JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2024, 25(7), 246–255
https://doi.org/10.12911/22998993/188602
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.04.21
Accepted: 2024.05.17
Published: 2024.06.01

The Productivity of Sareptsky Mustard Depends on the Sowing Rate and the Level of Biologization of the Crop Growing Technology

Oleksandr Zhuykov[1], Sergiy Lavrenko[1*], Tatyana Khodos[1], Viacheslav Ursal[1]

[1] Faculty of Agriculture, Kherson State Agrarian and Economic University, 23, Stritenska St., Kherson, Ukraine
* Corresponding author's e-mail: lavrenko.sr@gmail.com

ABSTRACT

The limiting factors for the popularization of Sarepta mustard in Ukraine are the lack of developed and ecologically adapted zonal technologies for its cultivation, certain dogmatism and stereotypes of the majority of agricultural producers regarding the economic feasibility of introducing Sarepta mustard in crop rotations, as well as bias regarding the effectiveness of biologic elements in the production technologies of plant raw materials. A field experiment was conducted to improve the technology of growing Sarepta mustard. The experiment scheme included the following factors and their variants: Factor A (culture cultivation technology) was represented by variants of the traditional zonal mustard cultivation technology; biologized technology (rejection of mineral fertilizers and their replacement with organic preparations) and organic (replacement of mineral fertilizers and synthetic pesticides with organic preparations). Factor B represented different rates of crop sowing (from 2.0 to 3.0 million pieces of similar seeds per 1 ha with an interval of 0.5 million). The Prima mustard variety was sown in the experiment. Plots in the experiment were placed using the method of split plots with partial randomization. An increase in the crop sowing rate from 2.0 to 3.0 million units/ha leads to a deterioration in the value of most biometric indicators (plant height, leafiness) and all indicators of the crop structure. However, taking into account the discrete nature of the real number of plants preserved in the agrocenosis at the time of the study, the values of such indicators as the area of the assimilation apparatus and the leaf index, as well as the yield of conditioned seeds of the culture, had a curvilinear relationship: with an increase in the sowing rate from 2.0 to 2.5 million pcs./ha grew, and subsequently decreased. The norm of 2.5 million seeds per hectare is recognized as the most optimal seeding rate for all variants of cultivation technology. Also, the study noted a significant advantage of the biological and organic technology of Sarepta mustard cultivation over the traditional intensive one in terms of both biometric and structural indicators, as well as the level of yield of conditioned seeds and its quality indicators, first of all, the content of raw fat in the seeds.

Keywords: Sarepta mustard, biologicalization, organic technology, plant height, assimilation apparatus area, crop structure, yield.

INTRODUCTION

A typical feature of modern domestic agricultural production in all agrarian zones without exception, and in particular in the southern Steppe, is a significant imbalance of field agrocenoses, which is determined by the ever-increasing expansion of highly marginal crops in them, which, unfortunately, are quite infrequently defined at the same time as economic attractiveness, so and ecological tolerance regarding the preservation and increase of existing biodiversity [Blyshchyk et al., 1998; Zhuykov and Zhuykova, 2006; Bazaluk et al., 2022; Lavrenko and Lavrenko, 2022]. If we focus on the group of technical oilseed crops, which are typical for the crop rotation of the Steppe, then over the last decade and a half, it is represented in the agro-climatic zone almost exclusively by two crops - sunflower and winter rapeseed, and only in farms with irrigation, we can add to this list soy [Ivanyshyn et al., 2016; Gadzalo et al., 2020; Zhenchenko, 2013; Lykhovyd et al., 2020; Zhuykov et al., 2020].

Due to the socio-political and economic situation in the country, almost the only effective measure that will allow to improve the situation in domestic crop rotations in a certain way, is to relieve the acuteness of the problem, which is increasingly mentioned by domestic scientists, namely the shortage of satisfactory and optimal precursors for winter wheat, to expand the nomenclature of such crops of field agrocenoses, which at the same time with high indicators of economic efficiency of production would have soil-improving properties and high technology of the cultivation process, we see the involvement of Sarepta mustard in field crop rotations [Borisonik, 1988; Lykhovyd et al., 2022; Zhuikov et al., 2022].

The excellent qualities of its predecessor, high ecological plasticity and technology of cultivation, and relative unpretentiousness to abiotic factors of life of this culture have long been known. According to some indicators (for example, cold resistance and drought resistance), it is a certain "benchmark" among spring oil crops. It has long found its fans among domestic and foreign farmers, but even today there is a certain bias towards blue mustard [Klishchenko, 2009]. Mustard should be sown in continuous rows with a row spacing of 12–15 cm, and the optimal rate of seed sowing should be 1.8–2.0 million similar seeds per 1 ha [Chekhov and Zhernova, 2009]. Deviation from the optimal sowing density in one direction or another significantly reduces seed yield.

Research conducted in the conditions of the southern Steppe of Ukraine, about the study of sowing methods and sowing norms of Sarepta mustard of the Svitlana variety, makes it possible to assert that the specified technological factors significantly affect the growth, development, and productive characteristics of Sarepta mustard [Zhernova, 2012]. The maximum level of yield of 1.56 t/ha and the collection of oil per unit of sowing area (0.527 t) were noted for the variant of the row method of sowing the width of the rows of 15 cm and the sowing rate of 2.0 million units. similar seeds per 1 ha.

As practical experience shows, the delay in the timing of sowing causes a decrease in the yield level by 15–20%, and the optimal sowing rate is 1.2–1.5 million units/ha for the row method of sowing and 0.8-1.0 million pcs./ha – for row widths of 30 cm or more [Zhuykov and Zhuykova, 2006]. The row method of sowing is practiced on relatively few weeded massifs, where in the fall or early spring, a complex of tillage operations was implemented qualitatively before the start of sowing. At the same time, in seed crops, it is desirable to sow in wide rows, giving preference to the width of the rows between 45–70 cm [Zhuykov, 2012]. The depth of sowing should depend on the type of soil and the humidity of its upper layer. During the early sowing period, the seeds of the culture should not be wrapped deeper than 3–4 cm, as an exception – due to the loss of moisture in the upper sowing horizon, the depth can be increased to 5 cm on heavy soils and even 7 cm – on sandy ones. After sowing, it is mandatory to roll the surface of the field or harrow it with trailing harrows if the soil is excessively wet [Zhuykov, 2013]. In any case, only varietal seeds of reproduction I, which meet the requirements of the state standard according to the sowing conditions, are involved in sowing. The timing of mustard sowing remains one of the most important elements of its cultivation technology in any agricultural zone. Thus, in the conditions of the southern Steppe of Ukraine, the maximum yield of Sarepta mustard seeds is ensured by sowing in the spring period, earlier or at the same time as spring crops. At the same time, the sowing rate should be increased by 5–10%.

The advantages of the very early sowing period of Sarepta mustard include the following: a sufficiently moistened sowing horizon of the soil and moderate air temperatures contribute to the formation of vegetative above-ground and root mass; the maximum competitive ability of the culture about weeds; as a culture of long daylight, Sarepta mustard, when sown in late spring, grows rapidly, which negatively affects its productivity; early sowing times minimize the harmful effects of crop seedling pests, primarily cabbage whiteflies [Beese, 1989]. The best way to sow mustard is a regular row with a row width of 15 cm, for which the seed wrapping depth is 2–4 cm, depending on soil moisture and its mechanical composition. The seed sowing rate should be in the range of 1.6–2.2 million units/ha; for the most accurate observance of the rate, seed drills with electronic control over the operation of sowing devices should be used [Shcherbakov et al., 2001].

As a rule, in Ukraine, the following algorithm for the preparation and sowing of gray mustard is standard: it is allowed to use conditioned varietal reproduction or elite seeds with indicators of laboratory germination of at least 85% and purity of 96%; on relatively little weedy areas, sowing is carried out immediately after pre-sowing cultivation, on weedy massifs – after 1.5–2 weeks from the beginning of spring field work and after additional intermediate cultivation [Zhernova, 2012].

At the same time, almost diametrically, other scientists declare other criteria for building a seed block of mustard technology [Shcherbakov et al., 2001]. According to their authoritative opinion, in the conditions of southern Ukraine, it is permissible to sow mustard at a time significantly later than the traditional time, namely at the same time as corn and sunflower, when the soil at the depth of seed wrapping will have a temperature of 10–14 °C, and the sowing rate should be reduced to 6–8 kg/ha. The main criterion for sowing depth in this case is soil moisture: in the early periods, the optimal depth is 3–4 cm, and in the late – 8–9 cm.

It was established that during the early sowing period, seed yield was 0.57–0.88 t/ha higher, depending on the crop variety. During the years of research, the highest yield of mustard was noted in the variants in which sowing was carried out with a seeding rate of 1.5–2.0 million units/ha [Kozina and Sendetskyi, 2017; Kozina, 2012].

They are contradicted by the results of research [Blyshchyk et al., 1998], which emphasizes that during the early sowing period, the highest level of mustard seed productivity of 12.5 tons/ha was noted for the variant of the row method of sowing and the seed sowing rate of 2.0 million pieces/ha. The reduction of the sowing rate to 1.5 million/ha, as well as its increase to 2.5 million/ha, led to its decrease to 11.5 and 8.4 t/ha, respectively. During the late sowing period, the yield of mustard was significantly lower and, parallel to the increase in the sowing rate from 1.5 to 2.5 million/ha, did not change significantly, being in the range of 7.2–7.5 t/ha.

Kulina E.N [1975] believes that with the row method of sowing with a row spacing of 15 cm, a decrease in the rate of sowing seeds from 3.0 to 1.0 million pieces/ha leads to an increase in yield by 10–14%. In the case of giving preference to the seed sowing rate of 2.0 million/ha, one should choose the wide-row method of sowing with a row spacing of 30 cm, which also provides an additional yield of up to 1.8 t/ha or 14% compared to the row method and the rate of 3.0 million/ha If we take into account the indicator M_{1000}, the best is the wide-row method of sowing with a row spacing of 45 cm, which on average over the years of research provided an increase of 3 t/ha or 25% compared to the control option. The further increase in the width of the rows to 70 cm, although it facilitated the subsequent mechanical care of the crops, did not have a significant effect on the seed productivity of the crop. The author considers the application of the wide-row method of sowing as the prerogative of exclusively seed plots, where he allows to increase the yield of the seed fraction from 76.6 to 84.8% with a maximum indicator of M_{1000} [Kulina, 1975].

A wide range of research on the technology of growing gray mustard is traditionally carried out by scientists from the country of origin of the culture – India. The influence of plant stand density on the yield and quality indicators of seeds was studied in the experiment, where the sowing scheme was represented by options of 30 × 20 and 50 × 20 cm (0.17 and 0.10 million units/ha, respectively). In the second variant, a significantly larger number of fruit branches on one plant was noted (6.2 and 6.9 pcs., respectively); the number of pods (254–301 pcs.); a total weight of seeds from 1 plant (5.7–4.2 g), seed yield (0.71 and 0.94 t/ha) [Gare, 1996].

Scientists in Pantnagar determined the influence of sowing dates and stand density on the yield and quality of Sarepta mustard seeds: the density of agrocenosis was represented by options of 232, 148, and 111 thousand plants per 1 ha. The maximum seed oil content (33.6%) and its yield (18.2 t/ha) were 232,000 during the early sowing period, and the delay in sowing and the reduction of the sowing rate led to a decrease in seed yield and oil content to 1.68 t/ha and 37.7%, respectively [185]. According to other data, the wide-row method of sowing (45 cm) and the sowing rate of 1.0 million units/ha is better than the row method, which is advisable to use on well-prepared and clean fields: the increase is often 23–25%. With the row method of sowing, the sowing rate should be 1.5–2.0 million/ha, in areas with sufficient moisture and provision of mineral nutrition elements – up to 3.0 million/ha [Sass, 1985].

Scientists of the Agricultural University in Dapoli (India) [Chavan et al., 1989] studied the sowing rates of Sarepta mustard of 150, 220, and 300,000 plants per 1 ha and options for row widths of 22.5, 30, and 45 cm. Over the years of research, the optimal rate of 150,000 pieces/ha with a row spacing of 22.5 cm. At the same time, according to the results obtained by German researchers, the optimum sowing rate for Sarepta mustard is recognized as a weight rate of 4 kg/ha (6 kg/ha for late sowing periods) and a row spacing of 13–25 cm, while reducing the distance between the rows of the latter significantly increases productivity. A similar rate of seeding is optimal for the narrow-row sowing method – this option yields 1.87 t/ha of seeds with an essential oil content of 1.16–1.39% [Chanhan et al., 1987].

About the most basic agricultural techniques for caring for crops, all researchers, without exception, agree that the most "bottleneck" of the Sarepta mustard cultivation technology is the protection of its seedlings from damage by cabbage flea beetles (*Phyllotreta cruciferae*) and the maximum strengthening of the competitive properties of crop plants about weeds, which becomes particularly relevant at the initial stages of growth and development [Stankevich and Pavlenko, 2016]. The vast majority of experts declare the use of synthetic herbicides included in the "List of drugs allowed in Ukraine" as the most effective way to control weeds in mustard crops [Stankevich and Pavlenko, 2016]. Conventionally, they can be divided into two production groups: soil, used for sowing or before the appearance of crop seedlings on the surface of the soil (Dual Gold, 96% k.e., Triflurex, 480 k.e.), and insurance or selective, which allow the application already during the vegetation period of the crop (Butyzan, 40% k.e., Select 120, k.e., Naraps, 38%, Galera, 48%, Lontrel Gold, 38%).

To protect seedlings and seedlings from soil-dwelling pests, seeds are treated with the insecticide Oftanol T, 50% z.p. before sowing. (40 kg/t), Chinook, 20% d.c.s. (20 l/t), Khinufur, 40% (18 l/t), Cruiser, 60% (8–10 l/t), Komandor, 32% (6–8 l/t) and other systemic contact-system preparations that can protect seedlings and seedlings of culture during the first 2–3 weeks [Sekun et al., 2008]. As an element of the biologicalization of Sarepta mustard cultivation technology, the positive practice of weed control in crop sowing should be perceived not through the use of herbicides, but with the help of mechanical methods of protection. This especially applies to post-emergence harrowing with light-toothed or trailing harrows [Kartamysheva, 2006]. Carrying out this agro-practice before the "rosette" phase allows you to destroy 75–85% of the young seedlings and seedlings of weeds and to form the optimal density of the plant stand. This procedure should be carried out in dry, sunny weather in the afternoon when the turgor of mustard plants is minimal, and at a speed of movement of the unit no more than 5–6 km/h. [Kyforuk et al., 2011]. By the time the rows are closed in the mustard crop, it is realistic to carry out 1–2 mechanized inter-row treatments for sowing the crop in a wide-row method [Klishchenko, 2009].

Mustard plants compete relatively weakly with weeds at the initial stages of the "ladder-rosette" development, that is before the rows are closed. With the row method of sowing, the closure occurs much earlier, the same practice shows that the use of herbicides is not mandatory for the continuous row method of sowing, but with the wide-row method and row spacings of 30–45 cm (and even more so 60–70 cm), as well as for in late and intermediate crops, their use is almost mandatory [Lisovyi, 1999].

Scientists believe that harmful biotic factors can reduce crop yields by 30–50% or more. When sowing poisoned seeds in the first half of the growing season, the culture is almost exclusively damaged by weeds: during the specified period, mustard grows more slowly than early spring, rhizome, and rhizome species. Therefore, it is necessary to use an integrated protection system based on preventive, agrotechnical, and, if necessary, chemical measures [Kyforuk et al., 2011]. It should be taken into account that elements of chemical protection are appropriate and economically justified only at excessive levels of weediness. Preference should be given to preparations based on such active substances as clomazon, metazachlor (up to three days after sowing), and trifluralin (before sowing with mandatory soil wrapping) [Ivantsova, 2004].

The use of auxiliary substances (for example, adhesives) is very relevant for crops of the Cabbage family, which have the peculiarity of not being sufficiently wetted by working solutions of pesticides due to a wax coating on the surface of the leaves and stems. Such compounds cause a decrease in surface tension in aqueous solutions, ensuring complete wetting of the treated surface, as well as accelerating the penetration of drugs into the plant and preventing the drug film from being washed away by precipitation [Doberiya and Mehta, 1987]. Gavrilyuk et al. [2008] believes that the system of chemical protection of blue mustard plants should be fairly built based on the use of similar preparations for spring rape. Separately, the author notes that for the use of glyphosate-based preparations in the mustard chemical protection system, it is prohibited to position a batch of such seeds as food raw materials [Gavrilyuk, 2004].

Most authors agree that Sarepta mustard is the most ecologically plastic crop among the oil-bearing cabbage family, however, in seasons with unfavorable weather conditions, and especially in the period "seedlings – the beginning of stemming", when plants show insignificant average daily growth, professional monitoring of the phytosanitary state of the crop is important to prevent damage to plants by harmful biotic factors, which in some years can cause the death of up to 60–90% of the population [Zhuykov, 2013]. According to the results of research, the share of the influence of the integrated system of protection of Sarepta mustard against a complex of harmful organisms in the total value of the economically feasible yield of conditioned seeds is often 55–65% and even more.

MATERIALS AND METHODS

The territory of the experimental field of the Kherson State Agrarian and Economic University, where the field experiment was established, is represented by a soil variety typical for the subzone of the southern Steppe – a dark-chestnut heart-saline medium loamy soil, the main water-physical indicators of which include the following: average compaction density in the meter horizon 1.35 g/cm^3, the lowest moisture content is 20.2% of the mass of absolutely dry soil, and the moisture content at withering is 9.3%. Relatively high moisture content is characteristic of the soil, and when it dries, it often causes the formation of a soil crust. After precipitation or irrigation, the soil of the experimental area is prone to flooding, and due to poor soil tillage operations, lumps, and depressions are formed due to a significant level of salinity and an unfavorable range of the ratio of Ca^{2+}/Mg^{2+}, which is only 2.3–2.7.

The results of the agrochemical analysis of the soil of the experimental site indicate that the reaction type of the soil solution is weakly alkaline with a pH value of 7.1–7.2, and the depth of mineralized groundwater is 12–17 m, due to which they can influence the formation of water-salt mode of 1.5–2.0 m layer, where active moisture exchange takes place in the "soil – air – plant" system. For the arable layer of the soil of the experimental field, the following values of the main agrochemical indicators were determined in the laboratory: the depth of the humus horizon is 43–46 cm, the content of humus is 2.15%, the amount of absorbed bases is 278–296 mg/kg, the total forms of nitrogen, phosphorus, and potassium are respectively 0.13, 1.66 and 3.3%. It should be noted that, on average, over the years of field research, the soil of the research area at the time of sowing Sarepta mustard was characterized by a low content of easily hydrolyzed nitrate nitrogen in the top layer – 19.8 mg/kg, a high content of mobile phosphorus – 66.4 mg/kg and excessive exchangeable potassium – 179.4 mg/kg of soil. The analysis of the agronomic seasons, during which the dissertation research was carried out, makes it possible to conclude that according to the most fundamental final indicator, which characterizes the weather and climate conditions for crop cultivation (hydrothermal coefficient), they had the following characteristics: 2021 – moderately humid year; 2022 is a dry year; 2023 is a middle year.

The goal was realized by setting up a two-factor field experiment and carrying out a complex of observations and laboratory studies. Factor A (culture cultivation technology) was represented by variants of the traditional zonal mustard cultivation technology; biologized technology (rejection of mineral fertilizers and their replacement with organic preparations) and organic (replacement of mineral fertilizers and synthetic pesticides with organic preparations). Factor B represented different rates of crop sowing (from 2.0 to 3.0 million pieces of similar seeds per 1 ha with an interval of 0.5 million). The Prima mustard variety was sown in the experiment. The repetition of the experiment is fourfold, the total area of the experimental plot is 0.9 ha, the total area of the plot of the first order is 250 m^2, and the accounting area is 200 m^2. Plots in the experiment were placed using the method of split plots with partial randomization. Plant height was studied with a ruler on 10 typical plants in each replicate. The area of the leaf surface of the culture was determined by the cuttings method. To determine the structure of the crop and chemical analysis of mustard seeds, two model sheaves were selected from each variant of the experiment, which included plants typical for the variant, and which were dried to an air-dry state. To determine the weight of 1000 seeds, two samples of 500 seeds each were taken and weighed to the nearest 10.00 mg on each variant in triplicate. Chemical analysis of mustard seeds was determined in laboratory conditions: crude fat – by the Soxhlet method by extraction with dichloroethane, and essential oil – by the method of additional extraction with a selective solvent (petroleum ether). The recording of the mustard seed harvest was carried out by the continuous harvesting method. The yield data of seeds resulted in standard humidity (10%)

and one hundred percent purity. The experimental data of sunflower were processed by the standard procedure of ANOVA within MS Excel software. The significance of the differences was proved for the reliability level of 95% (LSD_{05}).

The agricultural technique of growing Sarepta mustard in the experiment was represented by the following operations: the predecessor of the crop for all the years of research was winter barley, after harvesting, the soil was discus to a depth of 10–12 cm. After 10–15 days, mineral fertilizers were applied (on variants of the traditional cultivation technology culture) at the estimated rate, which averaged $N_{72}P_{32}$ over the years of research. Ammonium nitrate was used as a nitrogen component, granulated superphosphate was used as a phosphorus component. Organic fertilizers approved for use in organic crop production were used on variants of biological and organic crop cultivation technology. After applying fertilizers according to the scheme of the field experiment, plowing was carried out to a depth of 22–24 cm, autumn leveling of the soil with an anti-erosion cultivator to a depth of 10–12 cm.

The spring work cycle was represented by pre-sowing cultivation to a depth of 5–6 cm and pre-sowing rolling of the soil with rollers. Pre-sowing incrustation of elite seeds was carried out depending on the scheme of the experiment with synthetic or organic complex multifunctional fertilizers, insecticides, and fungicides. The crop was sown in early spring at a soil temperature of 4–5 °C at the depth of seed wrapping in the usual row method with a row spacing of 15 cm to a depth of 3 cm with post-sowing soil rolling. The rate of sowing depended on the variant of the experiment and corresponded to its scheme.

Care of Sarepta mustard crops was represented by measures to control the number and harmfulness of pests, pathogens, and weeds in the crop relative to the indicator of their economic threshold of harmfulness. Protection against weeds was realized, depending on the variant of factor A, by using the soil pre-emergence herbicide Triflurex 480 and the insurance herbicide Galera® at the rate of application of 0.3 l/ha or using mechanical methods of protection using specialized tools, against diseases and pests - through vegetation treatments with synthetic pesticides - Vantex® insecticide at a rate of 0.05 kg/ha; fungicide Propuls® at a rate of 0.5 l/ha or biological preparations approved for use in organic farming (chelated microfertilizer Oracle®, fungicides Viridin®, and Haubsyn Forte®, insecticides Actoverm®, Metawhite). Insecticidal and fungicidal vegetative treatments of mustard plants were carried out twice during the growing season in the phases of "bud formation" and "green pod" at the rate of consumption of the working fluid of 200–250 l/ha. In the case of a complex application, the tank mixture was prepared earlier than 30 minutes before processing. Harvesting was carried out by the method of direct (single-phase) harvesting with the combine "Sampo – 130".

RESULTS AND DISCUSSIONS

Research has established that the indicator of the average height of crop plants in the phase of full flowering depended both on the rate of sowing and on the level of biologicalization of the cultivation technology. The experiment noted a trend according to which the height of plants significantly decreased with an increase in the seeding rate, which was observed against the background of all variants of crop cultivation technology. Concerning the dependence of this indicator on the level of biologicalization of cultivation technology, the height of culture plants reached minimum values under traditional intensive cultivation technology, and the replacement of mineral fertilizers with organic complexes led to an increase in height by an average of 6.1 cm, and a complete transition in cultivation technology to organic fertilizers and organic pesticides did not have a significant effect on this indicator (85.8 cm versus 87.0 cm on average) (Table 1).

The leafiness index (the mass of leaves from 10 plants) was also characterized by a similar dependence on the factors studied in the experiment: with an increase in the rate of sowing the crop, the mass of leaves on the plant decreased, and this indicator reached its maximum values under the option of biological cultivation technology (on average, it was 13.2 g/plant), for organic – 12.4 g, and for traditional – 10.5 g, respectively. According to the results of our research, the nature of the dependence of the area of the assimilation apparatus of Sarepta mustard on the factors studied in the experiment turned out to be somewhat different. Thus, for all variants of cultivation technology, with an increase in the sowing rate from 2.0 to 2.5 million seeds/ha, this indicator increased significantly, and with a further increase in the sowing rate to 3.0 million units/ha, it decreased.

Table 1. The main biometric indicators of Sarepta mustard depending on the rate of sowing and the level of biologicalization of the growing technology in the phase of full flowering (average for 2020–2023)

Cultivation technology (factor A)	Sowing rate, million seeds/ha (factor B)	Height of plants, cm	Weight of leaves from 10 plants, g	Area of leaf apparatus, m²/ha	Leaf sowing index
Traditional (intensive)	2.0	82.9	119.8	80784	8.1
	2.5	81.5	107.0	109232	10.9
	3.0	78.4	88.1	72012	7.2
Biologized	2.0	89.5	154.4	94518	9.5
	2.5	88.7	131.2	124832	12.5
	3.0	82.8	111.0	115606	11.5
Organic	2.0	88.4	145.6	95232	9.5
	2.5	88.0	122.8	121636	12.2
	3.0	80.9	104.4	99309	9.9

The reduction of the leaf index with an increase in the sowing rate of the crop was especially rapid according to the variant of the traditional intensive cultivation technology. On average, according to factor B, the area of the assimilation apparatus was formed at the level of 8.7 thousand m^2 per 1 ha of sowing using intensive technology; for biologized – 11.2 thousand m^2; for organic – 10.5 thousand m^2, which indicates more favorable conditions for the production process.

Concerning the indicators of the structure of the crop yield, we concluded that during the second growing season ("flowering – full seed maturity") blue mustard plants continued to increase in linear size, although the intensity of average daily growth was significantly lower. The dependence of plant height on the factors of the experiment remained similar: with an increase in the sowing rate, this indicator decreased (from 4.5 to 7.9 cm), and the use of both individual elements of biologization and a complete transition to organic principles of cultivation led to an increase in the height of culture plants in comparison with traditional technology by 3.5–5.1 cm (Table 2).

The nature of the dependence of the remaining elements of the trial sheaf of the culture on the studied factors was similar: an increase in the rate of crop sowing from 2.0 to 3.0 million seeds/ha led to a decrease in the number of fruit branches from 4.4 to 2.9 units; number of pods from 65.4 to 31.5 pcs.; indicator M_{1000} from 3.5 to 3.0 g; seed productivity of one plant from 1.7 to 1.0 g (according to traditional technology). According to the biological technology of mustard cultivation, the dependence was similar: with an increase in the sowing rate, the number of fruit branches decreased from 4.8 to 3.1 pcs.; the number of pods from 77.2 to 39.0 pcs.; the M_{1000} indicator from

Table 2. Structural indicators of the Sarepta mustard harvest depending on the rate of sowing and the level of biologicalization of the growing technology (average for 2020–2023)

Cultivation technology (factor A)	Sowing rate, million seeds/ha (factor B)	Height of plants in the phase of full maturity, cm	Number of fruiting branches of the first order on the plant, pcs.	Number of pods per plant, pcs.	M_{1000}, g	Weight of seeds from one plant, g
Traditional (intensive)	2.0	150.5	4.4	65.4	3.5	1.7
	2.5	147.0	3.0	40.7	3.3	1.4
	3.0	142.4	2.9	31.5	3.0	1.0
Biologized	2.0	155.9	4.8	77.2	3.8	2.0
	2.5	151.2	3.4	55.1	3.7	1.8
	3.0	147.7	3.1	39.0	3.4	1.4
Organic	2.0	152.9	4.9	80.1	3.9	2.2
	2.5	150.0	3.7	59.6	3.7	1.7
	3.0	146.7	3.3	37.8	3.3	1.2

Table 3. The yield of conditioned seeds of Sarepta mustard depending on the sowing rate and the level of biologicalization of the growing technology (average for 2020–2023)

Cultivation technology (factor A)	Sowing rate, million seeds/ha (factor B)	Conditioned seed yield, t/ha
Traditional (intensive)	2.0	0.88
	2.5	1.19
	3.0	0.95
Biologized	2.0	1.49
	2.5	1.77
	3.0	1.29
Organic	2.0	1.41
	2.5	1.74
	3.0	1.52
LSD_{05}, t/ha	Of partial differences	A = 0.24; B = 0.18
	Of main effects	A = 0.28; B = 0.33

3.8 to 3.4 g, and the productivity of one plant from 2.0 to 1.4 g. The complete rejection of artificial fertilizers and pesticides (organic cultivation technology) against the background of an increase in the rate of crop sowing was characterized by a decrease in these indicators from 4.9 to 3.3 pcs.; from 80.1 to 37.8 units; from 3.9 to 3.3 g and from 2.2 to 1.2 g, respectively, which could not help but affect the value of the final indicator, which evaluates the effectiveness of one or another agricultural practice - the yield of conditioned seeds (Table 3).

The rate of 2.5 million seeds/ha was recognized as the most optimal seeding rate for all variants of the crop cultivation technology, which provided 1.19 t/ha for the traditional technology, 1.77 t/ha for the biologically produced, and organic – 1.74 t/ha. On average, according to the B factor, the seed productivity of the culture grown according to the traditional intensive technology was 0.98 t/ha, according to the biologized technology – 1.52 t/ha, and according to the organic method – 1.56 t/ha, which indicates the promising and the expediency of involving in the culture cultivation technology both separate elements of biologization, as well as the complete transfer of blue mustard cultivation to organic principles. According to the results of our research, the nature of the dependence on the studied factors of the main quality indicators of the seeds of the culture, namely: the content of fatty and essential allyl oil in it, turned out to be somewhat different. If we did not find a significant dependence between the rate of crop sowing and oiliness and ethereality during the two years of the study, then the influence of the cultivation technology on the formation of the specified quality indicators was significant (Table 4).

Table 4. The content of Sarepta mustard seeds of crude fat and essential allyl oil depending on the cultivation technology (average for 2020–2023)

Cultivation technology	Essential oil, %	Crude fat, %
Traditional (intensive)	1.22	38.6
Biologized	1.24	39.3
Organic	1.20	40.4

The inclusion of elements of biologization in the cultivation technology of the culture (replacement of mineral fats with organic preparations) made it possible to increase the content of crude fat in mustard seeds from 38.6 to 39.3%, and the implementation of a full organic cultivation technology (organic fertilizers in a complex with organic pesticides) – up to 40.4%. This positive effect is explained by us, firstly, by the absence of the repellent effect of organic pesticides on honey bees during the flowering of Sarepta mustard, which affected the more active visitation of the agrocenosis by this species and the improvement of pollination conditions; secondly, by more favorable conditions for the synthesis of fatty oil at the final stages of the ontogenesis of the crop (primarily due to the increase in heat resistance and drought resistance of plants under the influence of organic preparations).

CONCLUSIONS

An increase in the crop sowing rate from 2.0 to 3.0 million seeds/ha leads to a deterioration in the value of most biometric indicators (plant height, leafiness) and all indicators of the crop structure. However, taking into account the discrete nature of the real number of plants preserved in the agrocenosis at the time of the study, the values of such indicators as the area of the assimilation apparatus and the leaf index, as well as the yield of conditioned seeds of the culture, had a curvilinear relationship: with an increase in the sowing rate from 2.0 to 2.5 million seeds/ha grew, and subsequently decreased. The norm of 2.5 million seeds per hectare is recognized as the most optimal seeding rate for all variants of cultivation technology. Also, the study noted a significant advantage of the biological and organic technology of Sarepta mustard cultivation over the traditional intensive one in terms of both biometric and structural indicators, as well as the level of yield of conditioned seeds and its quality indicators, first of all, the content of raw fat in the seeds.

REFERENCES

1. Bazaluk O., Havrysh V., Nitsenko V., Mazur Y., Lavrenko S. 2022. Low-Cost Smart Farm Irrigation Systems in Kherson Province: Feasibility Study. Agronomy, 12(5), 1013. https://doi.org/10.3390/agronomy12051013
2. Beese G. 1989. Erfahrungea mit dem Anbau von Sareptasenf in der DDR. Feldwirtschaft, 12, 556–558.
3. Blyshchyk S.P., Nikytchyn D.I., Gutsalenko A.P. 1998. Study of some methods of mustard agrotechnics in arid conditions of the Zaporizhzhia region. Scientific and technical bulletin of the Institute of Oil Crops of the Ukrainian Academy of Sciences, 3, 187–189.
4. Borisonik Z.B. 1988. Handbook of oil crops. Kyiv: Urozhai, 184.
5. Chanhan C.P.S., Chanhan R.P.S., Singh S.P., Pathak D.C. 1987. A sowing method for better mustard production under saline irrigation. Indian Farm, 3, 82–86.
6. Chavan S.A., Kanade V.M., Khavilkar S.A. 1989. Effects of dates of sowing, plant densiti and levels of nitrogen on mustard. Magarashtra agr. Univ., 9, 12–14.
7. Chekhov A.V., Zhernova N.P. 2009. Technological aspects of growing white mustard in the conditions of the southern steppe of Ukraine. Scientific and technical bulletin of the Institute of Oil Crops, 14, 156–200.
8. Doberiya D.K., Mehta H.M. 1987. The influence of irrigative regime, norm of nitric fertilizators and wetting of seeds in ascorbic asid upon the elements of yeld structure, yeld capacity and oilness mustard seeds, 11, 15–16.
9. Gadzalo Y.M., Vozhegova R.A., Malyarchuk M.P., Gilchenko N.M., Reznichenko N.D. 2020. Ecological and economic efficiency of sideration in crop rotation on irrigated lands of southern Ukraine. Agroecological Journal, 2, 55–62.
10. Gare B.N. 1996. Behavior of grades mustard at different terms of sowing. J. Maharashtra Agr. Univ., 21(1), 147–148.
11. Gavrilyuk M.M. 2004. Basics of modern seed production. Kyiv: NNC IAE, 256.
12. Gavrilyuk M.M. Salatenko V.N., Chekhov A.V., Fedorchuk M.I. 2008. Oil crops in Ukraine: a guide. Kyiv: Osnova, 420.
13. Ivantsova E.A. 2004. Agrotechnical methods for protecting Sarepta mustard. Agriculture, 4, 46–47.
14. Ivanyshyn V.V., Roik M.V., Shuvar I.A., Tsentilo L.V., Sendetskyi V.M., Bunchak O.M., Kolisnyk N.M. 2016. Biologization of agriculture in Ukraine: realities and prospects: monograph. Ivano-Frankivsk: Symphony forte, 284.
15. Kartamysheva E.V. 2006. Problems and perspectives of Sarepta mustard cultivation. Agriculture, 4, 25–26.
16. Klishchenko S. 2009. Mustard and its cultivation technologies. Agroexpert, 1(6), 14–16.
17. Kozina T., Sendetskyi V. 2017. Growing white mustard for seeds and siderate. Collection of scientific works of the All-Ukrainian Scientific and Practical Conference “Actual issues of modern technologies of cultivation of agricultural crops in conditions of climate change”, June 15–16, 99–101.
18. Kozina T.V. 2012. Growth and development of plants and productivity of white mustard depending on the timing of sowing and sowing rates in the conditions of the Western Forest Steppe. Proceedings of the international scientific and practical Internet conference “Perspective innovations in science, education, production and transport”, Dnipropetrovsk, 12–13.
19. Kulina E.N. 1975. About sowing rates and methods of sowing mustard. Scientific works, 34, 135–141.
20. Kyforuk I.M., Boychuk O.M., Ivanyuk V.M., Stelmakh O.M. 2011.Recommendations for growing mustard in Carpathian conditions. Ukrainian farmer’s guide, 1, 216–222.
21. Lavrenko S.O., Lavrenko N.M. 2022. Monitoring of varieties and hybrids of sunflower and winter wheat for cultivation in the steppe zone of Ukraine. Taurian Scientific Herald. Series: Agricultural sciences, 124, 70–78. https://doi.org/10.32851/2226-0099.2022.124.10
22. Lisovyi M.P. 1999. Handbook of plant protection. K.: Urozhai, 743.
23. Lykhovyd P., Lavrenko S., Lavrenko N. 2020. Forecasting grain yields of winter crops in Kherson oblast using satellite-based vegetation indices. Bioscience research, 17(3), 1912–1920. http://www.isisn.org/BR17(3)2020/1912-1920-17(3)2020BR20-198.pdf
24. Lykhovyd P.V., Vozhehova R.A., Lavrenko S.O., Lavrenko N.M. 2022. The Study on the Relationship

between Normalized Difference Vegetation Index and Fractional Green Canopy Cover in Five Selected Crops. Hindawi: The Scientific World Journal, 2022, Article ID 8479424. https://doi.org/10.1155/2022/8479424

25. Sass H. 1985. Erntechn bei Raps aus der Sicht der Praktikers. Raps, 3, 148–149.
26. Sekun M.P., Lapa O.M., Markov I.L., Hetman S.V., Zhuravskyi V.S. 2008. Rapeseed cultivation and protection technology. Kyiv: Globus-Print, 116.
27. Shcherbakov V., Mishin S., Bakuma A. 2001. Let's talk about mustard. Proposal, 2, 38.
28. Stankevich S.V., Pavlenko O.O. 2016. Modern insecticides for the protection of canola and mustard from cruciferous fleas. The state and prospects of the development and implementation of resource-saving, energy-saving technologies for growing agricultural crops: materials of the international scientific and practical conference. Dnipro, November 22–23, 239–241.
29. Zhenchenko K. 2013. Sarepta mustard should be the leader in five-field grain row rotations. Grain and bread, 3, 53–54.
30. Zhernova N.P. 2012. The influence of sowing methods and sowing rates on the productivity of Sarepta mustard variety Svitlana. Agronomist, 1, 211–213.
31. Zhuikov O., Kyrylov Yu., Lavrenko S. 2022. The efficiency of sunflower cultivation on different levels of biologization. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22 (2), 807–814.
32. Zhuykov O., Burdiug O., Ushkarenko V., Lavrenko S., Lavrenko N. 2020. Photosynthetic activity and productivity of sunflower hybrids in organic and traditional cultivation technologies. AgroLife Scientific Journal, 9(1), 374–381. http://agrolifejournal.usamv.ro/index.php/scientific-papers/516-photosynthetic-activity-and-productivity-of-sunflower-hybrids-in-organic-and-traditional-cultivation-technologies-516
33. Zhuykov O.G. 2012. Biometric indicators, economic value characteristics and the level of seed productivity of white mustard depending on the method of sowing and the rate of sowing in the conditions of southern Ukraine. Taurian Scientific Bulletin, 81, 51–58.
34. Zhuykov O.G. 2013. Agrotechnological aspects of the main tillage system as a component of the zonal technology of growing black mustard in southern Ukraine. Irrigated agriculture, 59, 115–119.
35. Zhuykov O.G. 2013. Ecological and technological substantiation of the basic aspects of the primary seeding system of various mustard species in non-irrigated crop rotations of the Southern Steppe. Directions of development of modern agricultural systems: materials of the International Scientific and Practical Internet Conference dedicated to the 110th anniversary of the birth of Professor S.D. Lysogorova, December 11, Kherson, 133–152.
36. Zhuykov O.G., Zhuykova K.O. 2006. Water consumption of Sarepta mustard depending on the level of moisture availability and the rate of mineral fertilizers. Irrigated agriculture, 46, 104–109.