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RESEARCH ARTICLE

Photosynthetic activity of *Camelina sativa* plants depending on technological measures of growing under conditions of Precarpathians of Ukraine

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Abstract

The influence of technology elements of *Camelina sativa* growing, in particular, studying of the influence of different fertilizer doses on photosynthetic activity of *Camelina* plants under conditions of Precarpathians of Ukraine has been studied. The research results of mineral fertilizer influence on the dynamics of leave area growth and the formation of photosynthetic potential of crops have been presented. According to the results of research it has been established that the highest indices of leaf surface area, from 21.5 thousand m^2/ha to 49.2 thousand m^2/ha, *Camelina sativa* forms in the flowering phase. Application of mineral fertilizers significantly affects the leaf surface area and photosynthetic potential of *Camelina sativa*. It was found that application of mineral fertilizers had a significant effect on the leaf surface area of *Camelina sativa* and, accordingly, on the photosynthetic potential. Photosynthesizing activity of sowing any culture the head warehouse form of its productivity. The head of state of the art of modern technologies is the construction of such projects, which would be as efficient as possible to vikoristovuyu sleepy energy for the accumulation of stately valuable birth.

Keywords: *Camelina sativa*, mineral fertilizers, leaf area, photosynthetic potential, pure photosynthesis productivity

Introduction

Camelina sativa is a promising oil crop, the yield potential of which is not yet fully disclosed. Interest in ryegrass has been restored in recent years due to oversaturation of crop rotations with cereals, sunflower, as well as increasing demand for vegetable oils of different quality. It also attracts attention due to its unpretentiousness, precocity, stable yield, high plasticity and suitability for different soil and climatic conditions.

Due to low-cost environmentally friendly cultivation and, accordingly, a slight impact on the environment, red is becoming a favorite crop for the production of organic products. The use of rye oil in food and other industries has a huge market potential. In addition, rye oil contains a large number of essential polyunsaturated acids, including linolenic (up to 31%) and linoleic (up to 18%). These substances are not synthesized in the human body, so they were called essential (irreplaceable). Widespread use of rye oil in the food, cosmetics and perfume industries, as well as in medicine, makes rye an agricultural crop of the future. *Camelina sativa* is a promising oil crop, the yield potential of which is not yet fully disclosed. Interest in ryegrass has been restored in recent years due to oversaturation of crop rotations with cereals, sunflower, as well as increasing demand for vegetable oils of different quality. It also attracts attention due to its unpretentiousness, precocity, stable yield, high plasticity and suitability for different soil and climatic conditions.

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The production process of plants consists of photosynthesis and the processes of transformation and use of products and energy of photosynthetic origin for respiration, biosynthesis, growth and development of plant organism. The task of obtaining the largest amount of organic matter is in creation of photosynthetic systems that would provide the most efficient use of energy of Photosynthetically Active Radiation (PhAR) for the creation of photosynthesis products and their rational use in the processes of growth, development and crop productivity formation (Nychyporovych 1972).

The process of photosynthesis is complicated by its nature and extremely important. Crop yields largely depend on photosynthesis and the ability to provide its highest productivity (Babych 2005). All crop production is essentially a system of making the best use of photosynthetic function of plants. From this point of view, each agricultural measure aimed at increasing yields is effective in the following cases: if it makes opportunity to obtain in crops such an area of leaves that develops rapidly and reaches large sizes; if it increases intensity and productivity of each square meter of leaf area and keeps them active for a longer period of time and if it promotes the best use of photosynthesis products (Poluektov et al. 2006; Shiferaw et al. 2011; Litvinov et al. 2019).

Photosynthetic activity of any crop sowing is the main component of its productivity formation. The main task of modern technologies is to design such crop sowings that would use solar energy the most effectively for accumulation of economically valuable yield (Nechyporenko 1987). Nychyporovych (1988) noted that each variety has a certain interval concerning potential abilities to form assimilation surface, but it is often accompanied by thinned sowing norms or, conversely, thickened. The optimal sowing norm is considered to be the one at which the plant forms the maximum individual photosynthetic surface and mass. It should be noted that photosynthetic activity of *Camelina sativa* is insufficiently studied. It is also emphasized by the research actuality and the need for scientific substantiation of these processes under conditions of Precarpathians.

The area of leaves, dynamics of its formation and the productivity of photosynthesis per unit of leaf surface area are important indices determining photosynthetic potential, photosynthetic activity of crop sowings and their productivity. It is known that leaf surface size is closely connected with accumulation of organic matter by plants and the formation of crops. It largely depends on the conditions of mineral fertilization. Scientists note direct relationship between yield and the mass of vegetative organs of plants. The intensity of biomass and leaf surface accumulation by plants is determined by the level of mineral nutrition (Babych 2005; Karbivska et al. 2020). The optimal area of leaves is considered to be the one which provides maximum gas exchange of crop sowing. For most crops, it is 40 thousand m^2/ha-50 thousand m^2/ha (Hospodarenko and Rassadina 2015).

However, a larger area of leaves, according to many scientists, does not always determine high yields. Excessive development of leaf apparatus in crops causes mutual shading of middle and, especially, lower tiers of leaves, resulting in worsening of their lighting, reducing carbon dioxide absorption and pure photosynthesis productivity. It can often cause the reduction of yields (Behyshev 1953; Alyev 1974; Tester and Langridge 2010). Biological features of crops, weather conditions and agro-technological measures have a great influence on the dynamics of leaf surface development and its size (Goenadi 1995; Scherner et al. 2016).

It should be noted that the photosynthetic activity of *Camelina sativa* is insufficiently studied. This emphasizes the relevance of research and the need for scientific justification of these processes in the Carpathians of Ukraine. Therefore, the program of our research to identify the dependences of the formation of the photosynthetic apparatus of *Camelina sativa* during the growing season provided for the determination of such indicators of photosynthetic activity of plants as leaf surface area, photosynthetic potential and net productivity of photosynthesis.

Materials and Methods

Field research was carried out in the technological crop rotation of the department of growing technology, seed production and biochemistry of cruciferous crops at the Precarpathian state agricultural research station of the National Academy of Agrarian Sciences of Ukraine on sod podzolic soil during 2015-2018. The soils of experimental plot are-sod deep podzolic gleyed, the mechanical composition is large-dusted and heavy-clayed with a strong humus horizon up to 75 cm, and characterized by the following indices: acidity, pH-5.3, humus content (%)-2.75, soil provision with main nutrient elements (mg/kg):

nitrogen-82, phosphorus-46.0, potassium-119.0

The predecessor is winter wheat. The sowing was conducted according to experimental scheme. For sowing was used a variety Hirskyi, selection of Institute of AIP. Taking into consideration insensitivity of *Camelina sativa* to application of potassium fertilizers (Poliakov 2011; Hryhoriv 2020), the 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 to main tillage according to the scheme: Control-without fertilizers; Background-$P_{45}K_{45}$); Background–($N_{30}P_{45}K_{45}$); Background-$N_{30}P_{45}K_{45}$) + N60; Background–($N_{30}P_{45}K_{45}$) + Vimpel (500 g/ha) + Oracul multicomplex (1 l/ha) + Oracul colamine boron (1 l/ha) + Oracul sulfur active (2 l/ha). The experiment was repeated four times; the area of accounting plot is 20 m². The variant without fertilizers served as a control. Fertilization of *Camelina sativa* crops was carried out with nitrogen fertilizers, microfertilizers and growth stimulators according to corresponding variants of the experimental scheme in the rosette phase. In the experiment, was sown a variety of *Camelina sativa* Hirskyi, selection of Ivano-Frankivsk Institute AIP NAAS included in the State register of varieties suitable for distribution in Ukraine. The potential yield of the seeds is about 2.0 t/ha, green mass-40.5 t/ha (Abramyk et al. 2003; Karpenko et al. 2019; Kolisnyk et al. 2019).

The technology of growing *Camelina sativa* on the experimental plots was generally accepted for soil and climatic conditions of Precarpathians, with the exception of the studied factors (Syvyryn and Reshetnykov 1988).

Weather and climatic conditions of the region are one of the main factors in the formation of agricultural crop productivity and quality. It can be crutial criterion for expediency of growing agricultural crops and their implementation in a particular region, so much attention is paid to the analysis of weather conditions during the period of carrying out the research, which aimed to establish the productivity of *Camelina sativa* depending on varietal characteristics and agrotechnology of growing under conditions of Precarpathians of Ukraine.

Natural and climatic conditions that have been formed in Ivano-Frankivsk region contribute to the development of agriculture and forestry, cultivation of main agricultural crops. The analysis of hydrothermal conditions, which were developing during vegetation period of *Camelina sativa* in the years of research, was carried out according to the data of Ivano-Frankivsk regional meteorological station. During vegetation period of *Camelina sativa* in the years of research, the weather conditions differed significantly from the average long-term data both in terms of temperature indices and precipitation amount. Mathematical processing of the obtained analytical digital material was performed by the method of variance and correlation analysis according to Dospekhov (Dospekhov 1985), using the computer program "Agrostat". The purpose of research is to study the influence of technological measures of *Camelina sativa* growing on photosynthetic activity of plants under conditions of Precarpathians of Ukraine.

Results

On average, during the years of research, there was a direct dependence between the process of leaf surface area formation of *Camelina sativa* and elements of cultivation technology. It is known that development of leaf surface depends on the activity of meristem, which provides formation of leaves and beginning of cellular processes that cause its growth. The decisive role in this process belongs to nutrition elements, in particular nitrogen.

The studies have shown that the leaf surface area of *Camelina sativa* plants in the initial period of development increases slowly. In the following phases of vegetation the increase of assimilation surface occurs intensively. This index reached its maximum value in the blossoming phase, and then it decreased. The decrease of leaf area was stipulated by biomass drying in the phase of seed ripening and defoliation. The curvilinear character of the formation of leaf surface area indices in the ontogenesis of *Camelina sativa* depending on the influence of the studied factors has been established (Fig. 1).

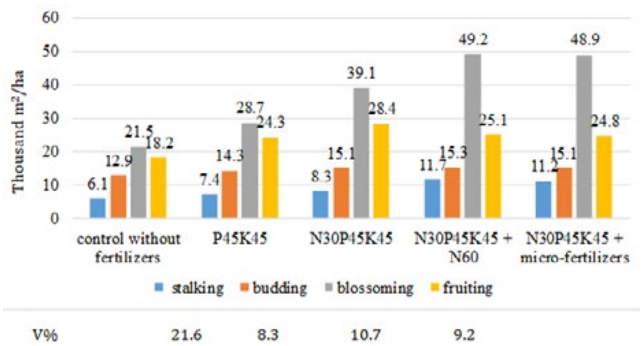


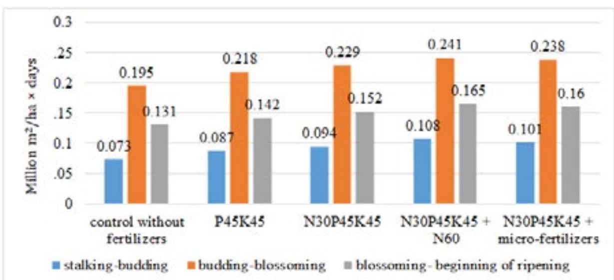
Figure 1. Formation of *Camelina sativa* leaf surface by phases of development depending on different technological measures of growing, average for 2015-2018. (V% 21.6, 8.3, 10.7, 9.2)

In a result of research, it was found that the use of mineral fertilizers promotes more intensive development of the leaf surface. In the process of our research we studied the dynamics of leaf surface area formation in the main periods of *Camelina sativa* growth. During the formation period of two real leaves, dependence between leaf surface area and fertilizer doses was not established.

In the process of research was established the dynamics of leaf surface area formation of *Camelina sativa*. The use of mineral fertilizers contributed to more intensive development of the leaf surface. Thus, in the stalking phase, the leaf surface area ranged from 6.1 thousand m^2/ha to 11.7 thousand m^2/ha depending on the variant of fertilization. In the budding phase, this index in the control ranged from 12.9 thousand m^2/ha. The largest leaf surface area of *Camelina sativa* was in the blossoming phase. Thus, in the control variant it was 28.7 thousand m^2/ha. With increasing the dose of nitrogen fertilizer from 30 kg/ha to 90 kg/ha of a.m., the leaf surface area increased to 39.1 thousand m^2/ha-49.2 thousand m^2/ha. The maximum leaf surface of *Camelina sativa* plants in the blossoming phase was observed in the experiment variant with the background+N_{60}-49.2 thousand m^2/ha. Application of micro-fertilizers and growth stimulators in the composition of complete mineral fertilizers provided a significant increase in the leaf surface area of *Camelina sativa* plants-up to 48.9 thousand m^2/ha.

In the fruiting phase *Camelina sativa*, the leaf surface area ranged from 18.2 thousand m^2/ha in the control up to 25.1 thousand m^2/ha-with application of mineral fertilizers at a dose of background + N60. Statistical analysis of the leaf surface area of spring ryegrass indicates a high (V=8.3-21.6%) level of variability of indicators over the observation periods depending on the studied factor. Analysing indices of photosynthetic potential of *Camelina sativa* crops during the growing season, it should be noted that this index was increasing from the beginning of growing season to the blossoming phase, after which its decrease was observed.

The studies have shown that photosynthetic potential of *Camelina sativa* depended on the use of mineral fertilizers, duration of interphase periods and intensity of leaf apparatus formation. In general, the change in the size of photosynthetic potential during the growing season was similar to the change in leaf surface area. An increase of nitrogen fertilizer doses had a positive effect on the size of photosynthetic potential of *Camelina sativa* crops (Fig. 2).

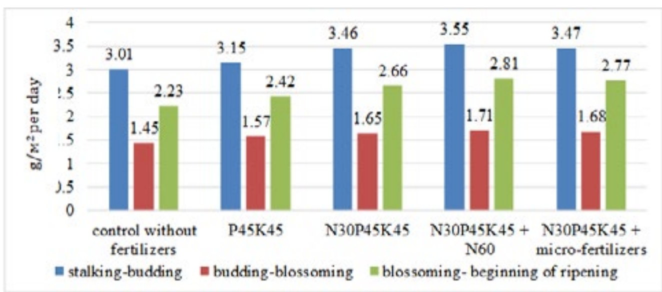


V% 9.2 4.8 6.3

Figure 2. Formation of photosynthetic potential of *Camelina sativa* crops depending on doses of mineral fertilizers, average for 2015-2018.

Data of Fig. 2 show that the index differed in the phases of development of *Camelina sativa* plants. Its minimum value was observed in the interphase period of stalking-budding, and the biggest-in the period of budding-blossoming. Thus, in the control variant, photosynthetic potential was the lowest in all phases of development. The maximum value of photosynthetic potential (0.241 million m^2/ha × days) of *Camelina sativa* plants was reached in the interphase period of budding-blossoming in the variant with background + N60. Increasing the dose of nitrogen fertilizers from 30 kg/ha to 90 kg/ha on a phosphorus-potassium background during the years of research increased this index by 37%-86% compared with the control variant in the interphase period of blossoming-ripening. It is proved, that photosynthetic surface of crops influences the efficiency of their work, which in its turn affects the formation of *Camelina sativa* productivity and is determined by such indices as Pure Photosynthesis Productivity (PPhP), which in its turn shows the amount of dry matter in grams per day and largely depends on the formed leaf surface. The indices of pure photosynthesis productivity are satisfactory, which have values in the range of 3 g/m^2-4 g/m^2 per day, good 4 g-6 g, very good-more than 6 g of dry matter per 1 m^2 of leaf area per day.

According to the results of calculations, the highest indices of pure photosynthesis productivity of *Camelina sativa* crops were formed during the stalking-budding period. Depending on the fertilizer doses, this index varied in the range of 1.57 g/m^2-3.55 g/m^2 per day (Fig. 3).



$\bar{x} \pm S_{\bar{x}}$ 3.05±0.05 1.57±0.02 2.42±0.04

Figure 3. Pure productivity of photosynthesis of spring *Camelina* crop depending on the elements of cultivation technology, average for 2015-2018.

It was determined that high indices of PPhP were observed in the period of stalking-budding and blossoming-ripening. Thus, in the period of stalking-budding the indices varied from 3.01 g/m^2 to 3.55 g/m^2 per day, in the period of flowering-ripening 2.23 g/m^2-2.81 g/m^2 per day. The highest indices among the studied sowing dates were obtained for fertilizers with a dose of $N_{30}P_{45}K_{45}$+N_{60}. In fertilized variants, the increase of assimilation surface area and size of photosynthetic potential was not accompanied by corresponding increase in productivity of photosynthetic work per unit area of the leaf surface. With application of mineral fertilizers PPhP varied depending on the dose of fertilizers from 3.15 g/m² per day (with application of $P_{45}K_{45}$) to 3.55 g/m² per day ($N_{30}P_{45}K_{45}$+N_{60}). During the period of maximum development of assimilation apparatus, which lasts from the budding phase to the flowering phase, the PPhP indices decreased slightly comparing with the previous period and ranged 1.45 g/m²-1.71 g/m² per day. It can be explained by the fact that with increasing of leaves area in crops and rising of their mutual shading, the indices of plant intensity and pure productivity of photosynthesis decrease in crops.

Conclusion

During cultivation of *Camelina sativa* under conditions of Precarpathians of Ukraine the maximum leaf surface (28.7 thousand m²/ha-49.2 thousand m²/ha), depending on fertilization peculiarities, is formed in the blossoming phase. The dynamics of photosynthetic potential is similar to the one for which the leaf surface area of plants is formed. Its photosynthetic potential is mostly affected by the level of nitrogen nutrition. We have found that the dynamics of PPhP indices formation during the growing season of *Camelina sativa* had sinusoidal character.

Thus, the main task in achieving high productivity of spring ryegrass is the highest possible formation of crops with the most developed leaf apparatus, which for a long time will be active both at the beginning and at the end of the growing season.

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