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DYNAMICS OF THE FORMATION OF THE ASSIMILATIVE SURFACE AND GROWTH PROCESSES OF OILSEED RADISH PLANTS DEPENDING ON GROWING CONDITIONS

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Statement of The Problem. Ensuring high productivity of agricultural crops under changing environmental conditions is one of the key challenges of modern agriculture. Oilseed radish (*Raphanus sativus* var. *oleiformis*) is an important multipurpose crop widely used for green manure, fodder production, and soil improvement. Its productivity largely depends on the intensity of growth processes and the formation of the assimilative surface, which determines the efficiency of photosynthesis and biomass accumulation [5].

Under the conditions of the Right-Bank Forest-Steppe of Ukraine, characterized by unstable moisture supply and increasing variability of climatic factors, the optimization of crop growing technologies becomes especially relevant. In particular, the level of mineral nutrition significantly affects plant growth, development, and the formation of leaf area, which directly influences yield formation.

However, the patterns of assimilative surface formation and growth dynamics of oilseed radish plants depending on growing conditions and varietal characteristics remain insufficiently studied. This limits the development of scientifically grounded recommendations for improving cultivation technologies and increasing crop productivity.

Therefore, the study of growth processes and the formation of the assimilative apparatus of oilseed radish under different levels of mineral nutrition in specific soil and climatic conditions is a relevant scientific problem.

Analysis of the latest research and publications.. Oilseed radish (*Raphanus sativus* L. var. *oleiferus* Pers.) is a valuable multifunctional crop widely used as green manure, biofumigant, and cover crop in modern agroecosystems. It is characterized by rapid biomass accumulation, high ecological plasticity, and the ability to form a powerful assimilative surface under different environmental conditions [3, 10, 11].

Scientific studies emphasize the importance of varietal characteristics and cultivation technologies in regulating growth processes of oilseed radish. In particular, Kovka N.S. highlights the influence of technological factors and varietal differences on plant development in the Right-Bank Forest-Steppe conditions [2]. The importance of environmental factors and nutrition systems in yield formation is also confirmed in the research of Bilonizhko Kh.V. [1].

The formation of assimilative surface is a key factor of crop productivity. Tsytsiura T.V. established that leaf area development significantly depends on sowing parameters and fertilization, which directly affects photosynthetic efficiency and biomass accumulation [4]. Further studies by Tsytsiura Ya.H. confirm the important role of mineral nutrition and microelements in enhancing growth processes and productivity of oilseed radish [5, 6].

Morphological and anatomical features of oilseed radish plants also play an important role in productivity formation. It has been shown that stem structure and anatomical characteristics depend on agrotechnological factors and cultivation conditions [7, 8]. These results confirm the close relationship between plant structure and environmental factors.

Modern studies demonstrate that oilseed radish has high adaptive capacity and can effectively realize its biological potential under different environmental conditions, making it an important component of sustainable agricultural systems [10, 11, 12]. The wide range of its agricultural applications is also confirmed in recent studies [9], while nutrition systems significantly influence seed quality formation [13].

Despite the significant number of studies, the dynamics of assimilative surface formation and growth processes depending on growing conditions remain insufficiently studied and require further systematization. This determines the relevance of continued research in this direction.

Purpose of the article. The aim of the article is to investigate the dynamics of growth processes and the formation of the assimilative surface of oilseed radish plants depending on growing conditions, in particular the level of organic fertilization and varietal characteristics, as well as to determine their influence on biometric parameters and crop productivity under the conditions of the Right-Bank Forest-Steppe of Ukraine.

Research methods. Phenological observations of oilseed radish plant growth and development were conducted throughout the growing season in accordance with generally accepted principles of field experiments and methodological approaches used in studies of oilseed radish cultivation [2, 4]. Plant height measurements were carried out along the diagonal of experimental plots at key phenological stages to ensure representativeness of the obtained data.

The assimilative surface area of oilseed radish plants was determined using the leaf imprint (paper tracing)

method, which is widely applied in agrobiological research for assessing leaf area dynamics and photosynthetic potential of crops [4, 10].

The yield of green biomass was determined using standard field experimental approaches to crop productivity assessment, based on generally accepted agronomic principles of oilseed radish cultivation [3].

Research results. Growth is one of the primary characteristics of plant development, reflecting continuous quantitative and qualitative changes in plant organisms. The intensity of growth processes depends on the developmental stage of the plant and the interaction between internal physiological mechanisms and environmental conditions. It should be noted that environmental requirements for growth and development do not always coincide, which leads to variability in morphogenetic responses among crop varieties [1].

Under field conditions, the realization of growth potential is significantly influenced by agronomic factors, including fertilization and varietal characteristics. In the conditions of the Right-Bank Forest-Steppe, the conducted studies on oilseed radish varieties *Zhuravka* and *Kiyanochka* demonstrated that organic fertilization (Greenodin Gray) had a pronounced effect on plant height formation [2].

The experiments were carried out on a plot size of 5 × 6 m (30 m²), which corresponds to 0.003 ha. Accordingly, the applied fertilizer doses per experimental plot were: 5 t/ha = 15 kg per plot, 10 t/ha = 30 kg per plot.

Over the two-year research period, plant height varied depending on the phenological phase, fertilization level, and varietal differences (Table 1).

Analysis of plant height dynamics shows that fertilization significantly enhanced growth intensity in both varieties throughout all phenological stages. In all fertilized treatments, plants clearly exceeded the control, confirming the positive role of improved nutrient supply.

The highest plant height values were recorded under the application of Greenodin Gray at 10 t/ha (30 kg per 30 m² plot). At the flowering stage, *Zhuravka* reached 102,4 cm, while *Kiyanochka* demonstrated a slightly higher value of 104,8 cm, exceeding the control variants by 27,6 cm and 28,5 cm, respectively. The application of 5 t/ha (15 kg per plot) also ensured a substantial increase in plant height across all developmental phases.

Overall, the *Kiyanochka* variety showed a slightly stronger growth response compared to *Zhuravka* under identical fertilization conditions, indicating its higher adaptive potential to an improved nutritional background in the conditions of the Right-Bank Forest-Steppe.

For optimal photosynthetic performance, plants must develop a sufficiently formed assimilative surface. The leaf area serves as the main organ for the accumulation of

Table 1

Dynamics of oilseed radish height depending on fertilizer, cm (average for 2024–2025)

Variety	Fertilization Variant	Development Phase			
		Rosette	Stem Elongation	Budding	Flowering
Zhuravka	Control (no fertilizers)	4,2	11,3	53,6	74,8
	Greenodin Gray, 15 kg/plot	4,6	13,8	60,4	88,7
	Greenodin Gray, 30 kg/plot	5,1	16,9	67,8	102,4
Kiyanochka	Control (no fertilizers)	4,4	11,9	55,1	76,3
	Greenodin Gray, 15 kg/plot	4,8	142	61,7	90,5
	Greenodin Gray, 30 kg/plot	5,3	17,4	69,2	104,8

Source: Compiled by the author

Fig. 1. Sowing of oilseed radish at the rosette stage

organic substances, which ultimately determines biomass formation and yield productivity. It is generally accepted that an optimal leaf area index during the period of active vegetation ranges from 40–60 thousand m²/ha. However, this parameter is variety-dependent, as genotypic differences influence the intensity and duration of leaf surface formation [3].

Thus, the development of an effective assimilative apparatus, combined with varietal characteristics and fertilization level, is a key physiological prerequisite for ensuring high productivity of oilseed radish under the studied agro-climatic conditions (Fig. 1).

Many researchers emphasize that the process of photosynthesis should be considered through the interrelation between leaf surface area formation, technological elements of cultivation, and abiotic environmental factors throughout the growing season [1, 13]. In oilseed radish, this period is relatively short, lasting approximately 45 days from emergence to the flowering stage.

In our study, conducted on two varieties of oilseed radish, *Zhyravka* and *Yamayka*, it was established that both fertilization level and varietal characteristics significantly influenced the formation of the assimilative (leaf) surface. The dynamics of leaf surface area development depending on fertilization variants and vegetation phases are presented in Table 2.

The obtained results indicate that, under the conditions of the Right-Bank Forest-Steppe, fertilization had a pronounced positive effect on the formation of the leaf assimilative surface in both oilseed radish varieties. Across all developmental stages, an increase in fertilization rate led to a consistent rise in leaf area formation compared to the unfertilized control.

The *Kiyanochka* variety demonstrated a slightly higher assimilative surface compared to *Zhuravka* at all growth stages and under all fertilization variants. The most significant differences were observed during the budding and flowering phases, which are critical for photosynthetic productivity.

The maximum leaf surface area was recorded at the flowering stage under the application of Greenodin Gray at 10 t/ha, reaching 62,7–64,0 thousand m²/ha depending on the variety. This confirms that both varietal characteristics and fertilization level play a key role in optimizing the photosynthetic potential of oilseed radish under regional climatic conditions [4].

Visual assessment of plant development during this period confirms the intensive formation of biomass and crop density, which is clearly observed when comparing the experimental plots (Fig. 2).

In their studies, the effect of fertilization on the nature of the leafiness of oilseed radish was studied. In the fertilized

Table 2

The effect of fertilizer on the formation of leaf surface area in the oilseed radish varieties *Zhuravka* and *Kiyanochka*, thousand m²/ha (average for 2024–2025)

Variety	Fertilization Variant	Development Phase			
		Rosette	Stem Elongation	Budding	Flowering
Zhuravka	Control (no fertilizers)	8,5	18,7	32,4	41,2
	Greenodin Gray, 15 kg/plot	10,2	24,9	45,6	54,3
	Greenodin Gray, 30 kg/plot	12,8	29,7	52,1	62,7
Kiyanochka	Control (no fertilizers)	8,7	19,2	33,1	42
	Greenodin Gray, 15 kg/plot	10,6	25,4	46,8	56,1
	Greenodin Gray, 30 kg/plot	13,1	30,2	53,1	6

Source: Compiled by the author

Fig. 2. Oilseed radish crops during the flowering stage: varieties Zhuravka and Kiyanochka

variants of the experiment, where organic fertilizers (Greenodin Gray) were applied, the leafiness in certain phases of vegetation slightly decreased (Table 3). This phenomenon can be explained by the redistribution of assimilates towards enhanced growth of the above-ground mass and the formation of a more powerful stem, which led to a relative decrease in the share of the leaf cover.

The results obtained indicate that the level of mineral (organic) nutrition significantly affects the morphological structure of oilseed radish plants, changing the balance between the leaf surface and other plant organs depending on the phase of development.

This figure 3 presents a comparative photographic illustration highlighting the morphological characteristics of oilseed radish varieties at the early stage of stem elongation. The left panel shows the *Kiyanochka* variety, characterized by a dense rosette of dark green leaves with a strongly wrinkled surface and pronounced serration. The plants exhibit initial stem elongation with noticeable branching and a slight purple pigmentation of the stems.

The right panel represents the *Zhuravka* variety, which differs by having lighter green leaves with a smoother surface, gently undulating margins, and less pronounced serration. The stems are thinner, predominantly green, vertically oriented, and exhibit lower initial branching compared to the *Kiyanochka* variety.

A white plastic object visible on the soil surface in the right panel serves as a reference for scale and comparative assessment of plant size.

The next stage was to establish that the dry matter yield of oilseed radish varieties *Kiyanochka* and *Zhuravka* was positively influenced by organic fertilizers (Greenodin Gray). On average, over two years of research, the maximum dry matter yield was obtained with fertilizer application at a rate of 10 t/ha (30 kg/accounting plot of 30 m²). With this option, a significant excess of control was observed, which indicates high efficiency under

In particular, the *Kiyanochka* variety formed slightly higher dry matter indices compared to the *Zhuravka* variety, which indicates its greater productive response to improved nutrition conditions. The variant with the application of 5 t/ha (15 kg/plot) also provided a significant increase in this index, but was inferior to the maximum level of fertilization.

The increase in dry matter yield is due to a more intensive growth of vegetative mass, activation of photosynthetic processes and more efficient use of nutrients by plants [5]. It was established that there is a direct relationship between the level of fertilization and the accumulation of dry matter, which is manifested in both studied crops (Table 3).

Analysis of the obtained data shows that the application of organic fertilizer Greenodin Gray significantly influenced the formation of the dry matter yield of oilseed radish throughout

Table 3

Effect of fertilizer on leafiness of oilseed radish, % (average for 2024–2025)

Variety	Fertilization Variant	Development Phase			
		Rosette	Stem Elongation	Budding	Flowering
Zhuravka	Control (no fertilizers)	72,5	78,4	84,6	80,2
	Greenodin Gray, 15 kg/plot	70,1	75,8	82,3	77,5
	Greenodin Gray, 30 kg/plot	67,8	73,2	79,6	74,1
Kiyanochka	Control (no fertilizers)	73,8	79,6	85,4	81,0
	Greenodin Gray, 15 kg/plot	71,4	77,0	83,1	78,6
	Greenodin Gray, 30 kg/plot	69,0	74,5	80,8	75,3

Source: Compiled by the author

а) ***б)***

Fig. 3. Oilseed radish at the stem elongation stage (a) – Kiyanochka, b) – Zhuravka)

Table 4

Effect of fertilizer on the dry matter yield of oilseed radish in the flowering phase, c/ha (average for 2024–2025)

Variety	Fertilization Variant	Development Phase			
		Rosette	Stem Elongation	Budding	Flowering
Zhuravka	Control (no fertilizers)	8,4	18,6	32,5	45,8
	Greenodin Gray, 15 kg/plot	9,7	22,3	38,9	54,6
	Greenodin Gray, 30 kg/plot	11,2	25,8	44,7	62,3
Kiyanochka	Control (no fertilizers)	9,1	19,8	34,2	47,5
	Greenodin Gray, 15 kg/plot	10,6	23,9	41,5	57,8
	Greenodin Gray, 30 kg/plot	12,3	27,6	47,8	65,9

Source: Compiled by the author

Table 5

The effect of fertilization on the yield of green mass of oilseed radish, c/ha (average for 2024–2025)

Variety	Fertilization Variant	Development Phase		Average	Deviation from control
		2024	2025		
Zhuravka	Control (no fertilizers)	185	192	188,5	-
	Greenodin Gray, 15 kg/plot	215	224	219,5	+31,0
	Greenodin Gray, 30 kg/plot	248	260	254,0	+65,5
Kiyanochka	Control (no fertilizers)	190	198	194	-
	Greenodin Gray, 15 kg/plot	225	236	230,5	+36,5
	Greenodin Gray, 30 kg/plot	260	272	266,0	+72,0

Source: Compiled by the author

the entire vegetation period. In both studied varieties, a gradual increase in dry matter indicators was observed from the rosette phase to the flowering phase, which is due to the intensive growth of the vegetative mass of plants.

In all fertilizer options, the indicators significantly exceeded the control. In particular, in the flowering phase, the dry matter yield of the *Zhuravka* variety was 45,8 c/ha in the control, while with the application of 15 kg/plot it increased to 54,6 c/ha, and with 30 kg/plot – to 62,3 c/ha. A similar trend was observed for the *Kiyanochka* variety, where the corresponding indicators were 47,5; 57,8 and 65,9 c/ha.

The highest values of dry matter yield were recorded at the maximum level of fertilization (30 kg/accounting plot, which corresponds to 10 t/ha), which indicates the effectiveness of the increased level of nutrition for the formation of crop productivity [6]. At the same time, the *Kiyanochka* variety was characterized by slightly higher indicators compared to the *Zhuravka* variety in all variants of the experiment, which indicates its better response to fertilization and higher productive potential.

The results obtained confirm the direct relationship between the level of fertilization and the accumulation of dry matter, and also indicate the feasibility of using the organic fertilizer Greenodin Gray at a rate of 10 t/ha to increase the productivity of oilseed radish in the conditions of the Right-Bank Forest-Steppe [7].

According to the data presented in Table 5 , on average for 2024–2025, there is a clear trend towards an increase in yield with an increase in the rate of fertilizer application.

The lowest indicators were recorded in the control variants: in the *Zhuravka* variety – 188,5 c/ha, in the *Kiyanochka* variety – 194,0 c/ha.

Applying 15 kg/plot provided a significant increase in yield: the increase compared to the control was 31.0 c/ha in *Zhuravka* and 36,5 c/ha in *Kiyanochka* . This indicates an activation of growth processes and improvement of the conditions of mineral nutrition of plants even at an average level of fertilization.

The maximum indicators were obtained with the application of 30 kg/plot, where the yield reached 254,0 c/ha in *Zhuravka* and 266,0 c/ha in *Kiyanochka* . The increase compared to the control was 65,5 and 72,0 c/ha, respectively, which confirms the high efficiency of the increased rate of organic fertilizer.

Overall, the *Kiyanochka* variety demonstrated slightly higher productivity compared to *Zhuravka*, indicating its better adaptive response to improved nutritional conditions and higher biological potential.

Thus, a direct relationship has been established between the level of fertilization and the formation of green mass yield of oilseed radish, which confirms the feasibility of using the organic fertilizer Greenodin Gray in the conditions of the Right-Bank Forest-Steppe of Ukraine.

Conclusions. The study demonstrated that organic fertilization (Greenodin Gray) significantly enhances the growth, assimilative surface formation, and productivity of oilseed radish varieties Zhuravka and Kiyanochka under the conditions of the Right-Bank Forest-Steppe of Ukraine. The highest indicators of plant height, leaf area, dry matter accumulation, and green mass yield were obtained at the application rate of 10 t/ha. The Kiyanochka variety showed a slightly higher response to improved nutrition conditions, indicating greater adaptive capacity and productivity potential compared to Zhuravka. A direct relationship between fertilization level and crop productivity was clearly established.

Further studies should focus on optimizing fertilizer application rates in combination with mineral nutrition, investigating the impact of different soil and climatic conditions, and assessing the economic efficiency of organic

fertilization. Additionally, it is advisable to explore physiological and biochemical parameters of plants to better understand the mechanisms underlying yield formation.

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Kovka N.S., Hrytsyshyn V.O. Dynamics of assimilation surface formation and growth processes of oilseed radish plants depending on growing conditions

Oilseed radish is a promising forage, green manure, and soil-improving crop characterized by high adaptability and intensive vegetative biomass formation. The efficiency of its cultivation is largely determined by the peculiarities of assimilation apparatus formation, which directly affects photosynthetic activity and productivity level. Therefore, studying the influence of growing conditions on plant growth, development, and leaf surface formation is of particular scientific importance. **Purpose.** The aim of this study was to investigate the peculiarities of growth, assimilation surface formation, and productivity of oilseed radish depending on the level of organic fertilization and varietal characteristics under the conditions of the Right-Bank Forest-Steppe of Ukraine. **Methods.** The study was conducted under field conditions at the experimental farm «Ahronomichne». Phenological observations, biometric measurements of plants, the leaf imprint method for determining the assimilation surface area, and records of green mass and dry matter yield were used. Statistical data processing was performed using generally accepted methods of variation statistics. **Results.** It was established that plant growth significantly depended on fertilization level and varietal characteristics. Plant height increased from 4.2–5.3 cm at the rosette stage to 74.8–104.8 cm at the flowering stage, with the highest values recorded in the Kyyanochka variety under increased nutrient supply. A similar pattern was observed in leaf surface formation, which reached 41.2–62.7 thousand m²/ha at the flowering stage. During ontogenesis, a gradual decrease in leafiness was observed, which was associated with the redistribution of assimilates within the plant. A direct relationship was established between the development of the assimilation apparatus and crop productivity formation. Dry matter yield ranged from 45.8 to 65.9 c/ha, while green mass yield ranged from 188.5 to 266.0 c/ha. The highest values were obtained with the application of the organic fertilizer Greenodin Grey at a rate of 10 t/ha. It was proven that optimization of organic nutrition is a key factor in enhancing growth processes, assimilation surface formation, and productivity of oilseed radish. **Conclusions.** In summary, it can be stated that the growth and development of oilseed radish plants significantly depend on organic fertilization conditions and varietal characteristics. The most intensive growth processes and assimilation surface formation were observed under an optimal level of organic nutrition. During ontogenesis, a natural change in plant leafiness occurs, which is associated with the redistribution of nutrients. The obtained results confirm a strong relationship between the development of the assimilation apparatus and crop yield level. It was established that optimization of the organic fertilization system is an important factor for increasing the productivity of oilseed radish under the conditions of the Right-Bank Forest-Steppe of Ukraine.

Key words: oilseed radish, growth and development, assimilation surface, organic fertilization, leafiness, productivity.

Ковка Н.С., Грицишин В.О. Динаміка формування асиміляційної поверхні та ростових процесів рослин редьки олійної залежно від умов вирощування

Редька олійна є перспективною кормовою, сидеральною та ґрунтополіпшувальною культурою, що характеризується високою пластичністю та інтенсивним формуванням вегетативної маси. Ефективність її вирощування значною мірою визначається особливостями формування асиміляційного апарату рослин, який безпосередньо впливає на інтенсивність фотосинтезу та рівень продуктивності. У зв'язку з цим особливої актуальності набуває дослідження впливу умов вирощування на ріст, розвиток та формування листкової поверхні культури. **Метою** даної роботи є дослідити особливості росту, формування асиміляційної поверхні та продуктивності редьки олійної залежно від рівня органічного удобрення та сортових характеристик в умовах Лісостепу правобережного України. У дослідницькій роботі використано **методи** польових досліджень в умовах дослідного господарства «Агрономічне». Використовувалися фенологічні спостереження, вимірювання біометричних показників рослин, метод листкових відбитків для визначення площі асиміляційної поверхні, а також облік урожайності зеленої маси та сухої речовини. Статистичну обробку даних виконували загальноприйнятими методами варіаційної статистики. **Результати** Встановлено, що ріст рослин істотно залежав від рівня удобрення та сортових особливостей. Висота рослин зростала від 4,2–5,3 см у фазі розетки до 74,8–104,8 см у фазі цвітіння, з максимальними значеннями у сорту Кияночка за підвищеного рівня живлення. Аналогічна закономірність спостерігалася у формуванні листкової поверхні, яка у фазі цвітіння досягала 41,2–62,7 тис. м²/га. Протягом онтогенезу відмічено поступове зниження облистненості, що пов'язано з перерозподілом асимілятів у рослині. **Результати** показують, що встановлено прямий зв'язок між розвитком асиміляційного апарату та формуванням продуктивності культури. Урожайність сухої речовини становила 45,8–65,9 ц/га, зеленої маси – 188,5–266,0 ц/га. Найвищі показники отримано за внесення органічного добрива Грінодін Грей у дозі 10 т/га. Доведено, що оптимізація органічного живлення є ключовим чинником підвищення ростових процесів, формування асиміляційної поверхні та продуктивності редьки олійної. **Висновки.** Підсумовуючи, можна зазначити,

що ріст і розвиток рослин редьки олійної суттєво залежать від умов органічного удобрення та сортових особливостей. Найбільш інтенсивні ростові процеси та формування асиміляційної поверхні спостерігалися за оптимального рівня органічного живлення. Упродовж онтогенезу відбувається закономірна зміна облистненості рослин, що пов'язано з перерозподілом поживних речовин. Отримані результати підтверджують тісний зв'язок між розвитком асиміляційного апарату та рівнем урожайності культури. Встановлено, що оптимізація системи органічного удобрення є важливим чинником підвищення продуктивності редьки олійної в умовах Лісостепу правобережного України.

Ключові слова: редька олійна, ріст і розвиток, асиміляційна поверхня, органічне удобрення, облистяність, продуктивність.

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