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Formation of *Camelina sativa* yield depending on the level of mineral fertilization under conditions of Precarpathians

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ABSTRACT

The influence of growing technology elements of *Camelina sativa*, in particular, influence of different fertilizer doses on yielding capacity of *Camelina sativa* plants under conditions of Precarpathians of Ukraine has been studied. Main results of three-year research concerning improvement of existing technologies of growing *Camelina sativa* variety Girsky depending on the background of mineral nutrition and application of micro-fertilizers and growth stimulants which would maximize varietal characteristics of the crop and meet the needs of farmers have been presented. It was found that the highest yield of *Camelina sativa* 1.95 t/ha had been obtained with application of mineral fertilizers in a dose of $N_{30}P_{45}K_{45}+N_{60}$, which was 0.99 t/ha more than in the control. The lowest yield - 0.96 t/ha was obtained in the control variant (without fertilizers).

1. INTRODUCTION

Camelina sativa - spring oil crop of the Cabbage family (Brassicaceae), genus Camelina. It originates from Eastern Europe and Southwest Asia, where wild forms of this plant are still present today. Camelina sativa as agricultural crop has been sown since the second half of the XVIII century. The first information about its growing relates to France, then Camelina glabrata crops were spread in Germany, Belgium, Holland, England [1- 3]. Camelina sativa is considered to be one of the oldest crops in Western Europe [4]. According to literature sources, Camelina sativa has been grown in Ukraine as an oil crop of secondary importance since 1940. At that time Camelina sativa crops covered an area of 11.4 thousand hectares [5]. Later, due to increase of sowing areas for growing sunflower, rapeseed and other oil crops, Camelina sativa was practically displaced and unfairly forgotten. Only small areas were sown with Camelina sativa for receiving raw materials in the production of soap and cosmetics, as well as a component of poultry feed [6], [7- 9]. At present, sowing area of Camelina sativa in Ukraine is 5-6 thousand hectares (3% of all oilseeds), which are mainly located in the northern part of the left-bank Forest-Steppe. However, these areas can be increased by 3-4 times. Short vegetation period allows plants to use moisture reserves efficiently and form crops due to precipitation during vegetation period [13], [14], [12]. In the 1980s, selection of Camelina sativa was resumed in the United States, Canada, Europe and Australia, primarily because of exceptional level of Q-3 fatty acids and α-linolenic acid. Recently, Camelina sativa has become the subject of various experiments assessing its future potential.

In 2007, about 15,000 acres of Camelina sativa were grown in the United States, mostly in Montana. Gradually, the area of Camelina sativa is increasing, and the interest is growing in other countries, partly due to stimulation of production and research funding, due to possible usage of the plant as raw material for aviation fuel [15]. Today, main oil crop for biodiesel production in EU and Ukraine is winter and spring rape. According to the forecasts of experts from Coordination Council Secretariat of the Cabinet of Ministers of Ukraine on issues of Agrarian Policy, 2.15 million tons of biodiesel are needed to replace annual consumption of 1.9 million tons of diesel fuel. For this purpose, 5.5 million tons of rape seed have to be used when producing 1 kg of biodiesel from 2.4 kg of rapeseed [10], [11], [16]. According to EU Biofuels Directive 2003/30, 10% of biofuels should be used for transport in the countries of European Union as early as December 2020. Therefore, when joining to EU, Ukraine is obliged to comply with this directive [4]. According to calculations of Lykhochvor and Petrychenko, when growing rapeseed for biodiesel on the area of 2.0 million hectares, all arable land in Ukraine can be used for cultivation [17]. A significant disadvantage of cabbage crops is large loss of yield because of pod cracking during seed ripening. With rapeseed yield of 2.0 t/ha and 10-15% of pod cracking, seed yield losses are 0.2-0.3 t/ha [18] [24], [25].

Thus, there is an objective reason to affirm that Camelina sativa as ancient but forgotten oil crop, in the nearest future, will find prominent place in the production of oil for biodiesel and high-protein fodders in the form of meal and mill cake, which is guaranteed by its extreme plasticity to agro-environmental conditions of growing and high profitability of production.

2. MATERIALS AND METHODS

Field research was conducted in technological crop rotation at the Department of Growing Technology, Seed Production and Biochemistry of Cruciferous Crops at Precarpathian State Agricultural Research Station of the National Academy of Agrarian Sciences of Ukraine on sod podzolic soil during 2015-2018. The soil of experimental plot is sod deep podzolic gleyed soil. By mechanical composition, they are coarse-dusty heavy-gleyed with strong humus horizon up to 75 cm and are characterized by the following indices: acidity, pH - 5.3, humus content (%) - 2.75, soil provision with main nutrition elements (mg/kg): nitrogen - 82, phosphorus - 46.0, potassium - 119.0. Predecessor is winter wheat. The sowing was conducted according to experimental scheme. A variety Girsky of selection of institute AIP was used for sowing. Taking into consideration insensitivity of Camelina sativa to application of potassium fertilizers [18], [7], effect of only nitrogen and phosphorus fertilizers was studied. In the experiment, mineral fertilizers in the form of ammonium nitrate and granular superphosphate were applied with main tillage according to the

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following scheme: Control - without fertilizers; Background – ($N_0P_{45}K_{45}$); Background – ($N_{30}P_{45}K_{45}$); Background – ($N_{30}P_{45}K_{45}$) + N_{60}; Background – (N30P45K45) + Vympel (500 g/ha) + Oracul multicomplex (1l/ha) + Oracul colamine boron (1 l/ha) + Oracul sulphur active (2 l/ha).

The experiment was based on four repetitions; the area of accounting plot – 20 m^2. The variant without fertilizers was used as control. Fertilization of Camelina sativa crops was carried out with nitrogen fertilizers, micro-fertilizers and growth stimulators according to corresponding variants of experimental scheme in rosette phase. In the experiment, was sown Camelina sativa variety Girsky of selection of Ivano-Frankivsk Institute AIP NAAS entered on the State Register of varieties suitable for growing in Ukraine. Potential seed yielding capacity is about 2.0 t/ha, green mass - 40.5 t/ha [19], [20]. Growing technology of Camelina sativa in the experimental plots was generally accepted for soil and climatic conditions of Precarpathians, with the exception of the factors studied [21].

Weather and climatic conditions of the region are one of determining factors in the formation of productivity and quality of agricultural crop yields. It can be decisive criterion for expediency of growing crops and their implementation in a particular region, so scientists are increasingly paying more attention to analysis of weather conditions during research period, which aimed to define Camelina sativa productivity depending on varietal characteristics and farming techniques under conditions of Precarpathians of Ukraine. Natural and climatic conditions which have developed in Ivano-Frankivsk region contribute to development of agriculture and forestry, growing of main agricultural crops. Analysis of hydrothermal conditions, which developed during vegetation period of Camelina sativa during the years of research, was conducted according to Ivano-Frankivsk regional meteorological station. It should be noted that in the years of research, weather conditions differed significantly from the average long-term data both in terms of temperature and precipitation during Camelina sativa growing season. It has been found that spring has become 0,80C warmer over the last two decades, mainly due to March, while in autumn air temperature has changed insignificantly. However, because of natural anomalies, there is an acceleration of flowering in spring and premature autumn flowering, which significantly affects vegetation period of crops and their productivity in general.

Mathematical processing of obtained analytical digital material was conducted by the method of disperse and correlation analysis according to Dospekhov and Ushkarenko and others, using computer program "Agrostat" [23], [22].

3. RESULTS AND DISCUSSION

It is known that duration of each vegetation period and phenophases significantly affects the level of plant yielding capacity. In dry weather, due to lack of nutrients, their duration is shortened and yields are reduced. With optimal moisture supply and level of mineral nutrition, their duration increases, which contributes to formation of higher productivity level.

Phenological observations have shown that studied factors had corresponding effect on vegetation period duration of Camelina sativa plants. Analysis of the research results showed that duration of vegetation and interphase periods of Camelina sativa depended mainly on fertilization system (Figure 1).

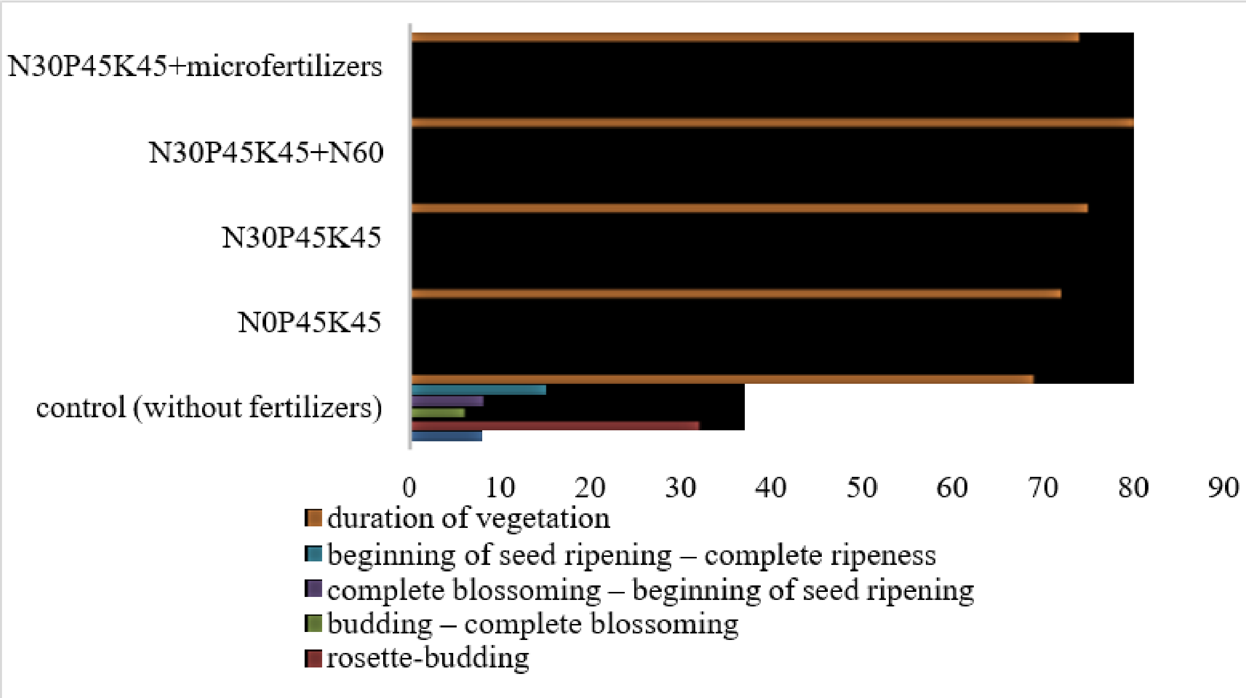

FIGURE 1: Duration of vegetation and interphase periods of Camelina sativa (mean value for 2015-2018)

On average, during the years of research (2015-2018), shoots appeared on the 8th day after sowing, which was facilitated by significant amount of precipitation and corresponding air temperature. Thus, shoots in the control variant (without fertilizers) appeared together with the ones in the other variants (variants with application of mineral fertilizers). Starting from rosette phase, duration of interphase periods extended depending on fertilizer variant.

It was found that rosette-budding period of Camelina sativa in the variants without fertilizers (control) lasted 32 days and with application of mineral fertilizers this period extended to 37 days. It should be noted that in the variants provided with nitrogen fertilization in two stages, an increase in duration of rosette-budding period to 37 days was noted. As it is known, application of high doses of nitrogen fertilizers can delay aging process of the plant organism, prolonging life of the leaves and strengthen the process of photosynthesis.

Thus, duration of interphase period budding-flowering in the control variant was 6 days. Application of mineral fertilizers helped to increase it by 1-3 days depending on fertilizer doses. Thus, in the variants with application of mineral fertilizers in doses $N_{30}P_{45}K_{45}$+ N_{60} duration of budding-flowering period was 9 days respectively.

Analyzing fertilization impact on the duration of vegetation period of crops, it should be noted that their application contributed to prolongation of individual interphase periods on average by 1-3 days compared to the variants without fertilizer application. It should also be noted that the results of research showed that the longest vegetation period of Camelina sativa plants was in the variant with application of complete mineral fertilizer in two stages - 80 days, which is 11 days longer than in the control.

It is known that prerequisite for crop yield formation is accumulation of total biomass by plant and crops. Usually, within one variety, under the same growing conditions, higher biomass corresponds to higher yields. Therefore, knowledge of biomass growth nature by individual plant and agrocenosis in total is an important condition for controlling and managing yield formation.

According to the results of research it was found that dry matter mass per 1 hectare during vegetation period was constantly growing. On average, during 2015-2018, regardless of Camelina sativa phases of growth and development, amount of dry matter in the variants with application of mineral fertilizers exceeded its indices obtained in the variants without fertilizers. It was defined that dry matter content in the control without fertilizers in the rosette phase was 0.64 t/ha (Table 1). The increase from application of mineral fertilizers varied from 0.16 t/ha to 0.41 t/ha.

TABLE 1. Dynamics of dry matter accumulation by plants of Camelina sativa depending on influence of growing technology elements, average for 2015-2018, t/ha

Fertilization variant	Phase of growth and development			
Without fertilizers (control)	rosette	budding	blossoming	ripening
$N_0P_{45}K_{45}$	0.64	1.30	1.87	2.76
$N_{30}P_{45}K_{45}$	0.80	1.59	2.28	3.26
$N_{30}P_{45}K_{45}$+N_{60}	1.43	2.92	4.17	5.76
$N_{30}P_{45}K_{45}$+microfertilizers	1.05	2.10	3.01	4.13
$\bar{X} \pm S_x$	0.82+0.08	1.57+0.14	2.28+0.18	3.31+0.26

The highest outcome of Camelina sativa dry matter in the ripening phase - 5.76 t/ha was obtained when applying mineral fertilizers in a dose of $N_{30}P_{45}K_{45}$ and foliar fertilization with nitrogen in a dose of 60 kg/ha. The structure of the crop yield is the ratio between main elements of yielding capacity: seeds and straw, aboveground part and root system, etc. And the level of crop yield depends on the number of plants per unit of area, pods per plant, seeds and seed mass.

Analysis of the yield structure presented in Table 2, shows a significant effect of mineral fertilizers on almost all indices of Camelina sativa yield structure.

TABLE 2. Indices of the elements of Camelina sativa yield structure depending on the influence of growing technology elements, average for 2015-2018

Fertilization variant	Number of pods, Pcs	Number of seeds in a pod, pcs	Mass of 1000 seeds, g
Without fertilizers (control)	28.2	12.1	0.96
$N_0P_{45}K_{45}$	33.5	13.2	1.03
N30P45K45	38.5	13.5	1.14
N30P45K45+N60	41.9	12.7	1.24
N30P45K45+microfertilizers	40.1	12.5	1.16
$\bar{X} \pm S_x$	33.2+5.3	0.2+4.6	0.03+7.3

Above given data show that application of mineral fertilizers had positive effect on certain indices of yield structure, one of which is the number of pods per plant. Thus, there was an increase in the number of pods per plant with increase of fertilizer dose. This index varied on average from 28.2 pcs. to 41.9 pcs. of pods per plant. It is known that one of the indices significantly affecting the yield of Camelina sativa seeds is the number of seeds per pod. It is the least variable element of yielding capacity of cruciferous crops.

The largest number of seeds was obtained in the variant with application of $N_{30}P_{45}K_{45}$, it was 13.5 seeds, while number of seeds per pod in the control was 12.1 pcs. The main structural element which largely determines the yield of Camelina sativa is the mass of 1000 seeds. It is varietal feature, but it is influenced by the factor of ripening conditions and can change due to the action of fertilizers.

It was found that there was an increase in the mass of 1000 seeds by 0.07-0.28 g. with increase of fertilizer dose. The highest index was obtained in the variant with application of $N_{30}P_{45}K_{45}$+N_{60}, it was 1.24 g, while in the control variant it was only 0.96 g. It was defined that there was an increase in the yield while increasing fertilizer doses. This regularity was observed during all research years. We also note that hydrothermal regime of the year significantly influenced yield increase.

According to our research data, the lowest yield of Camelina sativa seeds of variety Girsky, as expected, was observed in the variant without fertilizers (control) where it averaged 0.96 t/ha in 2015-1018 (Figure 2). Increasing the dose of mineral fertilizers to $N_{30}P_{45}K_{45}$ provided yield increase by 0.45 t/ha, or by 39.9%.

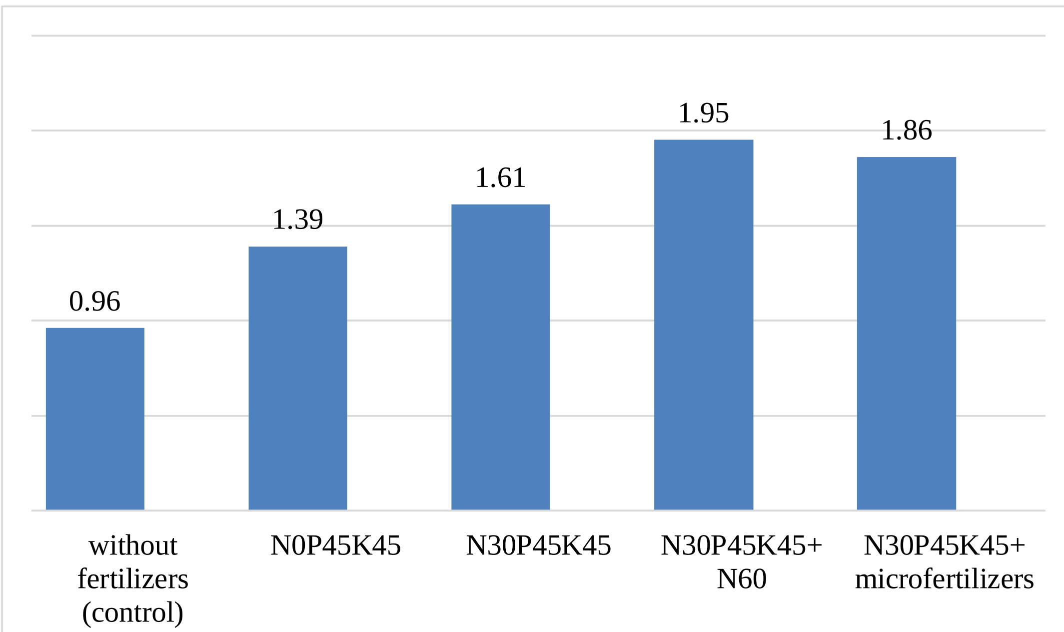

FIGURE 2. Yielding capacity of Camelina sativa depending on the level of mineral nutrition, t/ha (mean value for 2015-2018)

Further increase in doses of mineral fertilizers also contributed to crop productivity increase. Thus, in the variant with application of mineral fertilizers in a dose of $N_{30}P_{45}K_{45}$+ N_{60} productivity of the crop increased to 1.95 t/ha, which is higher than the control by 0.99 t/ha, and compared to the variant with fertilizer dose of $N_{30}P_{45}K_{45}$ - by 0.34 t/ha. Application of fertilizers on the fifth variant with a dose of $N_{30}P_{45}K_{45}$ additionally to main fertilization and in combination with microfertilizers and growth stimulators increased the yield to 1.86 t/ha, which is higher than the control by 0.9 t/ha, and comparing with the third variant ($N_{30}P_{45}K_{45}$), yield increased by 0.25 t/ha.

The results of disperse analysis showed that estimation of the factors studied were reliable according to Fischer criterion at probability level 95%. The most influential factor on the yield formation of Camelina sativa seeds were mineral fertilizers. Their share of influence is 45%. Analyzing obtained indices, it can be noted that with increase of fertilizer doses an increase of crop yield was observed (Figure 3).

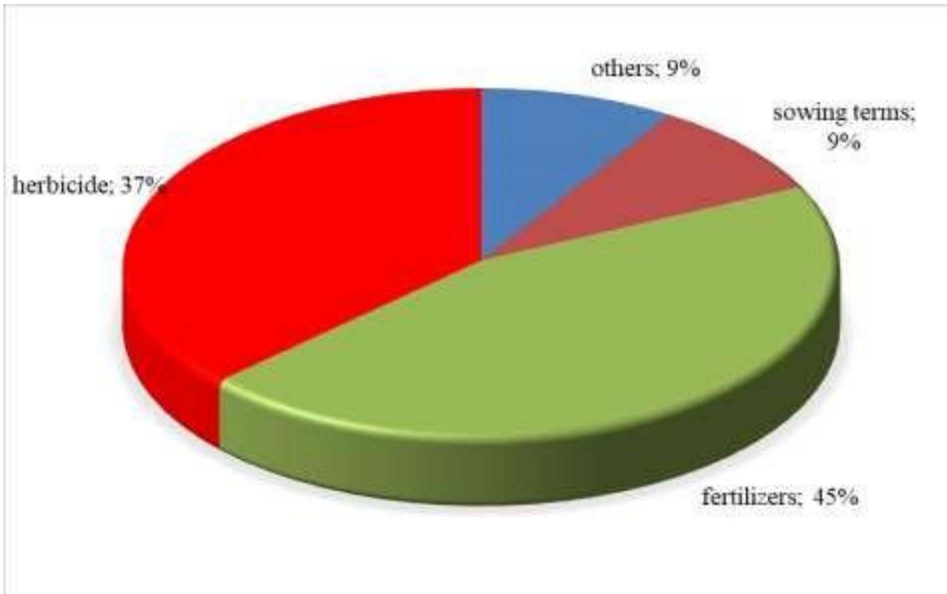

FIGURE 3. The share of factors in the formation of Camelina sativa yield

Another important factor in the formation of Camelina sativa yield is usage of crop protection system against weeds and diseases. The share of this factor in yield formation is 37%.

It was found that in addition to protection system and doses of mineral fertilizers, peculiarities of meteorological conditions in the years of research significantly influenced the yield level of Camelina sativa seeds.

4. CONCLUSION

Application of mineral fertilizers in doses of $N_{30}P_{45}K_{45}$+ N_{60} provides an increase in vegetation period duration by 11 days compared to the variant without mineral fertilizers. The highest yield of Camelina sativa of variety Girsky under conditions of Precarpathians on sod-podzolic soils (1.95 t/ha) was obtained with application of mineral fertilizers in a dose of $N_{30}P_{45}K_{45}$ and adding foliar nitrogen fertilization in a dose of 60 kg a.s. The lowest yield was noted in the control, which was within 96 t/ha.

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