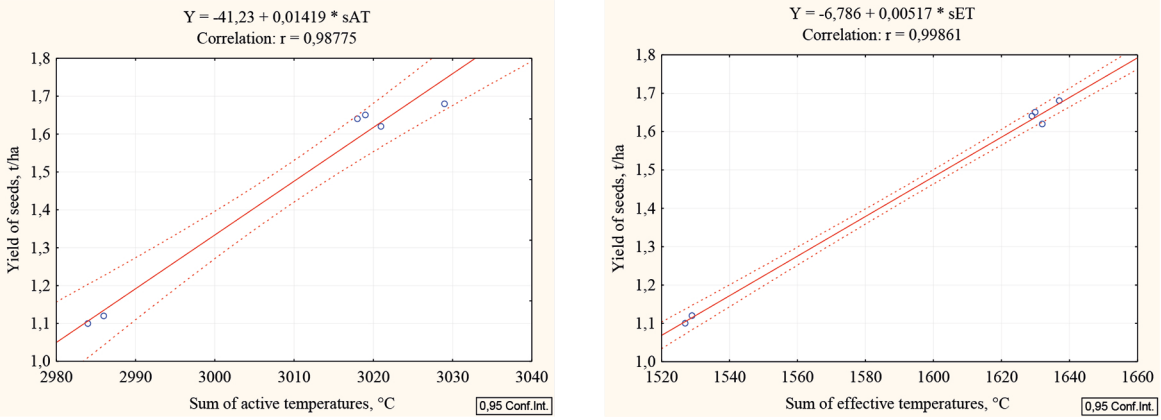


***Figure 3**. Correlation and regression dependence of the yield of common fennel seeds on the sum of active and effective temperatures during the first sowing period (soil thermal regime – 10-12°C)*

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

Thus, fennel by its biological characteristics needs early sowing dates, which range from the third decade of March to the second decade of April (depending on the growing region). Based on the conducted observations and analyses, (Kostenko, 2012) indicates the fastidiousness of common fennel to heat, moisture, and soil fertility.

Researchers in India prove the feasibility of early sowing of common fennel (Parashar & Lodha, 2012), since early spring crops are characterised by a lower incidence of crops with such a common disease as ramulariosis.

For the formation of optimal linear parameters of plants, high photosynthetic potential of agrocenoses, the formation of a high level of yield and accumulation of essential oil in seeds, the best row spacing width for most growing regions is 45 cm, as shown by the results of studies performed in the conditions of the Carpathian region. The researcher (Dmytryk, 2018) proves that with such agrotechnical parameters, the soil and climatic conditions of the zone allow obtaining a stable yield of fennel seeds at the level of 1.6 t/ha. In the conditions of the Western Forest-Steppe, fennel is able to form a yield of 1.56 t/ha under the conditions of sowing in the first decade of April with a row spacing of 45 cm and a seeding rate of 1 million germ. seeds/ha. The soil and climatic conditions of Polissya are somewhat less consistent with the biological characteristics of fennel and the yield is within 0.96 t/ha according to data (Stotska *et al.*, 2022) was obtained when sowing with a row spacing of 60 cm, that is, in these conditions, plants need a larger feeding area. With the specified width of row spacing and sowing at an early stage, plants increase such indicators as the raw mass of the plant, leaf surface area, photosynthetic potential, net photosynthesis productivity, and dry matter yield. Conclusions drawn by (Makuha, 2019) indicate that the maximum yield of common fennel seeds was obtained in the variant of the interaction of the early sowing period, row spacing width of 45 cm, nitrogen fertiliser doses of 60 and 90 kg a.s./ha, the indicators were 1.35 and 1.38 t/ha, respectively.

The largest areas of essential oil crops are concentrated in the Southern Steppe (Svidenko & Yezhov, 2015). Notably, the heat supply of the Southern Steppe zone of Ukraine allows growing common fennel as an annual crop with a growing season duration of 132-135 days, while in the conditions of the Western Forest-Steppe, 15-18 days more are needed to complete the generative period of plant development. Common fennel is among the most promising crops for the South of Ukraine, and a number of studies have confirmed the economic efficiency of its production in this growing area (Vozhegova *et al.*, 2021).

Such agrotechnical measures as increasing the width of row spacing and the number of plants per metre of linear row lengthen the duration of the generative period of development of fennel plants (Babii, 2015), this is conditioned by the formation of more umbrellas on plants with a larger feeding area. The author received the optimal yield due to the row spacing width of 45 cm and the seeding rate of 10 germinating seeds per running metre.

Thus, the feasibility of growing common fennel in different regions should be considered not only by technological factors, but also by biological ones (Stroyanovskyi & Khomina, 2021). In order to obtain a stable yield, determining the sum of active and effective temperatures when growing common fennel is an important aspect. Unfortunately, there is practically no research on this issue, with the exception of data obtained in the conditions of the Southern Steppe (Makuha & Fedorchuk, 2016; Makuha, 2020), which indicate a significant adaptive potential of the culture. According to researchers, the sum of active temperatures above 10ºC required for the formation of fennel seeds is on average 3,055ºC over the years of research, and the sum of the effective temperatures is 1,634ºC.

In recent years, there has been a redistribution of precipitation and heat regime in all zones of Ukraine, in the conditions of 2020 in the Western Forest-Steppe, when growing common fennel, the sum of temperatures was close to the data obtained in the steppe zone ten years prior, namely: active – 3,019ºC, and effective – 1630ºC, which indicates the prospects for growing common fennel in the climatic conditions of this zone.

CONCLUSIONS

The expediency of growing common fennel in the conditions of the Western Forest-Steppe of Ukraine in terms of the sum of active and effective temperatures during the growing season of common fennel was established, which contributed to the formation of a fairly high crop yield.

In the context of years of research, a similar trend was observed in the accumulation of the sum of active and effective temperatures during the growing season of common fennel, but the dynamics of plant development phases had their own characteristics and influence on the yield of seeds of the crop. In all the years of research, the total amount of active and effective temperatures was higher in the second period of fennel sowing. In the conditions of 2015, the sum of active temperatures was 3,018ºC, effective – 1,629ºC. The growing season of 2016 was characterised by slightly higher total temperatures: during the first sowing period, the sum of effective temperatures was 1,606ºC, during the second – 1,632ºC. The sums of active and effective temperatures during the growth and development phases of fennel plants in 2017-2019 were the lowest and amounted to 2,940-2,986 and 1,516-1,529ºC, respectively. The growing season in these years was the longest, and the yield was the lowest in all the years of research, but high enough for the conditions of the growing zone.

According to the accumulation of the sum of active and effective temperatures in the phases of growth and development of fennel plants, the conditions of 2020 were close to the conditions of 2016, the difference in values during the growing season was only 1-2°C. In the fennel ripening phase, the sum of active temperatures during the first sowing period was 3,013°C and 3019°C during the second sowing period, while the effective temperatures were at the level of 1,605°C and 1,630°C, respectively. Based on the results of the study, it was concluded that at the values of the integral net photosynthetic productivity in the range of 1,715.4-1,873.4 million kcal/ha in the conditions of the Western Forest-Steppe, it is possible to obtain a yield of common fennel seeds of about 1.74-1.77 t/ha.

The correlation analysis of yield indicators and the sum of temperatures, which can be attributed to the main uncontrolled factors affecting crop yield in a particular growing zone, showed the dependence of fennel yield on the sum of active temperatures (R=0.98-0.99; F=160.3-428.3). Prospects for further study are to investigate the effectiveness of growing common fennel as a two- and three-year crop, considering the sum of temperatures in the Western Forest-Steppe.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Агрокліматичне обгрунтування вирощування фенхелю звичайного в умовах Західного Лісостепу

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Анотація. Фенхель звичайний як рослина широкого спектру використання та високорентабельна культура, викликає значний інтерес у науковців та сільгосптоваровиробників і визначає актуальність досліджень з питань адаптації культури в умовах зони Західного Лісостепу та комплексу технологічних факторів при її вирощуванні. Метою досліджень було виявити вплив активних і ефективних температур, а також строку сівби, ширини міжрядь і норми висіву насіння на формування продуктивності фенхелю звичайного. В ході дослідження було використано загальнонаукові та математично-статистичні методи. В умовах Західного Лісостепу авторами було досліджено суми активних та ефективних температур в динаміці у розрізі різних за погодними умовами років досліджень та фаз вегетації рослин фенхелю звичайного. В результаті виконаних досліджень було проаналізовано показники інтегральної фотосинтетичнї активної радіації у вегетативний, генеративний та вегетаційний періоди росту і розвитку рослин. Було визначено рівень урожайності насіння фенхелю звичайного при вирощуванні на чорноземах глибоких малогумусних залежно від строку сівби, норми висіву насіння на ширини міжрядь за різних погодних умов років досліджень. Проведено кореляційний аналіз, який виконано за показниками урожайності насіння фенхелю звичайного і сумарних температур, які можна віднести до основних некерованих факторів, що впливають на урожайність сільськогосподарських культур в конкретній зоні вирощування. Було доведено доцільність вирощування фенхелю звичайного в умовах Західного Лісостепу України за показниками суми активних і ефективних температур впродовж вегетаційного періоду фенхелю, що сприяло формуванню достатньо високої урожайності насіння, а також встановлено оптимальний строк сівби, норму висіву насіння і ширину міжрядь за вирощування культури в конкретних ґрунтово-кліматичних умовах зони. Практична цінність роботи полягає в розробленні рекомендацій виробництву для аграрних підприємств умов Західного Лісостепу з питань оптимізації комплексу технологічних факторів при вирощуванні фенхелю звичайного

Ключові слова: фенхель звичайний; активні та ефективні температури; урожайність; строк сівби; ширина міжрядь; норма висіву насіння
