CHAPTER «AGRICULTURAL SCIENCES»

THE INFLUENCE OF THE METHODS OF TILLAGE ON BULK DENSITY, MOISTURE AND BIOLOGICAL ACTIVITY OF BLACK SOIL IN ORGANIC FARMING

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Abstract. The selection of technology for organic production of agricultural products in Ukraine, even in difficult times, is still relevant. The elements of technology may vary depending on the state of the field, resource capabilities of the farm, and set goals. Growing buckwheat is one of the ways to solve the food problem of Ukraine and other country especially under war condition. This crop is ahead of the rest of grain crops due to a much higher level of selling prices and payment of expenses by money earnings in Ukraine. **The purpose of the article** is to demonstrate the obtained data regarding water consumption of buckwheat, biological activity of the soil under different methods of basic soil cultivation in organic crop rotation. **The research methodology** was based on conducting field and laboratory research, using hypothesis and experimental methods. In the conditions of the North-Eastern Forest-Steppe of Ukraine (Sumsky district, Sumy), four soil tillage options for growing organic buckwheat were studied. Cellulolytic activity of microbiota was determined by the method of laying linen cloth in the soil; the moisture content in the soil was determined by the thermogravimetric method; harvest accounting was carried out by the sheaf method. **The results of the research** showed that when growing buckwheat in organic crop rotation, soil tillage is an important component of the technology. The choice of minimum tillage leads to an increase in the bulk density of the soil. The higher the water

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consumption ratio, the more difficult the conditions of plant growth and development, thus the highest water consumption ratio was obtained at disking options. The most effective were deep tillage up to 22 cm, which stimulated the accumulation of moisture in the root layer and the activity of soil microbiota. **Practical implications**. Plowing is recommended as the main method of tillage in the conditions of the North-Eastern Forest-Steppe of Ukraine for growing crops, particularly buckwheat in the organic crop rotation on the low humus medium loam typical chernozem (black soil). **Value/originality**. The obtained results encourage further research, more in-depth agrochemical analysis of soils, growth characteristics of buckwheat and other agricultural crops grown in organic crop rotation for possible combined tillage depending on plant requirements.

1. Introduction

The research provides the data on the soil fertility indices and buckwheat grain yield. The data was received as a result of experiment with different methods of basic tillage. In this way we could enrich the scientific information about soil processes and some properties of soil in the Left-Bank Forest-Steppe. The research also allows assessing the anthropogenic impact on the soil moisture dynamics and biological activity. The results of the research allowed us to make conclusions about the influence of different methods of basic tillage on some indicators of soil fertility. The obtained data provide better coverage of the debatable issues regarding crop rotations in organic farming.

In the current economic conditions when prices for energy, fertilizers and pesticides are rising, there is a need to reduce the cost of crop production through the improvement of existing elements of agricultural technology. One of the options to reduce the cost of production in the cultivation of crops, in particular, buckwheat, may be a complete or partial abandonment of main soil tillage, which reduces the depth of cultivation. The issue of tillage is becoming especially relevant on the background of global warming, war in Ukraine and the threat of a food crisis around the world. The issue of profit becomes the most important for agricultural producers, regardless of what happens to the soil. For decades, intensive land use in cultivation has led to a catastrophic level of land degradation, manifested in loss of humus, compaction, deterioration of soil structure and, respectively, in changing soil water movement, nutrient availability, growth and development of crops. We might not know the issues for plants, but they will be clearly visible in the future.

The issue of the depth of the main tillage for buckwheat and other crops is quite controversial, especially in organic farming due to the diversity of soils and climatic features. In organic farming, the main disadvantage is the increase in the number of weeds that appear in crops. Therefore, now the researchers' attention is on improving the cultivation system [1; 2]. Ukraine possesses unrealized export potential, which can be achieved through a combination of practices used in more developed countries [3; 4].

The study of the impact of basic tillage on biological processes is also insufficient. So, the purpose of this research was to study the impact of basic tillage systems on soil moisture, bulk density, biological activity of soil, as well as on buckwheat yield. The research was done as a stationary experiment conducted by the Department of Agriculture, Soil and Agrochemistry of Sumy National Agrarian University (SNAU).

As you know, tillage is a major agricultural practice in sustainable farming [5]. The first best-known assumptions as to the reason for tillage were made in the early 18th century by an English farmer Jethro Tull who is regarded the father of tillage. The soil is tilled to improve air, water and nutrient relationships for overall better crop performance. Why do we till the soil? In order to affect the water permeability of the soil and water-holding capacity, to adjust the temperature, taking into account the receipt and loss of moisture. When growing crops, the agronomist needs to make an ideal system of cultivation for comfortable growth and development of the plant. Accordingly, the factor of cultivation will affect the final result, which is the yield of the main and by-products [6]. This is because pulverization of soil by repeated tillage accelerates decomposition of organic matter which, in turn, affects indicators of soil fertility. The impact of cultivation on the indicators of physical parameters and biological indicators is significant. Sometimes improperly selected tillage leads to deterioration of soil structure, development of intense water or wind erosion, reduced humus content, poor plant water consumption and plant nutrition [7]. Thus, continuous tillage and exploitation of soils ultimately leads to soil properties breakdown. Tillage systems can be generally categorized into plow tillage (conventional tillage), reduced tillage with chisel plow, disc plow, harrow disc or cultivators and no-till systems that use direct drilling in untilled soil [8]. These various tillage operations create lots of impact of different intensities on physical and chemical properties of soil, such as bulk density, soil porosity, water-holding capacity, infiltration rates, hydraulic conductivity, soil temperature, organic matter content, and nutrient distribution. A number of research works have studied the impact of different methods of tillage on physical and chemical properties of soil, and there is a substantial interest in the shift to conservation and no-till methods [9]. Thus, the objective of this study was to review various research works that studied the impact of different tillage practices on soil fertility and compare the no-till system with the conventional one.

Traditional methods of tillage with the rotation of formation cause a change in soil structure, affecting its density, moisture, hardness and structure. Plowing produces a loose and lumpy structure, whereas minimum cultivation or its absence almost has no effect or reduces CO_2 emissions by increasing the amount of water available to plants [10; 11].

In our research, we described various methods of tillage [5]. They affect the soil differently due to its diversity, texture and parent rocks. First of all, the structure of soil is affected. Improper tillage, when the soil is dry or overwetted, or when it is not tilled in time, can lead to the formation of an unstable structure. Some scientists talk about the positive effect of minimum cultivation or no-till [12]. At the same time, plowing increases soil porosity, compared with minimum tillage or no-till farming, since it mixes a large layer of soil. The porosity is temporary as it takes place either in autumn or spring, and it changes under the influence of rain or melting snow [13].

Soil conservation concept entails all measures and techniques employed to maintain soil fertility at the lowest cost without significant decrease in crop yields. Scientists propose to carry out conservative tillage in crop rotation, because in this case the soil is covered with plant debris by thirty percent which reduces the risk of water erosion [14]. Tillage prepares the seedbed. When using plowing and flat tillage, a large layer of soil is mixed. When using minimum tillage, we regulate the temperature regime in the upper layer of soil, and respectively, air and water regimes. We also reduce fuel costs. It is the reduction of tillage depth and, in general, minimal mixing that is being discussed by scientists around the world, because we need to think about soil health and good quality products [6].

Farmers can now choose different methods of cultivation based on logistics. No-till farming means the soil is not mixed and sowing is straight. Minimum tillage is tillage to a minimum depth. The agronomist can choose contour strip tillage with mulching between rows.

The analysis of minimum tillage proves that using it we will minimally mix the layer, minimally shock microorganisms, and minimally change the soil structure. The rate of the remains on the soil surface should be 15-25 percent [15]. Scientists speak about the long-term effect of such treatment of the soil structure, such as the normal development of roots and microbiological activity in the rhizosphere [7].

Now scientists can use different methods to study pores, their size, and shape. Sometimes, X-ray equipment is used for this. It is proved that the use of minimum treatment reduces the number of pinched pores, and increases the number of uncompressed ones [16].

When growing row crops, ridge tillage is used after harvesting the predecessor. In this case, a little more fuel is consumed [17].

For favourable plant growth, it is necessary to create a loose structure of the ridges themselves, because the root system must develop both vertically and horizontally, capturing more soil particles [18]. This improves plant nutrition.

No less important role is assigned to mulching the plant. With global warming, high temperatures are recorded on the soil surface in summer, and the soil needs to be mulched. When tillage is done at right angles to the direction of the slope, it is called contour tillage.

If the crop is planned to be sown in areas with low steepness, it is necessary to carry out cultivation across the slope; in some cases, it is recommended to carry out contour farming. In this case, farmers oppose the development of water erosion, but here we must take into account the shape of the slope, its length, and steepness. The more clay particles the soil contains, the higher the resistance to water erosion is. The more sand and dust the soil contains, the more likely it will be washed away by rainwater, especially if the space is open [7].

When using no-till, the soil is prepared for the seedbed only during the sowing period, and the soil surface is covered with stubble of the predecessor.

According to a number of research works, continuous no-till helps to increase the soil organic matter and improve the soil structure. Therefore, soil erosion can be controlled by the farmer, and over time the yield of crops will increase significantly compared to intensive tillage.

Thus, we monitor the manifestation of water erosion over time. It is possible that at first there will be no desired effect, but we can observe a prolonged effect in future [19]. As a result of reduced soil disturbance, no-till improves soil organic carbon and benefits the overall soil quality. Researchers proved that against the background of climate change, continuous no-till is the most effective for preservation of the soil fertility and obtaining environmentally healthy products on a permanent economic basis.

Tillage methods for crop yields. Boosting of the tillage vigour (from no-till to deep plowing) increased the corn grain harvest from 5.36 to 6.31 t/ha, spring barley from 2.22 to 2.75, winter wheat from 3.97 to 4.60 t/ha, sunflower from 2.20 to 2.78 t/ha on the fertile soil [20].

The grain yield of the winter wheat and other crops demonstrated no significant differences. However, the method of conventional tillage indicates quite a substantial difference compared to no-till after the grain being harvested [21].

A method of tillage stands as a key one in curtailing the carbon content in soil, which may lead to the availability of the anaerobic environment that builds mineralization rate in the soil organic compounds. Hence, the tillage systems symbolize sustainable methods for retaining agriculture [22]. The proportion of growth of the plant root zone is inferred by loosening of the soil surface, which helps to optimize the water and air condition of the soil [23].

Accordingly, conservation tillage is a measure to enhance carbon stocks in arable soils. Therefore, organic agriculture enriches the soil condition and soil carbon deposit, and reduced tillage under organic farming conditions may enhance the potential of the soil [24].

In brief, reduced tillage systems under organic farming conditions can provide some soil organic carbon without the use of herbicides [24; 25]. Rational tillage should be soil-protective, especially in regions under intensive soil erosion processes, and also energy-saving. From these positions, existing tillage systems need to be improved in the direction of minimization.

Buckwheat cultivation in organic farming: pros and cons. Organic farming is basically a multimedia agro-ecological generation measure, and it is established on critical supervision of agro-ecosystems. To boost production and commodity climate, natural conditions are manipulated to improve the soil fertility, agro-environmental techniques of insect and blight management, as well as biodiversity advantages. In a broad context, organic agriculture is a realistic performance of the universal idea of "tolerable development" in agricultural production [1].

Basically, the organic farming is conducted with the smallest use of cheap agents without the use of genetically modified organisms, and it gives the output of environmentally comfortable stocks. Compared to common farming, organic farming has its advantages: it brings economically greater profit by reducing farmers' dependence on expensive chemical fertilizers and pesticides [26].

The fundamental basis inferring the advancement of organic farming is solvent request, which is primarily applied in regions with a massive phase of monetary growth [27].

The biggest problem in organic farming is weed management. Buckwheat and weeds are antagonists, and in the fight for moisture, nutrients, and sunlight buckwheat wins with confidence [21].

Thus, scientists point out that transition to no-till and reduced tillage increases the soil organic matter [30].

So, tillage is performed primarily to loosen the upper layer of soil in order to create a suitable seedbed for germination and growth of plants. Hence, tillage is a very important practice in agriculture. Having reviewed various researches done on tillage, we may conclude that different methods of tillage exert enormous impacts on the soil physical and chemical properties. There are a lot of papers where researchers discuss the impact of tillage on the soil structure, temperature, penetration resistance, moisture, infiltration rate and hydraulic conductivity, total porosity and bulk density, soil organic carbon, pH, cation exchange capacity, available nitrogen, phosphorus and exchangeable potassium. The range of differences depends on the soil structure and texture, as well as on the technology to choose. Conservation tillage and its various types generally improve the soil quality indicators including soil organic carbon storage. Conventional tillage causes loss of soil organic carbon and deterioration of other soil properties. Conventional tillage practices provide finer and loose-setting soil structure with modified soil bulk density and soil moisture content. Conventional tillage is the main cause of the poor bulk density. If this index is higher or very low, it will make negative effect on the soil and crops, decreasing total porosity, air permeability, plant-available water, tonnage, and quality of production. At the same time, there are research works that describe minimal effect or absolutely no effect of the chosen ways on physical indices and chemical properties of the soil, which is opposed by a number of other articles. All differences are explained by a chosen kind of crop, hybrids or sort, intensive or not precipitation, temperature of experimental plot and other factors. In last years, farmers started to promote minimum tillage or no-till farming. They have demonstrated that no-till farming enhances the availability of nutrients to the plants and improves different soil properties like bulk density, particle density, soil organic carbon, infiltration rate, percent of porosity, soil saturated hydraulic conductivity. Also, it controls soil erosion, and it is considered a more appropriate way to minimize leaching of nutrients along with water. Hence, chemical properties of soil are enhanced.

Summarizing the literature review, we can conclude that there is no consensus among scientists on the effectiveness of different methods of basic tillage on the conditions of crops growing, including buckwheat.

Site description and soil. The field study was performed in 2022-2023 at the Sumy National Agrarian University Research Farm, Ukraine. Buckwheat will perform well on well-managed soil with moderate fertility. It is unpretentious crop and can give a good harvest in different soils and climatic zones. Due to the specific root system, it can grow on soils with poor phosphorus supply, on compacted or gley ones. Buckwheat is undemanding to the reaction of the soil environment; it can both grow in soil with a strong acidic environment and neutral one. It has shown itself well on light soils – sandy loams and loams; it feels worse on heavy clayey soils. On medium-alkaline soils it does not give a good yield. With the introduction of a large amount of nitrogen fertilizers, the plant mass becomes large and stretched. It can lie down with intense gusts of wind, after which the plant will not rise and there will be a loss of yield.

The soil diversity of SNAU territory is represented mainly by typical low-humus medium loam chernozem (black soil) on loess loam. The main agrochemical parameters of the soil of the experimental field are presented in Table 1. As we can see from the table, the humus content is low for typical chernozem (black soil), but this can be explained by the non-application of organic fertilizers, except for green manure, in the experimental area. Mineral fertilizers have not been applied since 2010. The nitrogen content is very low, the phosphorus content is medium and the potassium content is medium too. The soil requires the application of organic fertilizers in the form of humus or compost. The reaction of the soil solution is close to neutral.

Table 1

Agrochemical characteristics of soil on the research plot

Indicator	Methods	Soil layer, см
		0–30
Humus content, %	Tyurin, titrometrically	3,30
Hydrolyzed nitrogen, mg/kg	Cornfield, titrometrically	90
Mobile phosphates, mg/kg	Chirikov, photometrically	110
Exchangeable potassium, mg/kg	Chirikov, photometrically	112
pH buffer	Potentiometric	6.2

Buckwheat mainly sown in Polissya and the Forest-Steppe of Ukraine, since the Steppe zone is too dry and hot for it. Sudden temperature changes are detrimental to it at the beginning of growth and during the period of harvesting. High temperatures during mass flowering can also lead to lower yields. Buckwheat does not do well with extreme temperatures. The ideal temperature for buckwheat crop is 21°C. Buckwheat does not tolerate frost or even cold temperatures. The coolest temperature it can tolerate is about 10°C. So, you should not plant buckwheat too early in the spring. Also, buckwheat does not tolerate droughts or hot summers.

The climate of Sumy district, as well as the whole region is continental. The average annual temperature of Sumy region is about 6.5 degrees Celsius, and over the past 100 years the temperature has risen by one degree. The warmest month is July, the coldest is January.

May 2022-2023 was moderately warm, there were fluctuations in humidity and heavy rains, but this did not affect the rising air temperature, there was no noticeable warming. In the second and third decades, we could observe almost summer indicators on thermometers. The average daily air temperature was 15.5°C. Precipitation was 61.3 mm – 113% with a long-term 54 mm. In May, frosts were also observed on the soil surface with minus 5° C to 0°C. There were four frosty days. Buckwheat was sown on 20.

During the spring period, the average daily air temperature was 8.2° C, which is higher by 0.1°C than the long-term temperature of 8.1° C. Precipitation was 118.9 mm – 90% with the long-term 132 mm. The sum of active air temperatures above plus 10° C for the spring period made 569° C, at the long-term – 620°C.

During the growing season of 2022-2023, the temperature was 1-2 degrees above the long-term average. Precipitation was unevenly distributed, especially a large amount in June – 2.5 times more than the long-term average, and in July it was also 2.5 times more. In August, again, there was a lot of rain – twice the long-term average.

Experimental design and treatments. The purpose of the research was to compare the effectiveness of different types of tillage, and to determine which methods of soil tillage are better for buckwheat and other grain crops on the black soil in organic farming. There were such options: plowing to the depth of 28-30 cm, tillage by subsurface cultivator to the depth of plowing, surface tillage by disk tiller to the depth of 13-15 cm and 6-8 cm.

The research was conducted as a stationary experiment of the Department of Agriculture, Soil and Agrochemistry of Sumy NAU, which began in 2005. The research presents data for the growing season of 2021. Four different methods of basic tillage were studied: plowing to the depth of 20-22 cm MTZ-80 + PN-3-35 (option 1), flat-cut tillage to the depth of plowing MTZ-80 + KLD-2,0 (option 2), disking to the depth of 13-15 cm T-150 + AG-2,4 (option 3), disking to the depth of 6-8 cm T-150 + AG-2,4 (option 4).

The minimum accounting area was 100 m^2, with three replications. In Fig. 1a/b the view of experimental plot is shown (appendix A, B).

Biological activity was determined by the method of laying linen cloth in layers of 0-10, 10-20 and 20-30 cm in the areas of the experiment to determine the cellulolytic activity by the method of Mishustin.

The principle of the determination method: white linen hot-ironed fabrics 10x5cm in size are weighed and attached to a strip of polyethylene film of the same size with threads in several places. You make a fresh cut of the soil to 40-45 cm depth and press the linens to vertical, well-flatted wall of soil (with a clip). On the other side, polyethylene is pressed with the

Figure 1 a/b. General view of the field

soil, then the soil is put for covering. The place of laying is marked with a label or shingles (pegs). In a month, and in conditions of drought or low temperatures, or after a longer period, the canvases are carefully removed, washed from the soil and semi-decomposition products, dried and weighed. Weight loss is analyzed by the intensity of the process of fiber decomposition. The initial weight of linen can be set for each piece of fabric, or by setting the weight of a certain area and subsequent recalculation. The following scale for estimating the intensity of fiber decomposition during the growing season is: very weak – less than 10%, weak – 10-30%, medium – 30-50%, strong – 50-80%, very strong – more than 80%.

In the soil layer of 0-30 cm, the average value for each option was calculated. The results were shown as a percentage of the initial mass.

Field moisture was determined by the gravimetric method. In this method, the amount of water in the soil is determined by decreasing the mass of moist soil when drying it at the temperature of 105°C for 6-10 hours. To determine the field moisture, soil samples are often taken from wells with a drill. Before starting work, the handle is fixed on the bar at the desired height. The ground drill is set on the ground vertically and rotated by the handle, pressing it into the ground. At the same time, you monitor the depth of its immersion on the marks. The sample is quickly mixed and taken into a pre-weighed box, filling it to 2/3 volume. The soil in the box is slightly compacted to reduce its adhesion to the lid and loss when opening. The box needs to be closed, its number is recorded in the field journal and placed in a special box, making sure that it is not overheated in the sun.

After drilling, the well is filled up and the soil is carefully compacted. Packages with boxes filled with soil are delivered to the laboratory, making sure that their lids are on top. Under such conditions, the soil does not stick to the covers.

The boxes with the soil delivered to the laboratory are placed on the table in order, each box is wiped, opened, soil particles that have stuck to the lid are shaken into the box, the lid is turned over, and the box is weighed on techno-chemical scales to the nearest 0.01 g.

Weighed boxes with soil are placed to dry in the oven, removing the lids and putting them on the bottom of the boxes. Drying of the soil is carried out at the temperature of 104-105°C for six hours. Boxes with dried soil are covered with lids, cooled in desiccators and weighed. The results are recorded and the boxes are dried again for two hours.

If the weight of the boxes deviates more than 0.01g from the initial weight after re-drying, the boxes are again placed in the oven and dried until the difference in weight is less than 0.01g. Further field moisture is calculated by the formula. Subsequently, using the data on soil density, calculated reserves of productive moisture in each 0-10 cm, the paper presents generalized data on moisture in 0-20 and 0-100 cm layers.

The bulk density of soil was selected at the same depth as when laying linen. The selection was carried out by the method of a cutting ring, followed by weighing and drying. Buckwheat yield was harvested on 1m^3 area from all the variants and replications.

In our research we dealt with such sort of buckwheat as Yuvileina 100, which is used for grain and food. The originator of this sort is the Institute of Agriculture of the Northeast, Ukraine. Crop capacity is 17.5-18.0 c/ha; it has high resistance to shedding and diseases (powdery mildew, perenosporosis). The growing season is 95-97 days in the north of Ukraine. It is relatively resistant to lodging, shedding, and drought. The protein content is 16.9%, the kernel size is 39.0%, the film content is 23.7%, and the grain yield is 71.3% [30]. It gives good results when making a complete mineral nutrition. The plant is compact in habit, determinant type, very tall with 4-6 branches; it has 26-32 days of mass flowering and 71-80 days of ripening. The fruit of the plant is medium size (length and width), teardrop-shaped with small wings, it has a medium length and thickness of the stalk. The fetus of the fruit is pale green at the time of filling, and when fully ripe it becomes dark gray with small dots and a moderate waxy coating on it. The shape of the faces of the fruit is flattened, and the tops are short with a moderate degree of expression of the base. The variety is characterized by a large weight of 1000 fruits and average levels of uniformity and filminess.

In organic farming we do not use any chemicals. Buckwheat is used for food and it is a dietary product, so herbicides should not be used in its cultivation. In our experiment, after we used different options for basic tillage in the autumn harrowing, pre-sowing cultivation was done in the spring. The predecessor of buckwheat is corn for grain.

In our experiment, we used the Agrostat program for mathematical tillage as a one-factor experiment (factor – tillage) (appendix D).

Results. *Cellulose-destroying bacteria's activity of black soils.* Scientists argue that a slight decrease in the intensity of tillage does not noticeably affect soil biodiversity, but with the cessation of tillage the number of organisms increases due to improved nutrient and air regime, structure, and density [31; 32]. It is established that the meso- and microfauna of the soil reacts differently to the rotation of the formation or different depth of cultivation. There is also a difference in the number of organisms depending on the timing of soil sampling. Comparing different types of treatment, it is emphasized that the structure of the soil improves depending on the reduction of the depth of cultivation [33; 34].

Cellulose is the major structural constituent of all parts of the plant, and it is probably the most abundant single organic compound known [35]. Through the action of microorganisms, it is decomposed in many natural processes under widely different conditions, in and on the soil, in lakes and rivers. It is largely digested by herbivorous animals and insects through the agency of microorganisms in the digestive tract. In its many industrial uses in the form of paper, fabrics, fibers and derivatives it is subject to microorganisms' attack. It is a potential source of useful products. Despite numerous conditions under which cellulose may be attacked and decomposed, the list of authentic cellulose-decomposing organisms, although including representatives of various groups, is relatively short, and there is little information as to the route and mechanism of decomposition and the enzyme systems involved, like in the case of the monosaccharide dissimulation. The conventional approach, which studies a pure cellulose substrate, is apparently too narrow and too rigid. In most natural conditions under which cellulose is attacked, the active agent is a mixed population, and the cellulose itself is in intimate association with other cell-wall constituents of different availabilities. Studies of pure culture substrate are essential but they can never be expected complete to illuminate the whole process of decomposition of cellulose as it occurs under natural conditions. It is the purpose of this research to examine the accumulated knowledge against the background of the broad problems to be solved.

The biological activity of the soil depends on many factors. These include weather conditions, farming technology, and types of crops grown. Successful organic farming requires high biological activity of the soil. Only then the organic matter that enters the soil as a result of manure application and tillage of legumes and intermediate crops can really be used. Soil microbial activity is subject to various factors. These include the content of organic matter, acidity, physical properties of the soil, the course of the growing season. Many of these factors can be influenced during agronomic activities.

Biological activity of soil is characterized by the intensity of interaction of biota with the soil environment. Indicators of biological activity include the total biogenicity of the soil, which is determined by counting the total number of microorganisms or individual physiological groups (nitrifying, cellulose-decomposing, nitrogen-fixing, etc.). The most characteristic indicator of soil organisms' activity is their production of carbon dioxide per unit area.

Chernozems (black soils) have a fairly high rate of biological activity of the soil. In ecological systems, as a result of a certain ratio of different factors in the soil, a biological equilibrium is established, which is most disturbed in anthropogenic use. Various agricultural techniques – crop rotation, tillage, irrigation, fertilizers, pesticides and other measures used in the cultivation of crops, significantly affect the soil microflora.

The biological processes, depending on the technology of growing crops, affect the properties and fertility of the soil. They change the quantitative composition and activity of the microflora, the main processes occurring in the soil, the level of fertility. Therefore, it is important to know the biological properties of the soil, especially when intensive technologies for growing crops are used with high rates of fertilizers and other agrochemicals [36].

It should be noted that no special microbiological knowledge is required to determine the total biological activity, so the methods are available not only in microbiological studies.

Application methods are simple and informative enough to define the intensity of microbiological processes in natural conditions. These methods can be successfully used both to determine the biological activity of different soils and to establish the influence of a certain factor on this indicator.

In our research, the laying of applications was performed in layers of 0-10, 10-20 and 20-30 cm. We put linen to the soil on 14 June, and we dug it up 62 days later. In Figure 2 you can see the linen in our experiment.

Table 2 presents the results of determination of biological activity of the soil and estimates the degree of decomposition of linen tissue over the years of the experiment.

In the layer of 0-10 cm, the linen was most intensively decomposed on the variant with Flat-cut tillage of 20-22 cm – 58,3%. The canvases were moistened, some particles simply remained on the ground, so we collected them carefully without loss. We received slightly less in option 1 – 49,5%. In options 3 and 4 we can see 20.3-23%, that was lower than with conventional tillage.

In the layer of 10-20 cm, the highest intensity was also found in the options 2-4, between options 2 and 3 no differences were observed. The biggest difference was observed between options 1 and 4.

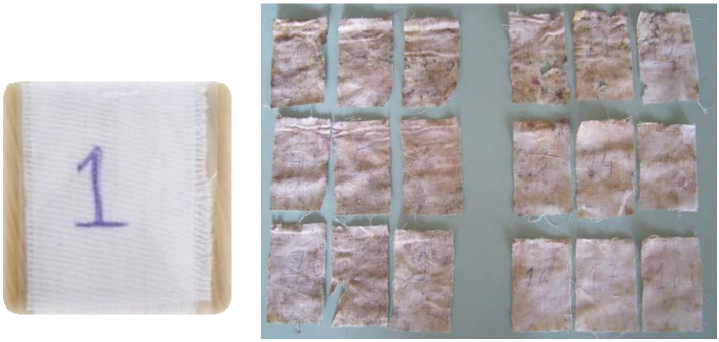

Figure 2. Condition of linen before and after application in the soil

In the layer of 20-30 cm, microorganisms had the lowest activity in the second variant – 14% and in the first – 14.7%. The most intensively decomposed canvas was observed in the layer where disking 6-8 cm was used.

Table 2

Decomposition of linen fabric for 62 days, depending on tillage, % (biological activity of the soil)

Soil depth, cm	Tillage methods			
	1. Plowing 20-22 cm	2. Flat-cut tillage 20-22 cm	3. Disking 13-15 cm	4. Disking 6-8 cm
0-10	49,5	58,3	20,3	23,0
10-20	39,6	48,0	48,2	49,1
20-30	14,7	14,0	20,0	28,9

Decomposition processes are natural, but ultra-fast and intense mineralization can lead to a decrease in humic substances. The more air is going to the soil, the more intense microbiological activity is, especially in cellulose decomposition.

Bulk density. Bulk density is calculated as the ratio between soil dry mass and volume. This is a very important soil property influencing soil water retention, aeration, traffic ability, and infiltration rate, and it is extremely sensible to soil management operations such as tillage. Bulk density is used to evaluate tillage and crop management effects on soil properties, and this information is useful for seedbed properties assessment. This physical index is used quiet often by scientists [37]. Soil density and hardness are indicators that characterize the composition and resistance of tillage tools and plant root systems. Some researchers [38] observed significant effect of soil treatments (no-till and plow tillage) on bulk density and total porosity. Bulk density is inversely related to soil porosity and it is an indicator of the capacity for air and water transport in the soil. One of the goals of tillage is to alleviate soil compaction by reducing bulk density. Studies on the bulk density of the soil surface layers showed differences according to the methods of tillage. The results of Rahman et al. [39] showed that at the beginning of growing, bulk density of soil under conservational tillage was 0–75 cm lower than in no-till farming, and absolutely opposite data was obtained during crops harvesting. This effect can be explained by the combined effect of the pressure of the tillage unit and the destruction of the soil structure – its division to soil granules of different sizes. The research by Rashidi and Keshavarzpour [41] compared different methods of tillage and determined their impact on field moisture, air permeability and the composition of the soil arable land. The significant effect of tillage on these indicators was confirmed, and the soil density was lower for the no-till option compared to disk tillage or plowing.

There is also an opinion that usage of different methods of soil tillage does not affect bulk density, the difference is only in profitability and resource savings [42-44].

The results of determining the soil density are presented in Table 3.

Table 3

Soil density according to the variants of the experiment, g/cm³

Soil depth, cm	Tillage methods			
	1. Plowing 20-22 cm	2. Flat-cut tillage 20-22 cm	3. Disking 13-15 cm	4. Disking 6-8 cm
0-10	1.14	1.17	1.12	1.24
10-20	1.18	1.24	1.24	1,29
20-30	1.22	1.29	1.32	1.36

Comparing the results obtained from the experimental plots, we can see that good bulk density was formed under plowing, flat-cut tillage and disking to 13-15 cm. The least soil mixing caused rising of bulk density to 1.24. On the depth of 10-20 cm the bulk density rose, and the highest data was obtained at disking of 6-8 cm – 1.29.

It is clear that the soil density increases with depth. There is a risk of having a plow pan in your field, especially with constant tillage to the same depth. Differencies of bulk density varied from 1.22 to 1.36 g/cm^3 with maximal data under disking treatments.

Soil moisture. In order for soil to function as a medium for plant growth, it must contain a certain amount of water. Studies of soil structure have shown that soil is a porous medium which contains pores of various sizes [45]. Water which enters the soil either remains in the pores or percolates through them to lower depths. Porosity is the opposite factor for water – air and water are antagonists. Ideal ratio between them is 25% to 25%. Studies on the impact of the methods of tillage on the water movement were described by Rashidi and Keshavarzpour [41], Aikins and Afuakwa [40], etc. Aikins and Afuakwa showed that more moisture was stored with disking in the experimental areas than in the areas without rotation of the formation. Opposite positions were obtained by other scientists, i.e. more moisture was observed in no-till farming [46]. This may be a factor that demonstrates the amount of precipitation in the time of tillage [40]. Rashidi and Keshavarzpour [41] reported that different methods of tillage significantly affected field moisture, and this index was quite higher in the conventional tillage than in no-till farming. Earlier, these researches got the similar data. Also, they emphasized the fact that conventional tillage is worse for soil to maintain good granular structure. Besides, during a stormy period or after spring soil particles can be leached with nutrients.

Water is the most important factor in the existence of living organisms. If you have enough water for plants, you can grow and harvest grains in the required amount. It promotes biological and chemical processes, determines the direction and intensity of the transformation of mineral and organic substances, their movement and formation of the soil profile.

Normal growth and development of plants, vital activity of soil microflora and fauna are impossible without the sufficient amount of water. To form 1g of dry matter, plants use from 200 to 1000g of water.

In the soil, water acts as a thermoregulatory factor and largely determines its thermal balance and temperature. Physical, physico-mechanical and technological properties of the soil also depend on the availability of water. Therefore, water is a necessary condition and factor of soil fertility.

The soil always contains moisture, the amount of which is constantly changing over time. These changes depend on the ratio of water entering the soil, precipitation, irrigation, groundwater and its consumption from the soil due to physical evaporation, transpiration, runoff, and so on. The intensity of these processes depends on climatic conditions, seasons, terrain, plant development, human production. In addition, the moisture content depends on the properties of the soil, such as particle size and chemical composition, structure, density, porosity, content of organic matter and colloids, surface condition, moisture capacity, permeability, and water capacity.

Moisture means the content of water in the soil at the moment [47].

In the early stages of growth and development, taking into account local conditions and selecting the right variety, plants should use favourable conditions to provide moisture at moderate temperatures. Instability in the provision of precipitation and soil moisture of the third subperiod of the growing season puts forward one of the most important requirements for the variety: increased drought resistance during the formation of generative organs. The variety should use favourable conditions of the flowering period and the beginning of seed formation. It must be sufficiently drought-resistant during the final growing season and at the same time, it should be able to use favourable conditions for grain filling.

At the beginning of the growing processes, you need 100-120% of water by weight. Buckwheat demands most moisture during flowering.

In the year of 2022 and 2023, the season of buckwheat growing was very difficult, as hydrothermal conditions were unfavourable due to abnormal quantity of precipitation in June and August; there were dry winds and high temperatures. During harvesting, the reserves of productive moisture in the soil almost halved (Table 4). The highest moisture at the sowing time was obtained in plowing plots – 31.1 mm in 0-10 cm layer, slightly less when disking to the depth of 6-8 cm – 29.1 cm; 28.3-28.7 mm were obtained at flat-cut tillage plots and disking 13-15 cm. Summing up the moisture reserves in the metre layer, it should be noted that there was the highest storage of water at plowing plots – 152.9 mm. During the growing seasons, soil water was taken by plants and reduced to 60.5-61.8 mm.

Table 4

Stocks of productive moisture in the soil at different times of sampling, mm

Tillage method	Depth of taken soil sample	
	0-30 cm	0-100 cm
	Sowing time /Harvesting time	
1. Plowing 20-22 cm	31,1/13,6	152,9/61,8
2. Flat-cut tillage 20-22 cm	28,7/13,6	151,3/61,1
3. Disking 13-15 cm	28,3/13,3	151,9/60,5
4. Disking 6-8 cm	29,1/14,5	150,7/60,5

So, water properties have been changed depending on the methods of tillage. Everyone knows that the speed and height of water level depends on the diameter of the pores, and hence, on the mechanical composition and structure of the soil. The higher water rises in the soil, the thinner the capillaries are, but the speed of the water decreases. Thus, in clay soils the water in the capillaries rises slowly, but to a greater height; in sandy soils it rises faster, but to a lesser height. In unstructured soils, compared with structural soils, water moves faster through capillaries and it is unproductively expended, evaporating into the atmosphere. Evaporation of water also depends on tillage and such factors as the presence of energy for the transition of water from liquid to gaseous state, the ability of air to transfer water vapour from the evaporating surface, the presence of water on the evaporating surface. With high water content, the water holding capacity is low, and when the amount of water decreases, it increases rapidly. The amount and availability of groundwater to plants is characterized by the moisture content of the soil, which is defined as the water content in the soil, expressed as a percentage of its mass or volume.

In order to determine the moisture reserves in the soil, you need to know the field moisture of the soil. We determined this indicator at the time of sowing and at the time of harvesting. Some researchers determine the middle of the growing season or the most critical for plants phases of development. Tillage was carried out in the autumn, then the condition of the soil stabilized during the autumn-winter period. When the soil reached physical maturity, we planned sowing buckwheat and, accordingly, soil sampling.

Field humidity is quite a variable indicator, which depends on the receipt of precipitation in the form of snow and rain from the soil structure and texture. Although water is in different forms in the soil, it must be remembered that it moves in different directions and under the action of different physical and biological forces.

Knowing the field moisture percentage, density of the soil and moisture of the plant wilting in a particular area, we calculated the reserves of productive moisture (this information was provided by the the Department of Agriculture, Soil and Agrochemistry, SNAU).

Determining the reserves of productive moisture in the spring is crucial for forecasting crop moisture and yield. There are relevant reference materials, which establish the security of culture on this indicator. So, in a metre layer more than 160 mm of precipitations are very good stocks of moisture, 90-60 mm – low stocks, etc.

The amount of productive moisture determines the type of soil climate during the growing season of plants, which is a leading factor in their productivity.

Buckwheat yield. Some scientists point to a decrease in grain yields, using shallow tillage or no-till farming in chernozem (black soils) [48].

For the period of germination and for normal development buckwheat should have about 22-26 mm of precipitation in the arable layer. In the further development it is desirable to have about seventy millimeters of moisture in a half-meter layer. Therefore, we can influence the soil moisture with tillage. In the flowering phase, buckwheat begins to absorb more water, and in 2021 the water supply was good.

It is believed that the yield of buckwheat mainly depends on weather conditions. Indeed, meteorological factors have a significant impact on its performance. At the same time, the data of research institutions, as well as the experience of Greek practitioners show that, adherence to technology determines the end result. Placement in crop rotation, i.e. the selection of the predecessor, is one of the important conditions for obtaining high and stable yields of any crop, including buckwheat. After all, it mainly determines the potential of soil fertility, namely: the provision of moisture and nutrients, purity from weeds, air and water regime, as well as physico-mechanical and chemical composition [49].

As we can see from data Table 5, plowing was the best option for buckwheat at the organic crop rotation. Perhaps, some insects were killed during this treatment and more water was stored in the soil. There was a significant difference between plowing and other ways of tillage. There were no significant differences between options 2 and 3, options 3 and 4.

Table 5

Buckwheat yield on the experimental plots

Tillage method	Buckwheat yield, centner per hectare	+/- to control
1. Plowing 20-22 cm (as control)	13.23	Control
2. Flat-cut tillage 20-22 cm	12.95	-0,28
3. Disking 13-15 cm	12.85	-0,38
4. Disking 6-8 cm	12.91	+0.32
LSD_{05}	0,252	

Table 6 demonstrates soil moisture balance and buckwheat water consumption ratio in the growing period of 2022-2023 in average.

We took data from Table 5 and Table 4, then we added yield of by-products (straw) and calculated how much water was taken by plants during the growing season (in average 2022-2023). The precipitation during the spring-summer period was obtained from the meteorological data from May to August. The precipitation used during the growing season is calculated by multiplying precipitation for May-August by precipitation utilization rate 0.7. For getting the water consumption ratio, we add the yield of grain and straw (for example, 1,32+2.67 = 3.99), then we divide total consumption of soil moisture and precipitation during the growing season by this yield (2466:3.99 = 618).

According to the rules, the higher the water consumption ratio is, the more difficult the conditions of plant growth and development are. The highest water consumption ratio was obtained at disking options.

Obtaining data on productive moisture reserves and taking into account the amount of precipitation in the period from sowing to harvesting, it is possible to assess / characterize the moisture content of crops. To do this, first of all, the evaporation from the area is calculated. It is the difference between moisture reserves in spring and at the end of the growing season, and minus the amount of precipitation (per decade, per month, during the growing season depending on the task). The coefficient of the biological curve of water consumption is 0.7; it is a constant calculated value for buckwheat.

Table 6

Soil moisture balance and buckwheat water consumption ratio (2022-2023)

The method of basic tillage	Total yield of main and by-products, t / ha	Stocks of productive moisture in the soil, mm		Used productive moisture from the soil during the growing season, mm	Precipitation during the spring-summer period, vegetation, mm	Precipitation utilization rate	Used precipitation during the growing season	Total consumption of soil moisture and precipitation during the growing season		Water consumption ratio
		at the time of germination	at the time of harvest					mm	t/ha	
1. Plowing 20-22 cm	1,32+2.67	152,9	61,8	91.1	222.1	0,7	155.47	246.57	2466	618
2. Flat-cut tillage 20-22 cm	1.29+2.58	151.3	61,1	90.2				245.67	2457	634
3. Disking 13-15 cm	1.28+2.56	151,9	60,5	91.4				246.87	2469	639
4. Disking 6-8 cm	1,29+2.58	150,7	60,5	90.2				245.67	2457	639

What can affect the water consumption coefficient of the crop and, accordingly, the transpiration coefficient given in Table 5? This is the kind of crop, its hybrid or variety, duration of the growing season. While relative humidity increases, transpiration decreases. Air temperature and wind speed also have their effect. If there is not enough moisture in the soil, the plant begins to emit less moisture to survive, which reduces total evaporation. Groundwater levels and other factors can also affect [50].

The transpiration coefficient of buckwheat can range from 209-736 [51].

Evaporation of water from the soil surface is mainly due to the size of the soil particles. It is known that agronomically valuable structure has soil particles of 0.25-10 mm size. Evaporation of water is minimal when the size of the elements is approximately 2 mm [51]. The more optimally balanced the mineral nutrition is, the lower the water consumption ratio is.

Growing buckwheat is one of the ways to solve the food problem in Ukraine and other countries, especially under war conditions. This crop is ahead of the rest of grain crops due to a much higher level of selling prices and payback of expenses.

At the beginning of the war in Ukraine, people bought a lot of cereals, and buckwheat quickly disappeared from store shelves, including organic buckwheat and even green one. It is clear that if people are poorer, they will not buy more expensive organic cereals, they will eat those foods just to survive.

But it should be remembered that economic efficiency of agricultural production means obtaining the maximum number of products per hectare of land with the lowest labour costs and funds for a unit of production. Domestic technologies of most crops, as a rule, are quite energy-intensive. One of the ways to reduce the cost of agricultural production is to minimize tillage, which is based on reducing the depth of the main tillage and introduction of flat tillage.

If we increase efficiency of technological measures that contribute to the productivity of buckwheat, it will be possible to increase production per unit of land at the lowest cost, as well as to increase profits and profitability in crop production.

Conclusions

1. Tillage to the depth of 20-22 cm, as well as plowing and flat-cut tilling increases the soil microbiological activity and causes intensive decomposition of linen. Intense decomposition can be explained by greater mixing of the soil and the influx of large amounts of air. At greater depths we could observe a decrease in biological activity for all options, but the data are higher on minimum tillage, in particular with disking to the depth of 6-8 cm.

2. With minimum tillage, the soil density increases slightly at all depths of taken soil sampling. In general, under options 1-3 in a layer of 0-10 cm a good structure for the plant was formed. At the depth of 20-30 cm, an increase in density to 1.32-1.36 g / cm^3 was observed with disking treatment.

3. In 0-30 cm soil layer more water was accumulated during the sowing period under disking 6-8 cm – 29.1 mm and plowing – 31.1 mm. During the harvesting period an accumulation of water was higher under disking 6-8 cm, but in 0-100 cm layer the level of water productivity was lower than during deep treatments.

4. The highest water consumption ratio was obtained at disking options. The higher the water consumption ratio is, the more difficult the conditions of plant growth and development are.

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