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The Impact Of Row Spacing On The Productivity Of Common Fennel Varieties *(Foeniculum Vulgare Mill)* Under The Conditions Of The Southern Steppe Of Ukraine.

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ABSTRACT

Common fennel (*Foeniculum vulgare Mill.*) is a valuable essential oil, medicinal, spicy, aromatic, melliferous, vegetable and ornamental plant. It finds application in medicine, cooking, various industries, in veterinary medicine, animal husbandry. Fennel belongs to highly profitable crops; therefore its cultivation in the southern Steppe of Ukraine will significantly improve the performance of agricultural enterprises, especially farms. Our field experiments were carried out in 2016-2018 in the Kherson region on dark chestnut soils typical for the zone. The experimental design included fennel varieties Oksamyt Krymu, Mertsyshor and four gradations of row spacing – 15, 30, 45 and 60 cm. In the experiment, the biometric characteristics of fennel plants reached their maximum values under sowing the Oksamyt Krymu variety with row spacing of 45 cm: plant height was 98.1 cm, leaf surface area – 28.1 thousand m^2/ha, dry overground mass of plants – 6.42 t/ha. The highest crop productivity and seed quality indicators were also recorded in this variant: yielding capacity was 1.32 t/ha, weight of 1000 seeds amounted to 5.31 g, essential oil content in seeds made up 5.98% in dry matter, relative yield of essential oil being 69.5 kg/ha. The Mertsyshor variety cultivation and any changes in the row spacing against 45 cm led to a decrease in the above-mentioned parameters. Thus, on dark chestnut soils of the southern Steppe of Ukraine, the most favourable conditions for fennel cultivation were provided by the interaction of the following parameters of the investigated factors: the Oksamyt Krymu variety, row spacing of 45 cm.

Keywords: common fennel, fennel variety, row spacing, biometric characteristics of plants, seed yield, essential oil content in seeds.

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INTRODUCTION

Common fennel (*Foeniculum vulgare Mill.*) belongs to the *Apiaceae* family and is native to the Mediterranean areas [1]. Fennel is a perennial plant grown as an annual or biennial crop depending on the soil-climatic conditions of the zone, heat resources availability, winter period specifics [2].

The popularity of fennel in the world is increasing [3]. It is a valuable essential oil, medicinal, spicy, aromatic, melliferous, vegetable and ornamental plant. Fennel finds application in medicine, cooking, various industries, as well as in veterinary medicine, animal husbandry [1, 4].

The beneficial properties of plants are caused by the essential oil and its major components – anethole, fenchone, estragole. Different organs of fennel plants contain chemicals, most interest is in seeds from which an essential oil is extracted [1, 5]. A number of chemical constituents and various therapeutic effects of this herb have been reported by different workers [6].

Fennel is a popular herb with a long history of use in traditional medicine for a wide range of ailments related to digestive, endocrine, reproductive, and respiratory systems [5]. Its medicinal applications include use as antispasmodic, carminative, diuretic, analgesic, expectorant, laxative, stomachic, appetite stimulant, anti-inflammatory cure. Recent studies have shown that essential oil can be used as a valuable antioxidant, antibacterial and antifungal agent [1, 5, 6].

The seed spices constitute an important group of agricultural commodities [7]. Fennel seeds, essential oil and extracts are commonly used to flavour food products and in manufacturing of condiments, perfumes, soaps, cosmetics, toothpastes, air fresheners [1, 4].

Fennel is widespread in almost all the countries, but not grown on a wide scale [3]. The traditional zones of its cultivation are sunny regions with sufficient rainfall and favourable temperature conditions [1]. The main fennel-producing countries are India, Russia, Mexico, Iran, China, Syria, Bulgaria, Turkey, Egypt, Ukraine, and others [3]. In India, seed spice fennel is grown covering an area of about 76 thousand ha with the production of 129 thousand tonnes in 2015-2016 [8]. It is one of the most important economic crops for export in Egypt [9].

In many countries of the world, considerable attention has been paid to improving the elements of the growing technology of this crop as well as to studies of varietal composition, fertilizers, irrigation, sowing dates and methods, seeding depth, plant density, etc. [7, 10-18].

In Ukraine the traditional zones of fennel cultivation are Western regions [4]. In recent years, due to the rapid development of various industries and increase of production capacity, there was a necessity of expansion of areas under common fennel and its introduction into rotation in new regions. Since 2011, scientific research and the introduction of this crop into cultivation under arid conditions in the southern Steppe of Ukraine have been conducted. In this zone fennel seeds are formed during one vegetative period, therefore the crop is grown as an annual plant. The cultivation of fennel as a biennial crop is connected with the risk of plant death and thin stand under the influence of a complex of adverse factors of the winter period [2].

Fennel is a promising, highly profitable crop. Major factors determining the economic efficiency of its cultivation are the local scale of sown areas, stable demand for raw material, high purchase prices, possibility of multi-purpose use of raw materials and their export to other countries. Therefore fennel cultivation will significantly improve the performance of agricultural enterprises in the region, especially farms tending to produce environmentally friendly products [19].

The introduction of common fennel in the southern steppe region of Ukraine requires improvement of separate elements of growing technology, taking into account specific soil-climatic conditions of the zone and their effect on the growth, development, productive processes of plants.

MATERIALS AND METHODS

The experiments (2016-2018) were carried out in the southern steppe zone of Ukraine on the fields of Nadiia farm of Velyka Oleksandrivka district in Kherson region, meeting generally accepted requirements and recommendations [20].

The climate of the zone is continental, hot and dry, characterized by low and unevenly distributed precipitation, low air humidity, frequent droughts and strong dry winds, a lot of heat and light. The sum of active temperatures above 10°C is 3200-3400°C, average annual precipitation is 340-400 mm, and the hydrothermal coefficient is 0.5-0.7.

Weather conditions during the years of research differed somewhat in the temperature regime, amount and distribution of atmospheric precipitation, but overall were typical for the zone of the southern Steppe of Ukraine.

The soil of the experimental plot is dark chestnut weakly alkaline medium loamy, typical for the zone. The arable layer of the soil contains humus (2.28%), nitrates (26), movable phosphorus (34), exchangeable potassium (250 mg/kg of soil), pH of water extract (7.0-7.2).

The experimental design included the following factors and their variants: Factor A – fennel variety: Oksamyt Krymu, Mertsyshor; Factor B – row spacing: 15, 30, 45, 60 cm. The trial was based on a split plot method with a four-fold replication. The sown area of the second-order elementary plot was 70 m^2; the record plot was 55 m^2.

The research tasks included determining the impact of the studied factors on the duration of interphase and vegetative periods, biometric characteristics of plants, yielding capacity and quality traits of fennel seeds under dry conditions of the southern Steppe of Ukraine.

Phenological observations, biometric measurements, harvesting and yield record, determining the 1000-seed weight, sowing qualities and essential oil content in seeds were done according to the relevant methods [20-23].

There were used generally accepted agricultural practices of fennel cultivation, except for the factors and variants studied. Winter wheat was the preceding crop in the experiment. We applied 60 kg of the active ingredient of ammonium sulphate per ha. Seeding date was the third ten-day period of March, seeding rate – 5 kg/ha, seeding depth – 2-3 cm, plant density – 600 thousand/ha. Fennel seeds were harvested when the fruits reached maturity on the central umbel and first-order umbels.

RESULTS AND DISCUSSION

The duration of the vegetative period, the basic biometric characteristics of fennel plants, quantitative and qualitative indicators of seed yield are genetically determined traits of the crop and variety. These indicators can vary within certain limits under the influence of soil-climatic conditions of the zone, specifics of weather conditions of individual years, agrotechnical measures.

Creating a favourable environment for growth and development of fennel plants, implementing the potential of its productivity and obtaining stable seed yield with high content of essential oil is connected with the improvement of the elements of growing technology of the crop.

The length of the sowing-sprouting period of fennel variety Oksamyt Krymu was 23 days. On the experimental plots of the Mertsyshor variety, fennel sprouts were observed 3 days later.

The duration of the sprouting-stem formation period varied depending on the investigated factors from 60 to 63 days. The range of variation in the length of the stem formation-flowering stage was 20-23 days. The period of flowering-maturity was the most stable in respect to the studied factors. Its duration on the plots of sowing fennel variety Oksamyt Krymu was 54 days, the Mertsyshor variety – 55 days. The length of the vegetative period of fennel was 134-141 days (Fig. 1).

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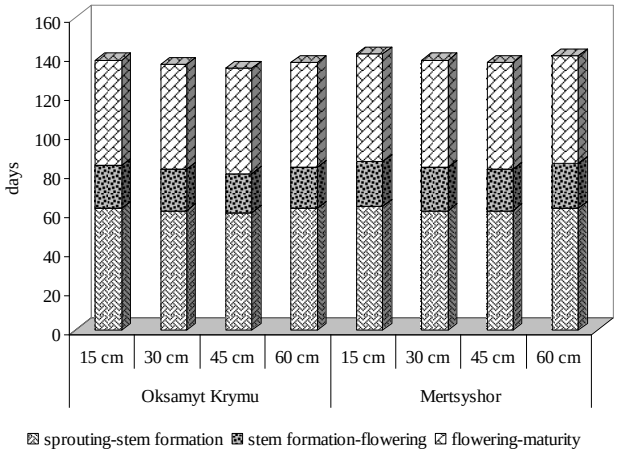

Figure 1: The duration of interphase and vegetative periods of common fennel depending on the factors under study, days

The length of the vegetative period of fennel variety Oksamyt Krymu was shorter by 2-3 days compared to the Mertsyshor variety. Changing the row spacing from 45 to 30 and 15 cm led to a longer vegetative period of fennel by 1-2 and 4 days, respectively. Sowing with row width of 60 cm prolonged the above mentioned period of the crop by 3 days.

The height of fennel plants changed in the context of variants from 82.4 to 98.1 cm (Table 1). The biggest value of this character was obtained on the experimental plots after sowing fennel variety Oksamyt Krymu with row spacing of 45 cm. The minimum value was recorded, when the Mertsyshor variety was sown with row spacing of 15 cm.

Table 1: Height of fennel plants depending on the factors under study, cm (average for 2016-2018)

Fennel variety, factor A	Row spacing, cm, factor B				Average for factor A
	15	30	45	60	
Oksamyt Krymu	86.3	92.4	98.1	87.9	91.2
Mertsyshor	82.4	90.1	95.2	85.7	88.4
Average for factor B	84.4	91.3	96.7	86.8	89.8
LSD_{05}, cm (assessment of significance of partial differences): A=1.41; B=2.04					
LSD_{05}, cm (assessment of significance of mean (main) effects): A=0.43; B=0.58					

On average, by factor A, the parameter under study of the Oksamyt Krymu variety was 91.2 cm. On the experimental plots of sowing fennel variety Mertsyshor, there was a 3.1% reduction in plant height compared to the Oksamyt Krymu variety.

On average, by factor B, the height of common fennel plants reached the maximum value – 96.7 cm under sowing with row spacing of 45 cm. The investigated indicator reduced when row spacing was changed in comparison with 45 cm. We observed a 5.6 and 12.7% height decrease with an inter-row narrowing to 30 and 15 cm, respectively. The inter-row widening to 60 cm led to a decrease in the height of fennel plants by 10.2%.

The leaf surface area of plants was minimal in the variants of the interaction of fennel variety Mertsyshor and row spacing of 15 and 60 cm and was 25.1 and 25.3 thousand m^2/ha, respectively. The most favourable conditions for the leaf surface formation of plants at 28.1 thousand m^2/ha were provided by a combination of the following parameters of the investigated technological practices: common fennel variety Oksamyt Krymu, row spacing of 45 cm (Table 2).

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Table 2: Leaf surface area of common fennel depending on the factors under study, thousand m^2/ha (average for 2016-2018)

Fennel variety, factor A	Row spacing, cm, factor B				Average for factor A
	15	30	45	60	
Oksamyt Krymu	25.7	26.8	28.1	25.9	26.6
Mertsyshor	25.1	26.2	27.4	25.3	26.0
Average for factor B	25.4	26.5	27.8	25.6	26.3
LSD_{05}, thousand m^2/ha (assessment of significance of partial differences): A=0.52; B=0.97					
LSD_{05}, thousand m^2/ha (assessment of significance of mean (main) effects): A=0.21; B=0.29					

The average factor value of the investigated feature under sowing the Oksamyt Krymu variety was 26.6 thousand m^2/ha. On the experimental plots of fennel variety Mertsyshor the leaf surface area decreased by 2.3%.

The results of the studies indicate a clear tendency to a lower the investigated character with changing the row spacing relatively 45 cm. The highest mean factor value of the leaf surface area of 27.8 thousand m^2/ha was recorded at row spacing of 45 cm. Fennel was sown with row spacing of 15, 30 and 60 cm, its leaf surface area decreased by 8.6, 4.7 and 7.9%, respectively.

The dry overground mass of plants changed according to variants of experiment from 5.57 to 6.42 t/ha. The least favourable conditions for accumulation of fennel dry matter were observed under sowing the Mertsyshor variety with row spacing of 15 and 60 cm – 5.57 and 5.69 t/ha, respectively. The most favourable conditions were ensured by the interaction of the following parameters of the investigated factors: the Oksamyt Krymu variety, row spacing of 45 cm. In this variant, the dry overground mass of fennel plants reached the maximum level of 6.42 t/ha (Table 3).

Table 3: Dry overground mass of fennel plants depending on the factors under study, t/ha (average for 2016-2018)

Fennel variety, factor A	Row spacing, cm, factor B				Average for factor A
	15	30	45	60	
Oksamyt Krymu	5.73	6.09	6.42	5.86	6.03
Mertsyshor	5.57	5.90	6.21	5.69	5.84
Average for factor B	5.65	6.00	6.32	5.78	5.93
LSD_{05}, t/ha (assessment of significance of partial differences): A=0.103; B=0.164					
LSD_{05}, t/ha (assessment of significance of mean (main) effects): A=0.041; B=0.048					

On average, by factor A, the analyzed characteristic of the Oksamyt Krymu variety was more than that of the Mertsyshor variety by 3.3%. Changing the row width relatively 45 cm led to a decrease of fennel dry matter. The range of reduction of this indicator, for factor B was 5.1-10.6%.

The yielding capacity of fennel seeds varied depending on the interaction of the investigated parameters of the technological practices in the range from 1.01 to 1.32 t/ha. Seed productivity of fennel was minimal in variants of sowing the Mertsyshor variety with row spacing of 15 and 60 cm and came to 1.01 and 1.06 t/ha, respectively. The investigated index reached the highest value of 1.32 t/ha under sowing the Oksamyt Krymu variety with row spacing of 45 cm (Table 4).

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Table 4: Seed yield of common fennel depending on the factors under study, t/ha (average for 2016-2018)

Fennel variety, factor A	Row spacing, cm, factor B				Average for factor A
	15	30	45	60	
Oksamyt Krymu	1.08	1.20	1.32	1.11	1.18
Mertsyshor	1.01	1.13	1.26	1.06	1.12
Average for factor B	1.05	1.17	1.29	1.09	1.15
LSD_{05}, t/ha (assessment of significance of partial differences): A=0.021; B=0.032					
LSD_{05}, t/ha (assessment of significance of mean (main) effects): A=0.007; B=0.009					

Among the studied varieties, the highest level of crop productivity (1.18 t/ha) was provided by sowing the Oksamyt Krymu. The mean factor value of seed yield on the experimental plots of sowing the Mertsyshor variety was lower by 5.1%.

The research results indicate a preference for fennel sowing with row spacing of 45 cm compared to other sowing methods under study (15, 30 and 60 cm). When fennel was sown with row spacing of 45 cm, average the seeds yielding capacity amounted to 1.29 t/ha. Sowing with row spacing of 15 and 30 cm led to a decrease of this indicator by 18.6 and 9.3%, respectively. With an increase in the row spacing up to 60 cm, the seed productivity decreased by 15.5%.

The highest weight of seeds per plant (2.20 g) was observed on the experimental plots of the Oksamyt Krymu variety sowing with row spacing of 45 cm. The number of seeds per plant was also maximal in this version and amounted to 414 (Fig. 2).

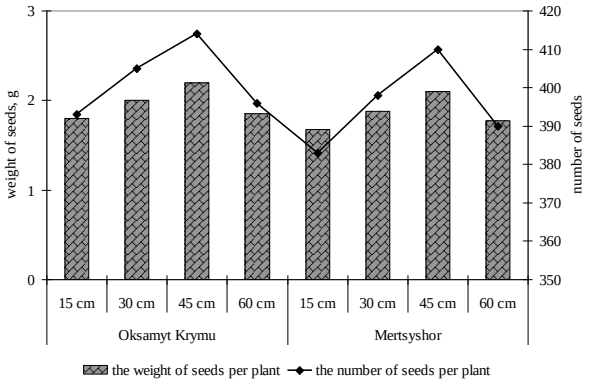

Figure 2: Seed productivity of certain plant of common fennel depending on the factors under study

Seed productivity of certain plant reduced when fennel variety Mertsyshor was sown in comparison with the Oksamyt Krymu variety. Changing the row spacing compared with 45 cm led to a decrease in the studied parameters.

The range of variation in the weight of 1000 fennel seeds, depending on the interaction of the investigated elements of the growing technology, was 4.39-5.31 g. This index was minimal on the experimental plots of sowing the Mertsyshor variety with row spacing of 15 and 60 cm and made up 4.39 and 4.53 g, respectively. The maximum of this indicator (5.31 g) was recorded in the variant of the interaction of sowing fennel variety Oksamyt Krymu and seeding with row spacing of 45 cm (Table 5).

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Table 5: Weight of 1000 seeds of common fennel depending on the factors under study, g (average for 2016-2018)

Fennel variety, factor A	Row spacing, cm, factor B				Average for factor A
	15	30	45	60	
Oksamyt Krymu	4.58	4.94	5.31	4.67	4.88
Mertsyshor	4.39	4.73	5.12	4.53	4.69
Average for factor B	4.49	4.84	5.22	4.60	4.78
LSD_{05}, g (assessment of significance of partial differences): A=0.093; B=0.136					
LSD_{05}, g (assessment of significance of mean (main) effects): A=0.027; B=0.039					

The mean factor value of the weight of 1000 fennel seeds on the experimental plots of sowing the Oksamyt Krymu variety amounted to 4.88 g. The investigated index of the Mertsyshor variety reduced of 3.9%.

The most favourable conditions for seeds formation were observed under sowing with row spacing of 45 cm. In this variant, the weight of 1000 fennel seeds reached the highest mean factor value of 5.22 g.

Reducing the row spacing from 45 to 30 and 15 cm caused a decrease of this indicator by 7.3 and 14.0%, respectively. With an increase in the row spacing to 60 cm, the weight of 1000 fennel seeds decreased by 11.9%.

The problem of high-quality seeds is especially timely in the cultivation of common fennel. It is connected with the morphological and biological characteristics of fennel seeds: a dense hull, small size, low sowing qualities compared to other crops [24].

The analysis of the indicators of sowing qualities of fennel seeds revealed similar regularities of effect of agrotechnical practices under study on the weight of 1000 seeds, laboratory germination and energy of germination. Larger seeds are characterized by better sowing qualities (higher laboratory germination and energy of germination), which may be due to better embryo development and accumulation of more nutrients in the endosperm [24].

The laboratory germination reached the maximum level of 82.7% on the plots of sowing the Oksamyt Krymu variety with row spacing of 45 cm. In this variant, the energy of germination was 40.1% (Fig. 3).

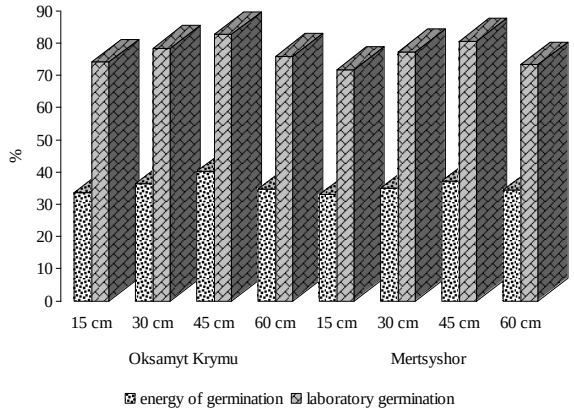

Figure 3: Sowing qualities of fennel seeds depending on the factors under study, %

The content of essential oil in fennel seeds reached its highest value of 5.98% in dry matter on the experimental plots of the Oksamyt Krymu variety sowing with row spacing of 45 cm. The mass fraction of essential oil in fennel seeds was minimal under sowing the Mertsyshor variety with row spacing of 15 and 60 cm – 5.46 and 5.51%, respectively (Fig. 4).

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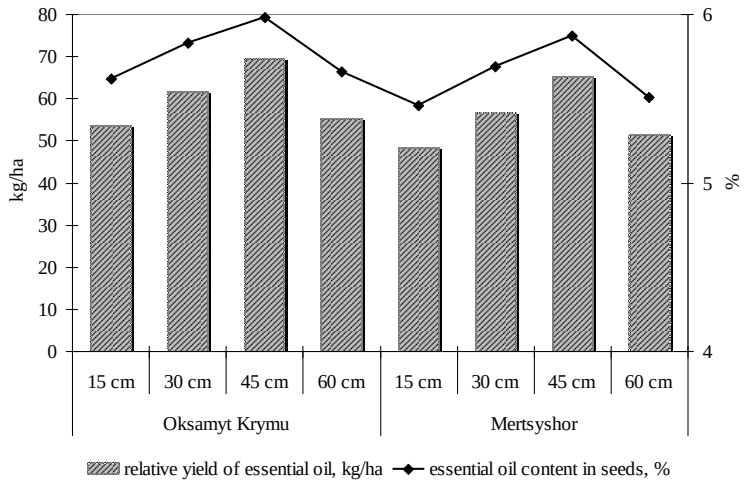

Figure 4: Content in seeds and relative yield of essential oil of common fennel depending on the factors under study

The mean factor value of this character on the plots of sowing fennel variety Oksamyt Krymu was 5.77% in dry matter. The content of essential oil in seeds the Mertsyshor variety decreased by 1.02-fold.

The highest factor average of the investigated index – 5.93% in dry matter was observed under sowing with row spacing of 45 cm. Changes in the row width both towards its decrease and increase negatively affected the mass fraction of essential oil in fennel seeds. The range of reduction of this parameter for all gradations of factor B compared with the variant of sowing with row spacing of 45 cm was 1.03-1.07 times.

The relative yield of essential oil from 1 hectare of the crop area changed depending on the interaction of investigated fennel varieties and sowing methods from 48.5 to 69.5 kg/ha. The lowest index under study was in variants of sowing fennel variety Mertsyshor with row spacing of 15 and 60 cm – 48.5 and 51.4 kg/ha, respectively. The maximum value (69.5 kg/ha) was recorded under sowing the Oksamyt Krymu variety, the row spacing being 45 cm (Fig. 4).

On average, by factor A, the relative yield of essential oil of the Oksamyt Krymu variety was 60.0 kg/ha. On the experimental plots of fennel variety Mertsyshor, there was observed a reduction in its value by 7.7%.

The average factor relative yield of essential oil in the variant of sowing with row spacing of 45 cm was 67.3 kg/ha. Changing the row width led to a 12.2-24.2% decrease in its value.

CONCLUSIONS

The most favourable conditions for fennel plant growth and development, seed formation and accumulation of essential oil on dark chestnut soils of the southern Steppe of Ukraine were ensured by the interaction of such parameters of the investigated technological practices as the Oksamyt Krymu variety, row spacing of 45 cm. In this variant, the biometric characteristics of fennel plants reached the maximum values: plant height was 98.1 cm, leaf surface area amounted to 28.1 thousand m^2/ha, dry overground mass of plants being 6.42 t/ha. The highest level of crop productivity and seed quality was also recorded under sowing fennel variety Oksamyt Krymu with row spacing of 45 cm: yielding capacity was 1.32 t/ha, weight of 1000 seeds – 5.31 g, laboratory germination – 82.7%, energy of germination – 40.1%, essential oil content in seeds – 5.98% in dry matter, relative yield of essential oil – 69.5 kg/ha.

We recommend that agricultural producers, when growing common fennel under arid conditions of the southern Steppe of Ukraine, carry out the Oksamyt Krymu variety sowing with row spacing of 45 cm.

REFERENCES

[1] Bown D. Encyclopaedia of herbs & their uses. London: Dorling Kindersley Limited, 1995, 383 p.

[2] Makukha O.V. Rost i razvitie rastenii fenkhelia obyknovennogo 2018; Aekonomika: ekonomika i selskoe khoziaistvo, 5 (29): http://aeconomy.ru/science/agro/rost-i-razvitie-rasteniy-fenkhelya-/.

[3] Fennel Global Production and Top Producing Countries: www.tridge.com/intelligences/ fennel/production.

[4] Lykhochvor V.V. Roslynnytstvo. Tekhnolohii vyroshchuvannia silskohospodarskykh kultur. Kyiv: Tsentr navchalnoi literatury, 2008, pp. 626-628.

[5] Shamkant B. Badgujar, Vainav V. Patel, and Atmanam H. Bandivdekar. *Foeniculum vulgare Mill.*: A Review of Its Botany, Phytochemistry, Pharmacology, Contemporary Application, and Toxicology 2014; BioMed Research International, Vol. 2014, Article ID 842674: 32 pages: http://dx.doi.org/10.1155/2014/842674.

[6] Musharaf Khan, Shahana Musharaf. *Foeniculum vulgare Mill.* A Medicinal Herb 2014; Medicinal Plant Research, Vol. 4, No. 6: 46-54.

[7] Dilip Singh. On-farm Assessment of Technological Innovation of Fennel (*Foeniculum vulgare Mill.*) Cultivation 2017; International Journal of Current Microbiology and Applied Sciences, Vol. 6, No. 7: 1504-1509.

[8] Horticultural Statistics at a Glance 2017. Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, p. 48.

[9] Shabbara M.H.M., Karima A. Mohamed, Yousria. A.E. Allam and Eman Abd Elghafoor Ahmed. Comparative analytical economic study of the high yield varieties production of *Foeniculum vulgare Mill.* (Fennel) between Arabic Republic of Egypt and India 2018; Middle East Journal of Agriculture Research, Vol. 7, Issue 4: 1514-1520.

[10] R.L. Meena, S.K. Ambast, S.K. Gupta, Anil R. Chinchmalatpure and D.K. Sharma. Performance of Fennel (*Foeniculum vulgare Mill.*) as Influenced by Saline Water Irrigation and Organic Input Management in Semi-arid Conditions 2014; Journal of Soil Salinity and Water Quality, 6 (1): 52-58.

[11] R.M. Solanki, M.S. Vasava and B.S. Gohil. Influence of Drip Irrigation and Fertility Levels on Growth, Yield and Water Use Efficiency of Drilled Rabi Fennel (*Foeniculum vulgare Mill.*) 2017; International Journal of Science, Environment and Technology, Vol. 6, No. 3: 1972-1978.

[12] Prakash Waskela, I S Naruka and R PS Shaktawat. Effect of Row Spacing and Level of NPK on Growth and Yield of Fennel (*Foeniculum vulgare*) 2017; Journal Krishi Vigyan, 6 (1): 78-82.

[13] Abd El-Aleem Wafaa, Hendawy SF, Hamed ES and Toaima WIM. Effect of Planting Dates, Organic Fertilization and Foliar Spray of Algae Extract on Productivity of Dutch Fennel Plants under Sinai Conditions 2017; Journal of Medicinal Plants Studies, 5 (3): 327-334.

[14] Muhammad Ayub, Rizwan Maqbool, Muhammad Tahir, Zoaib Aslam, Muhammad Ather Nadeem and Muhammad Ibrahim. Improved Growth, Seed Yield and Quality of Fennel (*Foeniculum vulgare Mill.*) Through Soil Applied Nitrogen and Phosphorus 2015; Pakistan Journal Agricultural Research, Vol. 28, No. 1: 71-76.

[15] Olga Makukha, Olena Markovska, Hanna Mynkina, and Yevheniia Chernyshova. The Impact of Seeding Dates and Depth on the Productivity of Common Fennel *(Foeniculum vulgare Mill.)* under the Conditions of the Southern Steppe of Ukraine 2018; Research Journal of Pharmaceutical, Biological and Chemical Sciences, 9(6): 1075-1083.

[16] Selim S.M., Ebtsam M.M. Abdella, Tawfik M.S.H. and Abou-Sreea A.I. Effect of Sowing Date, Sow Spacing and Bio-Fertilizer on Yield and Oil Quality of Fennel Plant (*Foeniculum vulgare Mill.*) 2013; Australian Journal of Basic and Applied Sciences, 7 (2): 882-894.

[17] Al-Dalain SA, Abdel-Ghani AH, Al-Dala'een JA, Thalaen HA. Effect of planting date and spacing on growth and yield of fennel (*Foeniculum vulgare Mill.*) under irrigated conditions 2012; Pak J Biol Sci., 15 (23): 1126-1132.

[18] S.G. Moosavi, M. Seghatoleslami, E. Ansarinia. Fennel Morphological Traits and Yield as Affected by Sowing Date and Plant Density 2014; International Journal of Biosciences, Vol. 5, No. 4: 222-229.

[19] Fedorchuk M.I., Makukha O.V. Ekonomichna otsinka tekhnolohii vyroshchuvannia fenkheliu zvychainoho pry introduktsii v umovakh pivdennoho Stepu Ukrainy 2013; Zroshuvane zemlerobstvo, Vyp. 59: 194-196.

[20] Yeshchenko V.O., Kopytko P.H., Opryshko V.P., Kostohryz P.V. Osnovy naukovykh doslidzhen v ahronomii. Kyiv: Diia, 2005, 288 p.

[21] Permiakov A.N. Programme "AreaS" 2.1: http://www.ssaa.ru/index.php?id=proekt &sn=06.

[22] Semena efiromaslichnykh kultur. Metody opredeleniia vskhozhesti: GOST 30556-98, ot 1998-05-23 (Mezhgosudarstvennyi standart). Minsk: Mezhgosudarstvennyi sovet po standartizatcii, metrologii i sertifikatcii, 1998, 8 p.
[23] Plody efirooliinykh kultur dlia promyslovogo pererobliannia. Metody vyznachennia masovoi chastky efirnoi olii: DSTU 7109:2009, vid 2011-01-01 (Natsionalnyi standart Ukrainy). Kyiv: Derzhspozhyvstandart Ukrainy, 2011, 12 p.
[24] Makukha O.V. Posevnye kachestva semian fenkhelia obyknovennogo (*Foeniculum vulgare Mill.*) 2018; Vestnik Prikaspiia, 1 (20): 14-18.