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STUDIES ON GRAY-BROWN SOILS WITH RAPESEED (*BRASSICA NAPUS* L.) AS A FORAGE CROP IN THE SHEKI REGION OF THE GREATER CAUCASUS

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SUMMARY

Forage crops' shortage has risen due to increased population in Azerbaijan. *Brassica napus* L. as a forage crop provides the opportunity to obtain oil, seeds, and dry biomass as feed for livestock in winter. Increased soil load and anthropogenic variations considerably affect the state of modern soil cover in the Greater Caucasus, Azerbaijan. Therefore, the study on gray-brown soils under rapeseed vegetation as a forage crop is crucially necessary. The timely study comprising the effects of various factors on the physicochemical parameters of extrusion products made it possible to determine the quantitative and qualitative characteristics of rapeseed oil. The standard deviations for the rapeseed with three sowing dates and density scenarios were 6%–23% and 17%–22%, respectively. The simulated biomass and grain yield of rapeseed with different sowing dates (standard deviation: 0.9–1.9 t ha⁻¹, Pe: 0%–35.3%) were notably generally better than those for different densities (standard deviation: 0.8–2.7 t ha⁻¹, Pe: 6.5%–90%).

Keywords: Gray-brown soils, soil section, forage crops, vegetation, harvest, green and dry biomass, seed yield, oil content

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Key findings: This study examines the effect of rapeseed (*B. napus* L.) on the agrophysical, agrochemical, and biological properties of dark gray-brown soils. In addition to post-cut, stubble, and root residues, the predecessor itself, alfalfa, had a good effect on increasing fertility. The highest seed yield with a significant increase in biochemical components was a formation from rapeseed.

INTRODUCTION

Agriculture aims to grow various crops, vegetables, and fruits beneficial for humans. However, rapeseed (*Brassica napus* L.) cultivation has become quite popular in the farming community, being a multifunctional and cost-effective crop. Rapeseed oil consumption by humans has existed since the Middle Ages; however, later speculation arose that high levels of erucic acid and the glucosinolates in its oil, a group of sulfur-rich compounds, could be harmful to human and animal health. Erucic acid (cis-13-docosenoic acid) is an unbranched, long-chain, monounsaturated fatty acid with 22 carbon (C) atoms and a double bond at the omega-9 position. Erucic acid (C₂₂H₄₂O₂), mostly found in plant seeds, belongs to the families Cruciferae and Tropaeoleaceae, and its proportion in the composition varies between 30% and 60% in rapeseed oil (Al-Shehbaz *et al.*, 2006; Barakat and Mayer-Laigle, 2017). Glucosinolates (β -thioglucoside-N-hydroxysulfate) are another compound found in rapeseed oil with no nutritional value. Glucosinolates (C₇H₁₁NO₉S₂R) are precursors of isothiocyanates, and approximately 120 different species have been identified in 16 families of dicotyledonous plants, with most of them used as human food. Glucosinolates and their degradation products usually have fungicidal, bactericidal, nematicide, and allelopathic activities.

Rapeseed often serves as a cover crop during the winter and also as a source of healthy vegetable oil, high-quality biodiesel, and nutritious feed for livestock. In the agriculture sector, rapeseed is one of the most accessible oilseed crops. In the Sheki-Zagatala economic region, the promising crops are spring rape and other Cruciferae family plants, also known as Brassicaceae, a large group of vegetables characterized by their cross-shaped (four-petaled) flowers. The rapeseed is vital in the production of food and industrial oil, bulk feed,

oilcakes, and nutritious meals for livestock (Chalishir *et al.*, 2005; Dogru, 2020; Bunyatova *et al.*, 2025).

Perennial legumes, such as alfalfa, red clover, white clover, and rapeseed, can be applicable as an effective biological approach for increasing soil fertility and crop yields. The formation and accumulation of soil nutrients in various ways are accessible to plants as one of the important factors affecting the crop plants' yield. In conclusion, rapeseed is an essential multifunctional crop that deserves more attention, protection, and improvement for sustainable agriculture (Hasanova and Mammadova, 2023).

The current problem is providing the industry with raw materials to produce biofuels based on vegetable rapeseed oil and livestock farming with feed protein also from rapeseed oilcake (Hasanova *et al.*, 2021). Analyzing samples of heat extrusion product samples makes it possible to determine their qualitative parameters and, accordingly, allocate them to uses, with rapeseed oil for technical and food use and rapeseed oilcake for farm animals and poultry feed. Rapeseed is the valuable oilseed crop providing raw materials for obtaining vegetable oil, oilcake, and meal (for animals). The rapeseed oil can also undergo fast processing and can act as a raw material for biodiesel fuel. For comparison, one liter of biodiesel releases into the atmosphere about 0.5 kg of CO₂ while one liter of regular diesel fuel shoots up to 3 kg. A green mass of rapeseed, occupying a hectare, is capable of releasing up to 10–11 million liters of O₂ into the atmosphere while absorbing 22 tons of CO₂ (Li *et al.*, 2018; Ismayil *et al.*, 2025). With the complexity of climate change, rapeseed-sowing times are constantly being adjusted. Therefore, it is crucial to understand the response of rapeseed growth to variations in sowing dates and improve its production (Ismayilova *et al.*, 2025a).

The crop growth model can function as an effective tool for quantitatively assessing the impact of environmental conditions and field management practices on crop growth and development (Ismayilova *et al.*, 2025b). Refined and deodorized rapeseed oil applies for food purposes, as well as in producing margarine and mayonnaise. At present, rapeseed has the highest potential in satisfying human, animal, and crop demands in various aspects, with beneficial effects on health, environment, and economy (Lim *et al.*, 2017). It can fully simulate the crop development

process and include the influence of external factors, which are widely helpful in agricultural forecasting, climate change impact assessment, and agricultural decision-making, optimizing the cultivation mode (Mammadova *et al.*, 2021, 2024a, 2024b).

The winter, semi-winter, and spring differ in their cold and drought tolerances; consequently, the crops' growing conditions also varied. The length of a mature stem differs from 120 to 150 cm (Figure 1 a-d), and mature seeds are spherical, 1.8–2.7 mm in

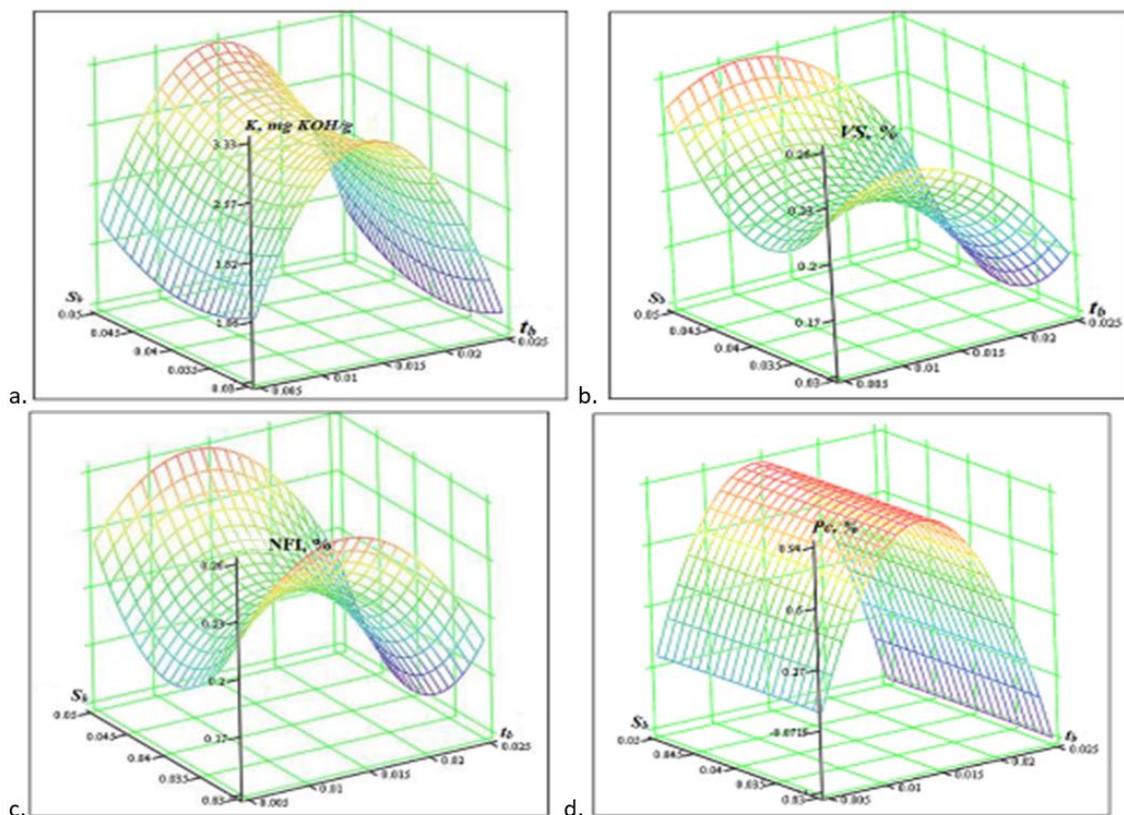


Figure 1. Dependence of the quality indicators in rapeseed (*B. napus* L.).

Note: a) Dependence of the quality indicator of rapeseed oil acid number (K) on the blade thickness (t_b) and the pitch of the screw blade (S_b) of the auger at a temperature of $T = 72$ °C, with a rotation speed of 15 s^{-1} ; b) The mass fraction of moisture and volatile substances (VS) on the blade thickness (t_b) and the pitch of the screw blade (S_b) of the auger at a temperature of $T = 72$ °C, with a rotation speed of 15 s^{-1} ; c) The mass fraction of non-fatty impurities (NFI) on the blade thickness (t_b) and the pitch of the screw blade of the auger (S_b) at a temperature of $T = 72$ °C, with a rotation speed of 15 s^{-1} ; and d) The mass fraction of phosphorus-containing substances (Pc) on the thickness of the blade (t_b) and the pitch of the screw blade of the auger (S_b) at a temperature of $T = 72$ °C, with a rotation speed of 15 s^{-1} .



Figure 2. Cultivation and use of rapeseed (*B. napus* L.) in agriculture.

Note: a) Rapeseed in the flowering phase; b) Rape oil and rapeseed; c) Preparing mature plants for drying; and d) Dried plant biomass for use in winter (December, January, and February) months.

diameter, with red-brown to dark brown or black color. *Brassica napus* L. oil is an ingredient used in the metallurgical industry for hardening some metals and as biodiesel fuel (transesterification involves reacting the rapeseed oil with an alcohol, typically methanol, in the presence of a catalyst base like potassium hydroxide) and in the cosmetology industry. Therefore, the rapeseed crop is greatly valuable with its various applications, and this plant can be an excellent option to replace regular vegetable oils (Figure 2).

The fertility determination of the Greater Caucasus gray-brown soils continued first by their structural composition, followed by the soil's ability to form aggregates of a specific size from the elements of the solid phase. The soil structural composition and its quality largely depend upon the type of plants cultivated in a crop rotation, the agrotechnical measures used for their maintenance, and the technology

applied in cultivating the crops. At present, large reserves in the restoration of the mountain structure had soils hidden in the bipolarization of agriculture and the development of an optimal structure of sown areas. This ensures the accumulation of organic matter in the soil, which has a considerable structuring effect (Mammadova *et al.*, 2024a, 2024b; Macnunlu *et al.*, 2025; Mirzezadeh *et al.*, 2025).

MATERIALS AND METHODS

The conducted research occurred in the fields of the Sheki Regional Center, Azerbaijan. The experimental plot area was 7.5 hectares, with the experiment deployed in time and space on three bookmarks. In the field experiment, the variants' placement was systematic (Mammadzada *et al.*, 2025). Field experiments proceeded in triplicate on plots with an

accounting area of 120 m² (4 m × 30 m), in compliance with the methodological requirements. The moisture content of the arable layer, when determined, employed drying in a thermostat at a temperature of 105 °C to a constant weight. The soil density testing used the cutting ring method by taking samples with undisturbed structure (g/cm³) (Nasirova *et al.*, 2022; Nazim and Oqtay, 2024). The nitrogen, phosphorus, and potassium (N, P, and K) contents underwent assessment in soil samples collected in the arable layer using a cylindrical auger of the P 05.07 brand. Driving the cylindrical auger into the ground by 30 cm engaged a jackhammer with a gasoline engine. Nitrate nitrogen (NO₃-N) determination utilized the Tyurin and Kononova method, while the mobile phosphorus and exchangeable potassium followed the approach according to.

The soil microflora activity ensued using the 'linen cloth application' method during the incubation period from sowing to harvesting. Postharvest and stubble-root residues were available on two sites (50 cm × 50 cm) in triplicate; for root residues, monoliths of 30 cm × 30 cm reached a cut to a depth of 0–30 cm according to the guidelines for conducting field experiments with forage crops (Rowell, 1999). The harvest recording took place by continuous threshing of the entire mass from the accounting area using a Niva-Effect combine with recalculation to 100% purity and 14% humidity (Al-Shehbaz *et al.*, 2006). Spring rapeseed cultivar 'Ratnik' (00) seeds were the samples used as the initial material. A press-extruder -30/4 and four screws with different pitch and blade width were the selected experimental equipment. The quality assessment of rapeseed oil and cake utilized organoleptic and physicochemical indicators (soil texture, structure, density, water holding capacity, pH, SOM, and others). The statistical analysis of the recorded yield data, as carried out on a computer, engaged the Microsoft Excel application as well as the STATISTIKA 5.5 program.

RESULTS AND DISCUSSION

For the better development of crop plants, the most optimal density of the arable horizon should progress from 1.06 to 1.21 g/cm³. During the cultivation of forage crops, on average, the density of the arable horizon over the years of research amounted to 1.11–1.13 g/cm³. In the stationary experiments, the alfalfa crop effect on the main agrophysical and biological parameters of soil fertility, productivity, and seed quality underwent studies (Shivanna and Sawhney, 1997).

The experimental plot soil was leached, dark gray-brown soil with medium depth, medium loam, and the following agrochemical characteristics: pHKCl (6.9) (in a 1M potassium chloride [KCl] solution), the sum of absorbed bases (48.8 mg-eq/100 g of soil), humus content (6.37%), and phosphorus and potassium content (P₂O₅ = 227 and K₂O = 119 mg/kg of soil, respectively). The largest reserves of productive moisture were evident in the spring—in the arable layer, it was 45.9 mm, while in the meter layer, and the said ratio was 143.1 mm. The highest accumulation of nitrate nitrogen forms in the arable layer was 45.9 mg. The mobile phosphorus content (H₂PO₄) was quite high (157–263 mg), and exchangeable potassium (K) appeared as an average indicator and amounted to 77–87 mg.

The results showed the dependences of the acid number (*K*), the mass fraction of moisture and volatile substances (*VL*), the mass fraction of non-fat impurities (*NFI*), and the mass fraction of phosphorus-containing substances (*Ph*) on the blade thickness (*t_b*). Likewise, the pitch of the screw blade (*S_b*) of the auger at a temperature of 72 °C with the rotation speed (Figure 1). Analyzing the influence of the geometric parameters of the screw on the quality of rapeseed oil resulted in the following conclusion. An increase in the thickness of the screw blade, the acid number, and the mass fraction of moisture and volatile substances boosts the mass fraction of non-fat impurities and phosphorus-containing substances. With an increase in the pitch of the blade, these quality indicators decrease (Figure 1c, d). A rise in the temperature of the technological

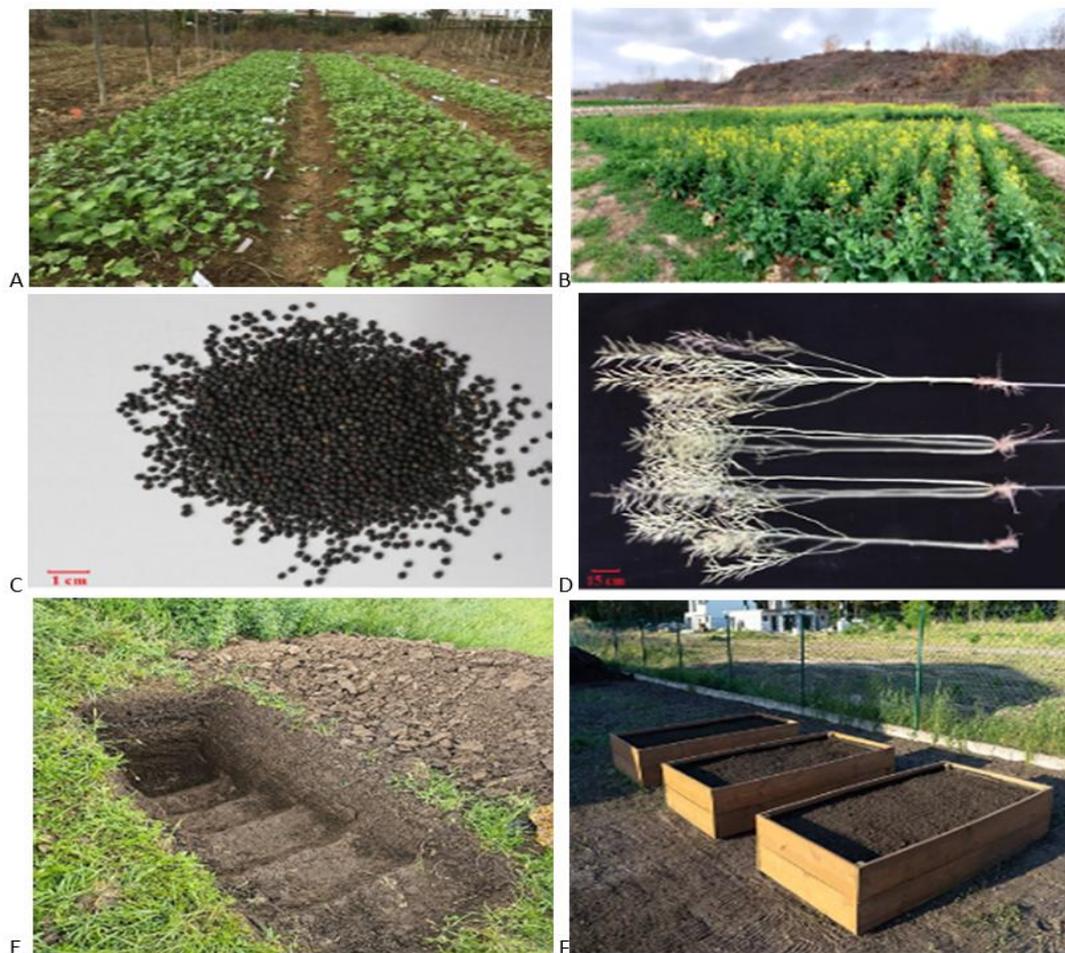


Figure 3. Winter-type rapeseed: A) Field established crop stand at a site in Kish Village of Sheki Region (May 2024); B) Blooming field in Vandam Village, Gabala Region (July, 2024); C) Mature seeds; D) Post-harvested and dried stem and siliques; E) Soil section in a rapeseed field (41.252790 N 47.189884 E) and experimental plots in Kish Village (41.242174 N 47.190485 E).

process and the rotation speed of the screw enhances the mass fraction of crude fiber in the rapeseed cake, while that of crude fat will decrease. With an escalation in the temperature of the pressing process, the total moisture content and the mass fraction of pastes increase.

The use of statistical methods evaluated the physical and mechanical properties of seed mixtures while studying the main physical and mechanical properties of rapeseed as an object of hulling. Zhang *et al.* (2019) reported that plowing increases the heterogeneity of the soil cover. With the influence of such a powerful anthropogenic factor as plowing, no sharp

variation in the quantitative structure of the microbiota resulted in the forest soil. Since the formation of sod-forest soils occurs under the canopy of a mixed-grass forest, the soil-forming processes here proceed more smoothly. Although for microbiological indicators, the differences between mounds and depressions appeared (Hasanova *et al.*, 2021).

The experimental results in the form of combined graphs of variation curves expressed the frequency as a percentage of the number of seeds: a) average diameter of rapeseed, b) average specific work of destruction of rapeseed, and c) average mass (Figure 3). The chi-square criterion served to determine the

difference between the actual frequency distribution of the average diameter of rapeseed seeds and the theoretical distribution for the variation series classes. The said calculation established that the chi-square criterion was less than its critical value with a confidence probability of 0.95 and the degree of freedom $k = 3$ ($k = m - s - 1$, where m was the number of intervals and s was the number of estimated distribution parameters for a normal distribution [$s = 2$]). In the studied humidity range (6.5%–13.8%), the obtained variation curves of the average diameter of rapeseed seeds obey the law of normal distribution with a confidence probability of 0.95.

For the studied range of rapeseed moisture content, the highest yield of these fractions was 61%–67% and falls into two classes, and their diameter ranged from 1.8 to 2.2 mm. The experimental curve 2 allows us to estimate the combined effect of the studied factors on the rapeseed seeds. Thus, with an increase in the average diameter of rapeseed seeds from 1.5 to 2.5 mm of their average mass, the average work of destruction decreases in the studied humidity range. With an external impact force on a spherical particle, a stress-deformation state arises in its volume, causing the necessary ultimate stresses and destruction, which rise with a decline in its diameter. Therefore, it is advisable to fractionate rapeseed by size, considering the value of the average specific work of destruction and subsequent separate hulling of each fraction.

Microbiological indicators (microbial biomass and abundance, microbial taxonomic composition and diversity, and microbial activity) of soil in a given territory, including those with different ecosystems, succeeded in their characterization by high spatial variability, which further complicates their use for its biological assessment (Nazim and Oqtay, 2024). The most optimal conditions for the vital activity of prokaryotic microorganisms attained development on mounds, and the maximum number of eukaryotic micromycetes was evident in the depressions. In the summer

period, in the variant with turfing, the species of the genera *Fusarium*, *Alternaria*, *Cladosporium*, and *Verticillium* reached isolation. However, the natural dark gray-brown soils turned out to be richer than the natural forest soil for the number of microbiota, which referred to its highest nutritional value, including due to humus. The quantitative indicators of the ecological-trophic groups of microorganisms obtained characterization by an increase, especially in ammonifying bacteria, which revealed its recent development, accompanied by a surge in microbiota activity. In sod forest soil, no sharp variation emerged in the quantitative structure of the microbiota even under the influence of such a powerful anthropogenic factor as plowing. However, the differences for microbiological indicators between the soils of hillocks and depressions remain both on virgin soil and on arable land.

The results further revealed that for the studied range of rapeseed moisture content, the highest yield of these fractions was 61%–67% and falls into two classes in their diameter, ranging from 1.8 to 2.2 mm (Figure 4). The average exchangeable potassium varied from 75 to 88 mg/kg. No differences existed between the actual data. By the stage of full maturity, the content of nitrate nitrogen in winter wheat was at the level of 45 mg/kg. The provision of nitrate nitrogen was 1.86–1.92 times higher for rapeseed than other forage crops (Hasanova et al., 2021).

An NDVI value of 0.46 became the defined threshold for CC extraction, and the NDVI pixels were below the threshold, representing the soil background. *Brassica napus* L. cover reached extraction after approximately 18–29 days (Figure 5). The rapeseed crop's effect on the agrophysical, agrochemical, and biological properties of dark gray-brown soils showed that the soil density for grain crops was at the optimal level of 1.10–1.12 g/cm³. In addition to post-cut, stubble, and root residues, the predecessor itself, alfalfa, had a better effect and greater role in increasing soil fertility. The highest yield, with a significant increase in the experiments, succeeded in the formation of

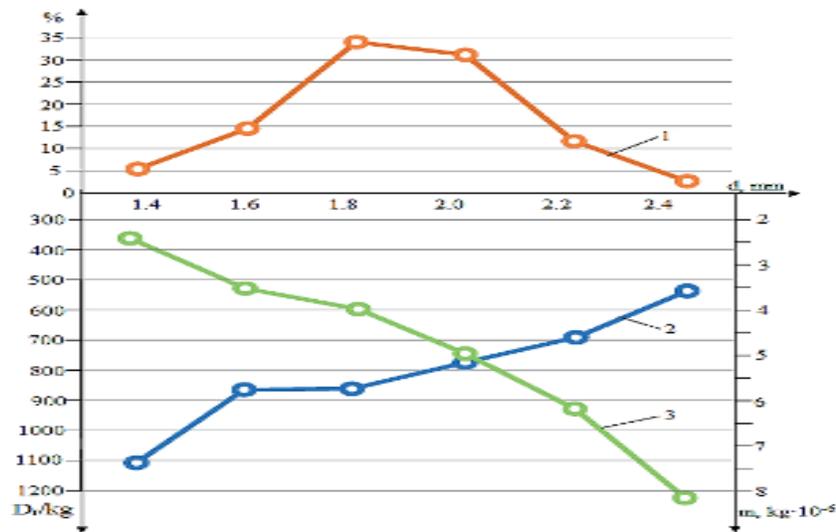


Figure 4. Moisture content ranges in rapeseed (*B. napus* L.).

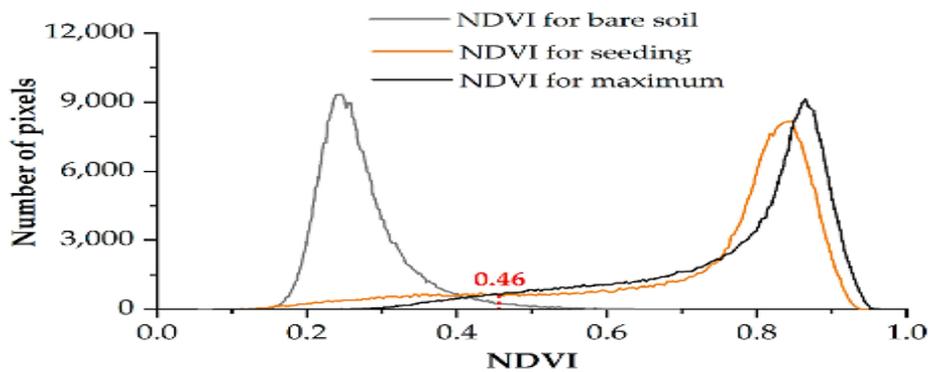


Figure 5. Distribution statistics of soil and winter rapeseed (*B. napus* L.) histograms based on NDVI.

rapeseed (3.97 t/ha) with the best quality indicators of seeds for biochemical components. Rapeseed could be beneficial as an indispensable means for the reclamation of soils contaminated with radiation. As a result, heavy metals (such as arsenic, cadmium, chromium, and lead) contained in the soil only in small quantities get into the seeds, accumulating mainly in the green mass. Including rapeseed in crop rotations of Azerbaijani agricultural producers helps solve the problem of oversaturation of crop rotations with grain crops. Rapeseed inclusion in them serves as a phytosanitary and environment-forming crop.

CONCLUSIONS

According to biological activity parameters of the soil, the decomposition of organic materials by microorganisms occurred in 57% of cases as strong and intense, in 15% of cases as an average, and in 24% of cases, the microorganism’s activity was weak. The standard deviations for the three sowing dates and density were 6%–23% and 17%–22%, respectively. The simulated biomass and grain yield for different sowing dates were generally better than those for different densities.

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