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AGROBIOLOGICAL FEATURES OF MUSTARD (*Brassica juncea* L) IN UKRAINE UNDER CURRENT CLIMATE CHANGE CONDITIONS

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ABSTRACT

The market for oilseeds in Ukraine is a large segment of the general market for agricultural products. Mustard (*Brassica juncea*L) is an oilseed crop that can restore the optimal ratio of crops in crop rotation and not reduce the rates of economic activity. Ukraine is among the top ten world leaders in its cultivation. The warming trends observed over the last 30 years in the world and in Ukraine, allow growing of mustard throughout the country. Consequently, it became necessary to develop varietal technologies for growing mustard for specific soil and climatic conditions. The objective of this research was to develop cultivation technology for *Brassica juncea*L in the conditions of the north-eastern forest-steppe of Ukraine for the first time. We studied the influence of weather conditions on the peculiarities of growth, development, formation of biomass, photosynthetic activity, productivity indices, yield, seed quality, oil production, depending on the variety, sowing time, seeding rates and fertilizer for growing bluish mustard. According to research results, for the formation of 1.71-1.91 t/ha of bluish mustard seeds in the conditions of the north-eastern forest-steppe of Ukraine on typical black soil, the cultivation technology should include: use of seeds of modern high-yielding adapted varieties; start sowing at soil temperature of 4-5 °C at a depth of 10 cm; the rate of fertilizer N₃₀P₃₀K₃₀ (during pre-sowing cultivation) and seeding rates of the varieties Prima - 1.5 million pieces/ha, and Retro -2.0 million pieces/ha.

Keywords: *bluish mustard, sowing date, fertilizer rates, seeding rates, yield.*

INTRODUCTION

Brown mustard (*Brassica juncea* L.) – trowse mustard or Indian mustard – is grown extensively for oil in India, Pakistan, China, Canada and in other countries (Masierowska, 2002; Melnik et al., 2015).

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of crops in crop rotation and not reduce the rates of economic activity. Ukraine is among the top ten world leaders in its cultivation. The warming trends observed over the last 30 years in the world and in Ukraine, allow growing of mustard throughout the country. Consequently, it became necessary to develop varietal technologies for growing mustard for specific soil and climatic conditions (<http://www.ukrstat.gov.ua/>). Mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.) oil. Mustard is a multi-vector industrial crop due to its diverse use. It is very important as an oilseed crop; quality of the oil produced from its seeds is not inferior to the sunflower oil. Mustard oil is widely used for food, as well as in many industries - canning, baking, confectionery, margarine, soap and pharmaceutical. In addition to oil, the seeds of bluish mustard contain essential oil, which is used in cosmetics and perfumes. Bluish Mustard is used to produce mustard powder necessary for toast mustard in food industry and mustard plasters in medicine (Shekhawat et al., 2012; Melnik et al., 2015; Zhuikov O.G., 2014). The objective of this research was to develop cultivation technology for *Brassica juncea* L. in the conditions of the north-eastern forest-steppe of Ukraine for the first time.

MATERIALS AND METHODS

Studied the influence of weather conditions on the peculiarities of growth, development, formation of biomass, photosynthetic activity, productivity indices, yield, seed quality, oil production, depending on the variety, sowing time, seeding rates and fertilizer for growing bluish mustard.

The experimental part of the work was conducted at the training and practical center of Sumy National Agrarian University (Ukraine) for three years (2015, 2016 and 2017). It is situated at 50 52.742N Latitude, 34 46.159E Longitude at an altitude of 137.7 m above mean sea level in the north-eastern forest-steppe of Ukraine. Experiments were laid on black soil, characteristic for coarse-medium loam. Two sorts were sown at plant densities 1,5 million plants/ha with 10 rows in each plot and 15 cm between rows.

To determine the dynamics of linear growth, the pre-marked plants were studied. The area of the leaf surface was determined by the method of "carving", and the net productivity of photosynthesis and photosynthetic potential were determined according to the methods of A. O. Nychiporovich. The content of chlorophyll in the leaves was determined by means of preparing the solution in an alcohol extract with the further determination by a spectrophotometer ULAB 102 (Grytsaenko, 2008). Harvesting of the crop was carried out plot by plot by means of the Massey Ferguson 307 direct combining, when the color of the main stem and the pods was yellow, and the leaves fell off, simultaneous weighing the seeds according to the options of the experiment and sampling to determine the moisture and purity. Harvesting was brought up to 100% of purity and 10% of moisture content of the seeds.

Hydrothermal coefficient (HTC) (G. T. Selyaninov) were determined by the

formula: $HTC = \frac{\sum K}{\sum T \times 10}$, where K is the amount of precipitation, mm, for a period with an average daily air temperature above 10° ; T is the sum of the temperatures, $^\circ$, for the period with the average daily air temperature above 10° .

The oil content of the seeds was determined using the device Spinlock Magnetic Resonance Solutions. Data were subjected to ANOVA at 5% level of probability with the statistical software STATISTICA (version 8).

RESULTS AND DISCUSSIONS

The success of its cultivation mustard is largely determined by the changing environmental conditions, that is, weather and climate. Observations by the metrological network of Ukraine testify to the fact that regional climate change, especially temperature rise, has already affected a number of meteorological characteristics. The average annual air temperature has increased, the terms of formation and duration of snow cover have changed, the heat supply of the growing season gradually increased, and the number and intensity of adverse meteorological phenomena (drought, heavy rain, etc.) has increased (Melnik et al., 2015). For example, in the Forest-steppe of Ukraine we considered the main meteorological parameters for the period from 2000 to 2017. Thus, according to the results of the analysis of meteorological conditions for 18 years, it has been established that for the period of the growing (farming) season (April-August), there was an average of 281.9 mm of rainfall, with fluctuations from 171.4 to 461.7 mm. In this region, the average temperature during this period amounted to 2710.8°C with fluctuations ranging from 2311.0°C to 3090.7°C . Increase in the heat supply of the growing season was noted at 285.8° and decrease in the amount of precipitation by 12.1 mm. Based on HTC which for the past 18 years has decreased from 1.21 to 1.05, it was established that the conditions of this region correspond to the conditions of the Steppe zone of Ukraine. Analysis of weather conditions during the investigated years found that for the hydrothermal coefficient (HTC) in 2015, there was a severe drought in April (HTC = 0.08), weak drought in July and August (HTC = 0.76 and 0.77), excessive moisture in May (HTC = 2.5), and sufficient (adequate) moisture in June (HTC = 1.24). The vegetation period in 2016 was characterized by a sufficient level of humidification in April and June (HTC = 1.45 and 1.02). In July, there was a weak drought (HTC = 0.86), and in May and August, excessive moisture were observed (HTC = 3.04 and 1.87). It should be noted that in 2017, the dry conditions were different for most months, particularly in April and August which observed a very severe drought (HTC = 0.06 and 0.21), while strong and average drought respectively were observed in May and June (HTC = 0.43 and 0.57). Only July was sufficiently humid (HTC = 1.19). According to the Ukrainian State Register for Plant Varieties (SRPV), in 2017, the agricultural producer presently have 10 varieties of bluish mustard.

An important segment of the market in Ukraine is occupied by high-performance adapted hybrids of domestic breeding: the Institute of Oil seeds of NAANU, Institute of arable farming of NAANU, Precarpathian State Agricultural Experimental Station of NAANU and a number of other institutions. According to results of research conducted in 2015-2017 at the Department of Crop Production in Sumy National Agrarian University in Ukraine, a regional technology for bluish mustard cultivation, which involves the selection of adapted hybrids and optimization elements was developed. Having analyzed the grey mustard varieties in terms of yield formation and their suitability for the cultivation in the Northeastern Forest-steppe of Ukraine, we concluded that the period of vegetation of the grey mustard varieties varies from 88 to 95 days. Demeter, Prima and Chornyava varieties had the longest vegetation period. We recorded the shortest period of vegetation for Rosava variety. The average area of the leaf surface at the flowering stage was 42.8 thousand m²/ha, determined by the method of carving. The varieties of Prima, Mriya, Retro and Demetra had the above average value. An indicator close to the average value was characteristic for Felitsia variety. Rosava, Roksolana and Chornyava had the smallest leaf surface area. The content of chlorophyll "a" and "b" among the studied varieties, determined on the ULAB 102 spectrophotometer, varied from 0.97 to 1.14 in mg/g of the fresh weight.

The varieties of Prima (1.91 t/ha), Retro (1.83 t/ha) and Demetra (1.81 t/ha) formed significantly higher seed yield capacity. Average yield was recorded in the varieties of Mriya (1.69 t/ha), Felitsia (1.58 t/ha) and Roksolana (1.33 t/ha). The yield of the varieties of Rosava (1.25 t/ha) and Chornyava (1.07 t/ha) was significantly lower.

With the help of the infrared analyzer Spinlock Magnetic Resonance Solutions., we determined the maximum content of oil in the Prima variety seed - 40.1%. Retro and Felitsia varieties (38.9%) showed the above average value. The varieties of Mriya (37.3%) and Rosava (31.0%) had significantly lower values. The average oil yield over the years of research was 0.60 t / ha (Fig. 1).

In order to study the nature of the influence of morphological parameters on productivity, a regression analysis of the main indicators was carried out. A number of authors argue that there is a strong connection between the length of the pod and the number of seeds in it (Zhyikov, 2014). However, the results of studies by other scientists indicate that the length of the pods is not a direct element of the structure in the seed productivity (Vyshnivsky, 2011). The results we have received confirm this very trend. Thus, the calculated correlation coefficient is not significant ($r = 0.05$), and the regression line is in a horizontal position.

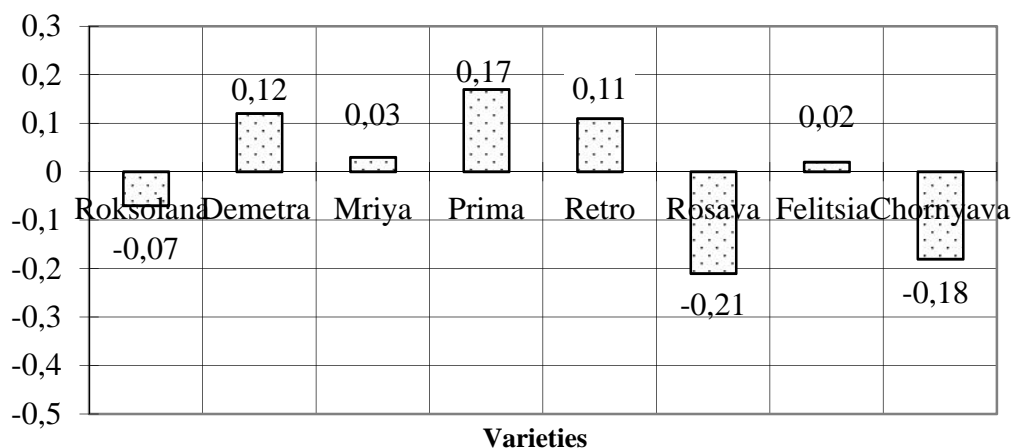


Fig. 1. Deviation from the average (0.6 t/ha) for the oil production of the bluish mustard varieties, depending on the variety, t/ha (average over 2015-2017)

The timing of sowing determine the level of moisture and nutrients availability for the plants. A properly established term will enable the formation of highly productive plants of the spring mustard (Kurmi 2002; Singh 2002). The change in climate conditions in Ukraine over the past decades has had an impact on the soil maturity and allowed sowing all the crops as well as mustard at earlier dates (Melnik et al., 2015; Zhykov, 2014). Sowing of the grey mustard varieties of Prima and Retro in the first sowing term (the soil temperature was 4-5 °C) contributed to the maximum period of vegetation 92 and 90 days respectively, the second (the soil temperature was 6-7 °C) and the third (the soil temperature was 8-9 °C) terms the vegetation period was reduced by 3 and 6 days respectively on the average. The first term of sowing ensured the formation of the leaf surface area in the flowering phase of Prima and Retro varieties at the level of 44.2-45.6 thousand m²/ha. The second term sowing reduced the figure by 8% and for the third term by 15% compared with the first sowing term. The highest yields were typical for Prima variety - 1.86 t/ha in the first sowing term. During the second sowing term, there was a slight decline in the yields up to 1.75 t/ha. The third sowing term significantly reduced the yields to 1.53 t/ha. Retro variety recorded a similar tendency to decrease yields for the late sowing. The first term is 1.76 t/ha, the second - 1.67 t/ha, and the third - 1.46 t/ha. Late sowing also caused a decrease in the content of oil by 0.3% and 0.4% respectively (Fig. 2). According to the results of a dispersion analysis, a rather significant impact of the factor "conditions of the year" (55.0%) was established. In addition, the factor "sowing times" (36.6%) had a rather significant impact on the yields of mustard. The influence of the factor "variety" was 3.9%, the factor "others" - 4.3%, "factor interaction" only - 0.1%. Consequently, weather conditions (moisture reserves, temperature mode, etc.) make adjustments in determining the optimal timing of sowing and all together affect the mustard yields.

We would like to note the influence of the studied norms of mineral fertilizers on the duration of the varieties' vegetation period. Introduction of mineral fertilizers contributed to an increase in the duration of the vegetation period: prima variety had $N_{30} P_{30} K_{30}$ - 5 days longer, and $N_{60} P_{60} K_{60}$ - 7 days longer, Retro variety - 6 days longer compared with the control.

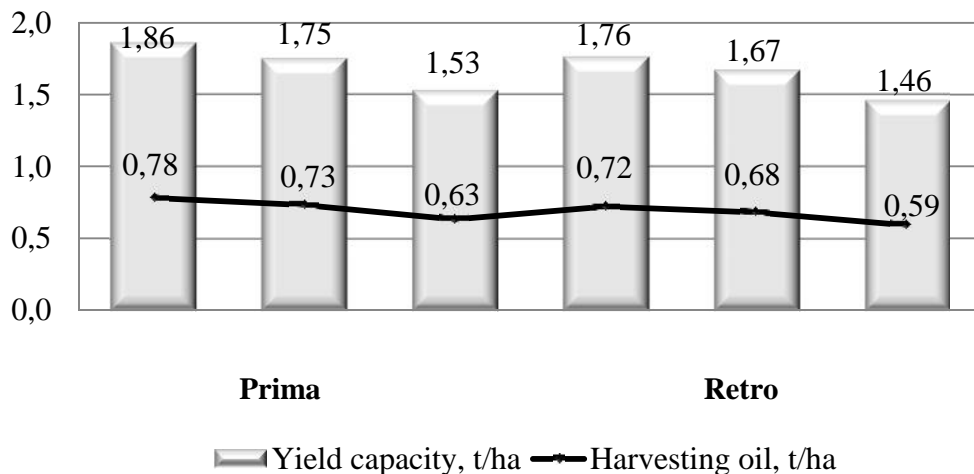


Fig. 2. Yield capacity and harvesting of the bluish mustard oil depending on the variety and timing of sowing, t/ha (average over 2015-2017)

Improvement of the mineral nutrition level in the studied varieties increased the leaf surface area. The maximum value of the leaf surface area was fixed in the flowering phase in the variant with the norm of fertilizers $N_{60}P_{60}K_{60}$ - 47.9-51.2 thousand m^2/ha , which exceeded the indicator in the control variant of 14.7-16.0 thousand m^2/ha , on the variant with the norm of fertilizers $N_{30}P_{30}K_{30}$ the leaf surface area was 44.2-45.6 thousand m^2/ha , which exceeded the control variant by 10.4-11.0 thousand m^2/ha . The analysis of experimental data of P. S. Vyshnivsky and others as to the influence of mineral fertilizers on the formation of the yield capacity of mustard under the conditions of the Northern Forest-steppe of Ukraine showed that the application of nitrogen fertilizers on the background of phosphoric-potassium (P45K45) contributed to the increase in yield capacity of the mustard seed of the variety from 0.08 to 0, 73 t / ha, with the indicators at the control of 0.90 t/ha. The efficiency of nitrogen fertilizers was 0.11-0.65 t / ha. The maximum yield capacity rate of 1.78 t / ha provided the maximum dose of mineral fertilizers $N_{60}P_{60}K_{60}$, where the gain to control was 0.88 t/ha (Vyshnivsky, 2011).

We observed a significant increase in the yields of Prima variety when applying $N_{30}P_{30}K_{30}$ on 1.89 t/ha, which is 0.47 t/ha more than the control variant. The maximum yields were obtained on the variant with the norm of fertilizers $N_{60}P_{60}K_{60}$ - 2.03 t/ha, which is 0.61 t/ha more than the control variant. Retro variety also showed a significant increase in the yields by 0.41 and 0.53 t/ha in the variants

with fertilizer rates of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ compared with the control variant. We would like to note that in both varieties, the difference in the yields between fertilizer standards is negligible. The highest content of oil in Prima variety was on the control variant (40.4%). Application of fertilizers in the rate of $N_{30}P_{30}K_{30}$ reduced the content of oil in the seeds by 0.3% and fertilizers in the rate of $N_{60}P_{60}K_{60}$ caused a decrease in the content of oils by 0.7%. In Retro variety, we also recorded the highest oil content in the control variant, which reached 39.7%. Fertilizing in the rate of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ reduced the oil content by 0.5% and 0.6% compared to the control. At the same time, proceeding from higher levels of the yields, application of fertilizers contributed to an increase in oil production: $N_{30}P_{30}K_{30}$ by 0.15-0.19 t/ha, $N_{60}P_{60}K_{60}$ by 0.20-0.24 t/ha compared to the control. One of the important components of cultivation technology is the determination of optimal sowing standards, as to acquire high yields it is necessary to ensure a rational amount of crops and productive branches per area unit.

We determined that a longer period of vegetation was at the sowing rate of 1.5 million pp./ha - 90-92 days, further increase in the sowing rate contributed to a decrease in the period of vegetation in the studied varieties by 3-7 days on an average. The leaf surface area of Prima variety in terms of seed sowing rate of 1.5 million pcs/ha was at the level of 44.5 thousand m^2 /ha, which is 9.2 and 17.0 thousand m^2 /ha less than the sowing variant of 2.0 and 2.5 million pieces/ha. Retro variety had the leaf surface area of 40.5 thousand m^2 /ha in the variant with the sowing rate of 1.5 million pieces/ha. Increasing the sowing rate up to 2.0 and 2.5 million pcs/ha increased this figure to 46.7 thousand m^2 /ha and 54.8 thousand m^2 /ha respectively. The net productivity of photosynthesis calculated by A. A. Nychyporovych in the interphase period of budding - flowering in the variant with the sowing rate of 1.5 million pcs/ha was 4.34 $g/m^2/day$ an increase of the sowing rate up to 2.0 and 2.5 million pcs/ha contributed to the reduction of the net productivity to 3.58 and 2.60 $g/m^2/day$, respectively. Retro variety had a similar tendency.

An optimum sowing rate for Prima variety was found to be 1.5 million pcs/ha, which ensured the highest yield of 1.89 t/ha. By increasing the seed rate to 2.0 and 2.5 million pounds per hectare, yields dropped significantly to 1.81 and 1.75 t/ha respectively. Retro variety's yield was 1.71 t/ha with the sowing rate of 1.5 million pounds per hectare. A maximum yield was obtained at an optimum sowing rate of 2.0 million pounds/ha - 1.77 t/ha, an increase in the sowing rate up to 2.5 million pounds per hectare significantly reduced the yields to 1.69 t/ha (Fig. 3).

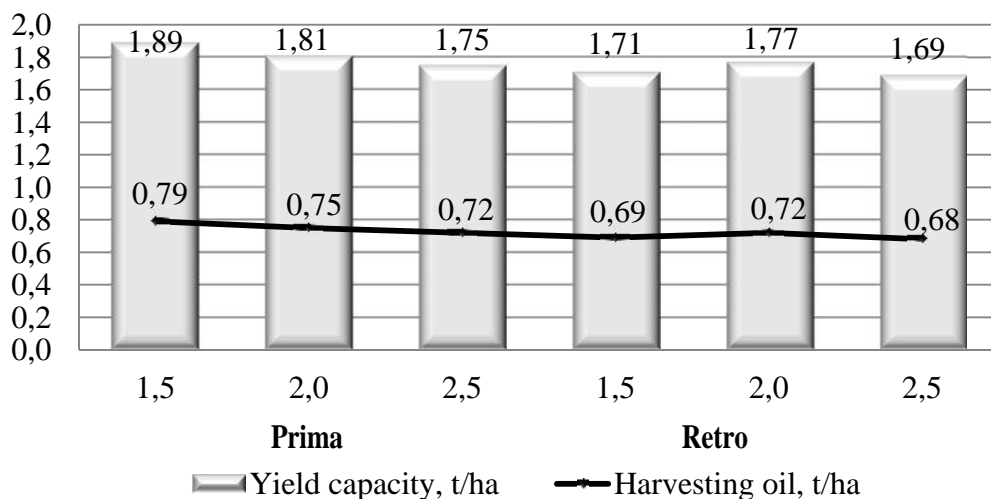


Fig. 3. Yield capacity and harvesting of the bluish mustard oil depending on the variety and seeding rates, t/ha (average for 2015-2017)

Analysis of the indices of economic and energy efficiency of Prima variety production, depending on the studied elements of cultivation technology, showed that the highest indicators of the level of profitability of seed production are 101-120%, the coefficient of energy efficiency of the production - 3.17-4.82. We recorded the maximum values in the first sowing term in a non-fertilized variant with the sowing rate of 1.5 million pcs./ha. Retro variety's maximum profitability indicators were within the range of 89-112%, the energy efficiency ratios - within the range of 3.07-4.69. They formed the maximum indices in the first sowing term in a non-fertilized variant with a sowing rate of 2.0 million pcs./ha.

CONCLUSION

According to research results, for the formation of 1.71-1.91 t/ha of bluish mustard seeds in the conditions of the north-eastern forest-steppe of Ukraine on typical black soil, the cultivation technology should include: use of seeds of modern high-yielding adapted varieties; start sowing at soil temperature of 4-5 °C at a depth of 10 cm; the rate of fertilizer $N_{30}P_{30}K_{30}$ (during pre-sowing cultivation) and seeding rates of the varieties Prima - 1.5 million pieces/ha, and Retro - 2.0 million pieces/ha.

According to the results of the analysis, trends in the meteorological parameters caused the expansion of the range of area under bluish mustard cultivation in Ukraine, which contributed to the increase in total national production of oilseeds. Having all the opportunities (natural, climatic, logistical and human), Ukraine will increase its presence in the world market of oilseeds.

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