Soil properties and soybean yield depending from the use of green manure of oats

Alexander Naumenko[1*], *Yulia* Oborskaya[1], and *Maxim* Shelikhan[1]

[1]Far Eastern State Agrarian University, Blagoveshchensk, Russia

Abstract. Green fertilizer (green manure) serves as an inexhaustible and constantly renewable source of nutrients and organic matter. The search for ways to increase the efficiency of traditional ways of using green manure, and the development of new methods for their use are an important task of modern agriculture. The purpose of the research is to determine the effect of green manure on the agrochemical properties of the soil, soybean yield and their degree of relationship in the conditions of the Amur Region. Studies on the assessment of oat green manure were carried out from 2016 to 2022 in the village of Kovrizhka, Konstantinovsky district, Amur region, within the boundaries of the land use of the peasant family farm "Pchela" . The experiment was placed in a production environment, where each of the five fields was taken as a variant, with the corresponding area: field 1 - 240 ha, field 2 - 158 ha, field 3 - 270 ha, field 4 - 350 ha and field 5 - 256 ha. In each field, in accordance with the scheme of the experiment, oats were cultivated for green manure, mineral fertilizers were not used. Green manure of oats contributed to an increase in the pH_{H2O} value to 6,80-6,93 units , pH_{KCl} value to 5,50-5,70 units pH. The content of mobile phosphorus, determined by the method of A.T. Kirsanov, decreased every year of research, while the minimum values of the content of this element were recorded in 2022 (11-87 mg/kg of soil). The positive effect of green manure was reflected in the content of exchangeable potassium, while an increase in the content of this element was noted only in 2019 by 12-73 mg/kg of soil, and after 3 years, the indicators were lower by 37-73 mg/kg of soil.

1 Introduction

The Amur Region is the main producer of agricultural products in the Far East region. The gross harvest of soybeans is about 70% in the region and more than 50% of grain crops. The share of the Amur region in the production of soybeans in the Russian Federation is 35%, which determines the specialization on a national scale. The relevance of increasing the efficiency of crop production is determined by federal and regional projects [12]. The main areas for sowing agricultural crops in the region are concentrated on the territory of the Zeya-Bureya plain, where the most fertile soils are located. Therefore, the expansion of soil areas is carried out by introducing infertile brown forest, brown forest gley, meadow gley and alluvial soils into the arable land. As a rule, large areas of these soils have a thin

* Corresponding author: prorector-science@dalgau.ru

arable layer, increased acidity, a low content of mobile forms of kicking elements, and unfavorable physical properties. Obtaining high stable yields of agricultural crops on these soils is possible with a steady increase in their fertility [11]. Fertile soils are the foundation of high stable soybean yields, which are always higher on cultivated soils, regardless of the weather conditions of the growing season. Fertilizers are a powerful means of increasing soil fertility and crop yields, provided they are properly applied [7]. In modern conditions of farming, the active use of various fertilizer systems is envisaged. The most common are mineral fertilizers, the use of which makes it possible to increase the productivity of arable land in a very short time. Optimization of mineral nutrition most fully reveals the potential of soil fertility for individual crops. This is especially true for agricultural lands with a low content of nutrients and organic matter [2]. The studies of some scientists confirmed the positive effect of mineral and microfertilizers in the Amur region on the productivity of crops, increasing the protein content in seeds, increasing the leaf surface area and the maximum accumulation of dry matter [5, 10, 3]. At the same time, numerous studies have established that the excessive use of mineral fertilizers is currently the main cause of many environmental threats, such as soil degradation and eutrophication of water basins [19].

The sustainable functioning of agroecosystems is largely due to the nature of management, which should be focused on the development of science-based crop rotations that ensure the maximum yield of products per unit area while maintaining soil fertility [18]. Crop rotations include green manure crops that improve the phytosanitary condition of crops of cultivated crops. Embedding them in the soil closes a small biological cycle of substances, increases the content of humus, improves its composition, soil structure [1]. The introduction of plant mass stimulates the biological activity of the soil, affects the biomass of microorganisms, the composition of the microbial community, and the activity of enzymes [16, 9, 4]. Green fertilizer improves the vital activity of soil microorganisms, as it is a juicy food rich in energy for them. When the embedded green fertilizer decomposes, the soil and above-ground air is well enriched with carbon dioxide, improving the air nutrition of plants. Due to green manure, the possibility of moving nutrients into the lower soil horizons is sharply reduced. In addition, green manure somewhat reduces soil acidity, reduces the mobility of heavy metals, increases moisture capacity, water permeability, reliably protects soil from water and wind erosion, significantly increasing the profitability of agriculture [14].

In the conditions of the Far East region, a favorable effect of green manure on crop yields is noted. However, there is another vision of the role of green manure in increasing soil fertility and crop yields. For example, the period of validity of green manure is ambiguously estimated. In some experiments, the aftereffect of this type of fertilizer lasted 4-5 years, and judging by other observations, the weakening of the effect of green fertilizers was outlined already in the third year [17]. The search for ways to increase the efficiency of traditional ways of using green manure, and the development of new methods for their use are an important task of modern agriculture.

The purpose of the research is to determine the effect of green manure on the agrochemical properties of the soil, soybean yield and their degree of relationship in the conditions of the Amur Region.

2 Materials and methods

Studies on the assessment of oat green manure were carried out from 2016 to 2022 in the village of Kovrizhka, Konstantinovsky district, Amur region, within the boundaries of the land use of the peasant family farm (PFF) "Pchela". The experiment was placed in a production environment, where each of the five fields was taken as a variant, with the corresponding area: field 1 - 240 ha, field 2 - 158 ha, field 3 - 270 ha, field 4 - 350 ha and field 5

- 256 ha. In each field, in accordance with the scheme of the experiment, since 2016, oats for green manure were cultivated annually, mineral fertilizers were not used (Table 1).

Table 1 - Scheme of production experience by years of research

Variant	Years						
	2016	2017	2018	2019	2020	2021	2022
Without green manure	5 4 3 2* 1*	5 4 3*	5 4*	5*	-	-	-
Green manure of the 1st year	-	1, 2	3	4	5	-	-
Green manure of the 2nd year	-	-	1, 2	3	4	5	-
Green manure of the 3rd year	-	-	-	1, 2	3	4	5
Green manure of the 4th year	-	-	-	-	1, 2	3	4
Green manure of the 5th year	-	-	-	-	-	1,2	3
Green manure of the 6th year	-	-	-	-	-	-	1, 2
Note: 1, 2, 3, 4, 5 - number of the field under study; * - the field where green manure crops (oats) were sown with subsequent incorporation into the soil							

In the peasant family farm "Pchela" a five-field crop rotation is observed with 65% saturation with soybeans and 35% saturation with oats. As a precursor of soybeans, oats were sown on the green mass of the Altaisky large-grain variety (stem of medium height (95-110 cm), resistant to lodging; leaves of medium length, wide, pubescence absent; the variety is mid-season, the growing season is 78-90 days). Sowing green manure culture was carried out by SMF (spreader of mineral fertilizers) - MX LBR. The density of standing oat plants per 1 m^2 was 74-78 plants. In the phase of milky-wax ripeness of oats, the green mass was embedded into the soil with a BDM-7 disk tool.

We cultivated soybeans of the variety Lydia. According to the international classification, this variety is included in the group of ultra-early varieties, according to the production classification - early-ripening; the duration of the growing season is 96-104 days, it is intended for cultivation in moderately cold adjacent regions. 7 days before sowing, the seeds are treated with a disinfectant Maxim XL (active ingredient - mefenoxam + fludioxonil 10 + 25 g / l), in combination with Teknokel Amino Molybdenum fertilizer (water-soluble molybdenum composition - 8.0%, free amino acids L - 4.0%), in a ratio of 1:2, at the rate of 7 liters of working solution per ton of seeds. Soybean cultivation technology is generally accepted for the Amur region.

The studied objects were soybean plants, five production fields with a predominance of alluvial meadow light loamy soils. These soils develop on lower parts of the relief in the near-channel and low floodplains, on spits and islands, near active riverbeds, on rocks of predominantly light granulometric composition with a pronounced layering of soil-forming alluvium, under willow forests and motley grass .

Alluvial meadow soil has the following parameters of physical and chemical properties: actual acidity in the root layer - 6.2 units pH, down the soil profile, the value of this indicator increases. The exchange acidity is 6.0 units pH. Hydrolytic acidity in the soil profile varies from 2.8 in a layer of 0-10 cm to 1.2 mg-equivalent / 100 g of soil in a layer of 40-90 cm. The sum of absorbed bases is 38.8-58.5 mg-equivalent / 100 g soil. The cation exchange capacity is in the range of 52.4-60.5 mg-equivalent/100 g of soil, while the degree of base saturation is 95-98%.

The humus content in the upper horizon can reach up to 4%. The content of mineral nitrogen in the alluvial meadow soil varies from 100 to 25 mg/kg down the profile. The content of mobile forms of phosphorus fluctuates - 29-66 mg/kg. Exchangeable forms of potassium are also characterized by a low content and vary from very low - 40 mg to medium - 100 mg / kg.

Alluvial meadow soils are characterized by a heterogeneous granulometric composition. The most common are sandy, light loamy. Predominant in the composition of fine earth is either a fraction of sand, or fine sand and coarse dust. The silt content is low, sometimes there is no silt fraction at all. Rarely, there is a change in the granulometric composition in the direction of weighting in soils territorially located down the longitudinal profile of river valleys.

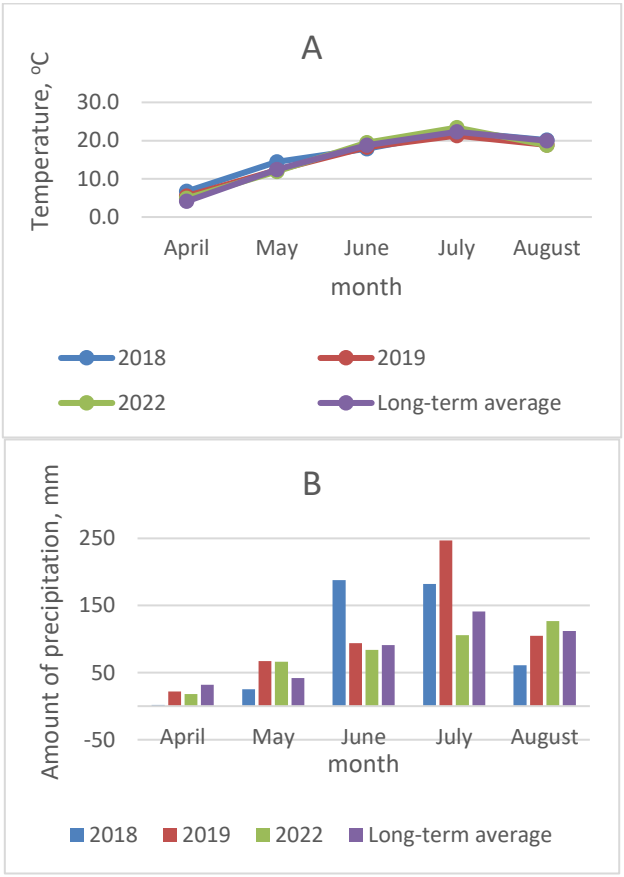

Fig. 1. Meteorological conditions of the growing season in the years of research (A - average monthly air temperatures, B - average monthly precipitation)

In order to identify changes in soil properties due to the use of oat green manure, soil samples were taken in the spring of 2018, 2019 and in the fall of 2022 with a reed drill to a depth of 0-20 cm, combining individual soil samples (17-20 pieces) into a common sample. The selection was carried out by the envelope method, taking into account the area of the field. In soil samples, pH was determined by the potentiometric method (GOST-26483-90), mobile phosphorus and potassium were determined by the method of A.T. Kirsanov (GOST 54650-2011). In the experiment, phenological observations were performed, soybean yield was recorded by direct combining with conversion to standard moisture content (14%)

through a computer program built into the VECTOR 410 combine for each field. When assessing the strength of the correlation coefficients between the indicators of agrochemical properties and soybean yield, the Chaddok-Snedekor scale was used.

During the years of the research, the meteorological conditions in the Konstantinovsky district of the Amur region somewhat differed from the long-term average values (Fig. 1).

Agrometeorological conditions during the years of research were difficult. Waterlogging in 2018, 2019 affected crop yields. The low temperature regime during these years also affected the yield. In 2022, the summer temperature period was characterized by typical data for the Amur Region, while precipitation was unevenly distributed. An excess of the long-term average was noted in May and August by 24 and 15 mm, respectively.

3 Results

3.1 The effect of green manure on the agrochemical properties of the soil

In the studies carried out on the fields of the peasant family farm "Pchela" in 2018, when determining the actual acidity, it was revealed that the reaction of the soil environment changes from close to neutral to neutral. In the variants without the use of green manure (field No. 5 and No. 4), the reaction of the soil environment corresponds to close to neutral 5.70 and 5.80 units pH (Table 2). After the application of green manure of the first year on field No. 3, the value of the actual acidity increased to 6.10 units pH. In the fields where green manure was used 2 years ago, the reaction of the medium was neutral, the acidity value was 6.70 and 6.80 units pH.

In the conditions of 2019, the same pattern remained as in 2018 - the maximum value of the actual acidity (6.93 and 6.35) was noted in the variant with the use of green manure of oats three years ago (field No. 1 and No. 2). The lowest value of actual acidity was recorded in the variant without the use of green manure fertilizer - 5.73 units pH.

In 2022, the change in the pH of the aqueous suspension was proportional to the year of green manure use. When green manure was planted 3 years ago (field No. 5), the value of the actual acidity was 6.22 units, and when green manure was used 6 years ago (field No. 1), this indicator was at the level of 6.88 units - the reaction of the medium is neutral.

Table 2. Agrochemical properties of alluvial meadow soil as a result of incorporation of oat green manure

Variant	pH H_2O			pH KCl			P_2O_5			K_2O_5		
	units pH						mg/kg soil					
	2018	2019	2022	2018	2019	2022	2018	2019	2022	2018	2019	2022
Without green manure	5,70 5,80	-	-	5,10 5,20	-	-	58 81	-	-	144 151	-	-
		5,73	-		4,31	-		30	-		157	-
Green manure of the 1st year	6,10	5,98	-	5,50	5,12	-	49	20 6	-	156	177	-
Green manure of the 2nd year	6,30 6,80	6,23	-	5,70 5,70	4,98	-	82 255	56	-	133 133	168	-
Green manure of the 3rd year	-	6,35 6,93	6,22	-	5,16 5,56	4,82	-	35 23 6	11	-	169 206	84
Green manure of the 4th year	-	-	6,32	-	-	4,90	-	-	38	-	-	118
Green manure of the 5th year	-	-	6,70	-	-	5,32	-	-	53	-	-	112
Green manure of the 6th year	-	-	6,56 6,88	-	-	5,06 5,50	-	-	30 87	-	-	132 148
Note: below the line - field No. 1, above the line - field No. 2												

In 2018, the soil of the studied fields was characterized from slightly acidic to close to neutral reaction of the environment in terms of exchangeable acidity, the values were in the range of 5.10-5.70 units. pH (Table 2). In the variant with the use of green manure (planting oats in the phase of milky-wax ripeness) one year ago (field No. 3), the reaction of the medium was slightly acidic, the exchange acidity had a value of 5.50 units pH. At the same time, it should be noted that this year the soil in fields No. 1 and No. 2 had a high value of exchange acidity of 5.70 units pH.

In 2019, in our studies, exchangeable acidity acquired a strongly acidic, acidic, and slightly acidic reaction of the medium to a greater extent. In the variant without the use of green manure (field No. 5), the value of pH KCl extract was the lowest - 4.31 units pH. At the same time, the use of green manure fertilizer three years ago ensured the maximum value of exchangeable acidity - 5.16 and 5.56 units pH.

In the conditions of 2022, there was a positive shift in the value by 0.51 units of exchange acidity in the soil of field No. 5, where green manure was used three years ago. A similar situation was noted in the soil of field No. 3, where an increase in the value of exchangeable acidity occurred by 0.34 units pH compared to 2019. After the use of green manure six years ago (fields No. 1 and No. 2), the value of exchangeable acidity was at the level of 5.50 and 5.06 units pH.

In our studies, when determining the chemical properties of the soil in 2018, an ambiguous effect of green manure fertilizers was revealed. Thus, the content of mobile phosphorus, determined by the method of A. T. Kirsanov in the variants without green manure, was 58 and 81 mg/kg (Table 2). According to the data presented in the monography by I.G. Kovshik [7], in accordance with the gradation of soils for the Amur Region, such a content is considered to be elevated. In the first year after green manure incorporation (field No. 3), the content of mobile phosphorus was 49 mg/kg of soil. In the soil of field No. 2, the content of phosphorus was at the level of the field without the use of green manure (82 mg/kg). The highest content of mobile phosphorus was found in the soil of field No. 1 - 255 mg/kg.

In 2019, the content of mobile phosphorus in the variant without green manure is characterized as low - 30 mg/kg (Table 2). After green manure incorporation in field No. 4, the content of mobile phosphorus increased to 206 mg/kg. In field No. 3, where green manure was plowed up two years ago, the content of mobile phosphorus was at the level of 56 mg/kg. Field No. 2, where green manure was used 3 years ago, is characterized by a low content of phosphorus at the level of 35 mg/kg, which corresponds to the content of this element in the variant without green manure. Also, as in 2018, a high content of mobile phosphorus was recorded in the soil of field No. 1 in the year of observations - 236 mg/kg.

In 2022, the content of mobile phosphorus, determined by the method of A.T. Kirsanov, varied from very low (11 mg/kg) to high (87 mg/kg) availability. At the same time, there is no regularity in the distribution of phosphorus content in the soil depending on the year of application of the green manure crop - oats.

Potassium, along with nitrogen and phosphorus, is one of the main plant nutrients. In our studies in 2018, the content of exchangeable potassium in the alluvial meadow soil was characterized by different values according to the experimental options. So, in the fields where green manure was not used (fields No. 5 and No. 4), the content of exchangeable potassium was 144 and 151 mg/kg of soil, respectively (Table 2). The content of exchangeable potassium in the variant with the use of green manure fallow was the highest in field No. 3 a year ago - 156 mg/kg of soil. At the same time, the lowest content of the determined element (133 mg/kg of soil) was noted in fields No. 1 and No. 2, where green manure was used two years ago. Apparently, such a decrease occurred due to an increase in the removal of this element with the alienated part of the soybean crop.

In the conditions of 2019, in the variant without green manure (field No. 5), the content of exchangeable potassium was 157 mg/kg in accordance with the gradation of soils, such a content is considered increased (Table 2). Field No. 4 is characterized by a high content of exchangeable potassium (177 mg/kg), green manure was used in this field a year ago. Green manure incorporation 2 years ago (field No. 3) contributed to a slight increase in potassium content by 11 mg/kg of soil compared to the variant without green manure. The content of potassium in the soil of fields No. 1 and No. 2 with green manure incorporation three years ago was 206 and 169 mg/kg, respectively.

In 2022, a decrease in the content of exchangeable potassium was recorded in all fields of production experience. Thus, the lowest value was noted in the soil of field No. 5 - 84 mg/kg, where green manure was plowed 3 years ago. The incorporation of oat green manure 4 and 5 years ago provided almost the same value - 118 and 112 mg/kg of exchangeable potassium, respectively. The maximum content of potassium (148 and 132 mg/kg) was noted in the soil of fields No. 1 and No. 2, respectively.

3.2 Effect of green manure on soybean yield

Evaluation of the productivity of soybean variety Lydia in the peasant family farm "Pchela" was analyzed in each studied field under production conditions. So, in 2016, in the first year of planting green manure crops (oat of variety Altaisky large-grain), two fields were occupied - No. 1 and No. 2. At the same time, the soybean yield in the remaining three fields of the crop rotation was at the level of 1.2-1.4 t/ha (Fig. 2).

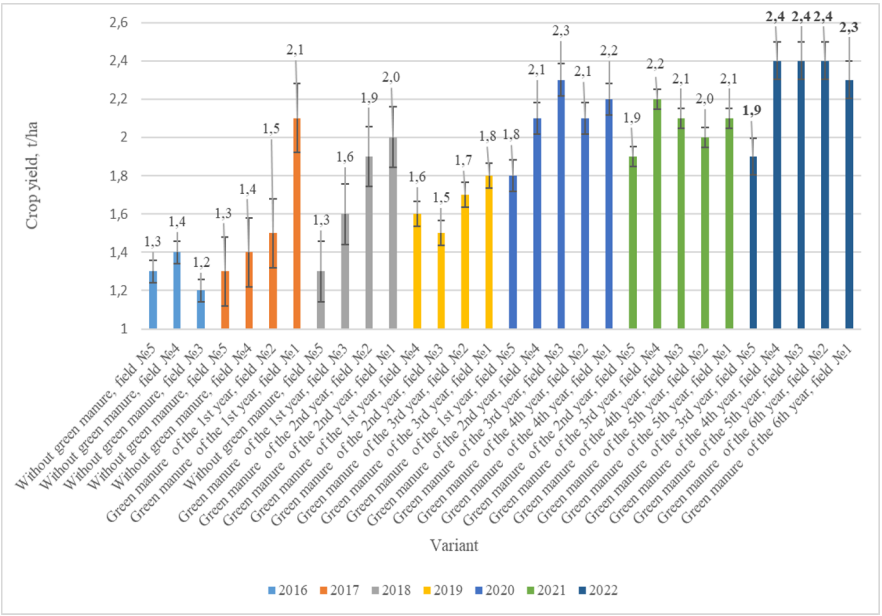

Fig. 2. Yield of soybean of the variety Lydia in the peasant family farm "Pchela" during the years of research

In 2017, the highest soybean yield (2.1 t/ha) was obtained in field No. 1 using green manure a year ago. In field No. 2, the yield was 1.5 t/ha, which is relatively higher than in the fields without the use of green manure 1.3-1.4 t/ha.

According to the data of 2018, in field No. 5, without the use of green manure fallow, the yield was 1.3 t/ha. After green manure incorporation in field No. 3, the yield increased

by 0.4 t/ha compared to 2016 and amounted to 1.6 t/ha. The influence of green manure aftereffect can also be observed in 2019, when the green mass embedded in the soil in 2018 in field No. 4 contributed to an increase in soybean yield by 0.2 t/ha compared to 2017. Yield data for field No. 3 confirms the assumption of a decrease in yield in the second year of green manure fallow, where soybean yield decreased by 0.1 t/ha. A similar situation was noted in field No. 1 and No. 2, where green manure was planted three years ago, the yield was less by 0.2-0.3 t/ha.

Near-optimal weather conditions in 2020-2022 of the research years ensured an increase in the yield of soybeans of the Lydia variety. At the same time, it was in 2020 that the first crop rotation was completed with the incorporation of green manure in one of the fields. In the conditions of 2020 and 2021, the maximum yield of soybeans of the early ripening variety Lidiya was obtained in fields No. 3 and No. 4, where green manure was planted three years ago - 2.3 and 2.2 t/ha, respectively. In 2022, the maximum soybean yield (2.4 t/ha) in three fields was obtained, where green manure was planted 4, 5 and 6 years ago.

In general, for the entire period of research from 2016 to 2022, there is a tendency to increase soybean yields from the use of oat green manure as a green fertilizer. However, it should be noted that in a detailed analysis of soybean yield data, the period of maximum effect from the incorporation of green mass of oats into the soil was established - it is 3 years.

3.3 Relationship between agrochemical indicators of soil and soybean yield

In order to determine the relationship between the yield of soybeans in the peasant family farm "Pchela" and certain indicators of agrochemical properties, we performed a correlation analysis of the data obtained. The results show that in 2018 the yield of soybean of the early maturing variety Lydia was in a very weak dependence on the value of the actual acidity, the correlation coefficient was 0.327 (Table 3). At the same time, the value of exchangeable acidity and soybean yield in 2018 were characterized by a high bond strength, the phosphorus content was determined by the method of A.T. Kirsanov - is completely interconnected with the value of soybean productivity (r = 0.942).

Table 3 - Pair correlation coefficients (r) for 2018, 2019 and 2022

Yield in the respective year	Indicator			
	pH H_2O	pH KCl	P_2O_5	K_2O
2018	0,327	0,888	0,942	0,634
2019	0,803	0,631	0,913	0,943
2022	0,527	0,452	0,488	0,698

The yield of soybeans in 2019, to a greater extent, depended on the content of mobile phosphorus and exchangeable potassium in the alluvial meadow soil - the coefficients were 0.913 and 0.943, respectively. At the same time, a high dependence of soybean yield on the value of actual acidity (r = 0.803) and an average dependence on the value of exchangeable acidity (r = 0.631) were established. In 2022, a significant dependence of soybean yield on the content of potassium in the soil and a moderate dependence on soil acidity and the content of mobile phosphorus in it were noted.

4 Discussion

The reaction of the environment is essential for the direction of soil processes and the level of soil fertility. Acid-alkaline conditions depend on soil types, their subtype, generic differ-

ences and can vary widely. The acidity of the soil affects the solubility as well as the uptake of various nutrients by the plant. On acidic soils, such nutrients as iron, zinc, manganese, boron, etc. are most digestible. At the same time, a low pH value can greatly inhibit growth and even have a damaging effect on plants. For each plant species, there are limits on the value of the reaction of the environment at which their growth is possible, but for most plants, the most favorable is a slightly acidic (pH 5-6 units) or neutral (pH 7 units) reaction of the environment. In studies carried out on alluvial meadow soil in the peasant family farm "Pchela" , a positive effect of oat green manure on changing the soil response was established. Thus, the use of green manure 2 years ago provided an increase in the actual acidity in 2018 by 0.9-1.0 units pH compared to variants without green manure. In 2019, the same trend was noted for an increase in the value of actual acidity in the soil of field No. 1 by 0.27 units compared with field No. 5, where green manure was not applied. In 2022, the value of the actual acidity was in the range of 6.22-6.88 units pH, which indicates the establishment of a neutral reaction of the medium in all fields. A.V. Safonov [15] found a positive effect of green manure on the physicochemical properties of the meadow chernozem soil of the Penza region.

The indicators of soil exchange acidity changed ambiguously during the years of research, while the maximum values were recorded in the soil of field No. 1, so in 2018 - 5.70; in 2019 - 5.56; in 2022 - 5.50 units pH, where green manure was embedded 2, 3 and 6 years ago, respectively. Changes in the values of exchangeable acidity by options, in our opinion, were due to a significant amount of precipitation in 2018 in June and in 2019 in July, when the long-term average values were exceeded. The light granulometric composition of the alluvial meadow soil contributed to the leaching of alkaline elements. Similar changes in the reaction of the environment to the acid side in light gray forest light loamy soil, which is confirmed by a decrease in the pH of the salt extract by 0.07-0.08 units pH and noted in the studies of V.I. Titova [20].

In the scientific literature, there are conflicting data on the effect of green manure crops on the content of mobile phosphorus in the soil. This is due to the different types of green manure crops, the methods of their incorporation into the soil, and the peculiarities of the soil and climatic conditions during the experiments [8, 20]. In our studies, the absence of an increase in the content of mobile phosphorus as a result of the incorporation of oat green manure in alluvial meadow soil was recorded. In the conditions of 2022, a decrease in the content of phosphorus in the soil of all variants was noted, and this can be explained by an increase in the removal of nutrients, including phosphorus, with the yield of the cultivated crop - soybeans. At the same time, it should be noted that the soybean yield in 2022 increased by an average of 1.0 t/ha compared to 2016, when green manure with oat green mass was just started to be used in the peasant family farm "Pchela" .

The positive effect of green manure on the potassium content in the soil of all the studied fields was recorded in 2019, when the increase was 26, 12 and 36.73 mg/kg of soil in the variants where green manure was planted 1, 2 and 3 years ago compared to 2018. However, after 3 years of active use of the soil for growing soybeans, the content of exchangeable potassium decreased in all variants by 73.59.56 and 37.58 mg/kg compared to 2019. Such a decrease in the content of exchangeable potassium is associated with an increase in the removal of nutrients with the soybean crop. At the same time, it should be taken into account that mineral fertilizers have not been applied in all the studied fields since 2016.

Under the conditions of the production experiment in the peasant family farm "Pchela" , the yield of Lydia soybeans varied over a wide range over 6 years of research. According to I.G. Kovshik [6], the weather conditions of the growing season are of decisive importance in the formation of soybean yield. To a greater extent, the weather conditions that develop during the period of seedlings - flowering of soybeans have a greater impact on yield indicators. The pair correlation coefficient between the yield indicators and the sum of

temperatures in this period was 0.564, the sum of precipitation and the hydrothermal coefficient, which also takes into account soil moisture, was 0.469 and 0.582, respectively. Thanks to the research of Pavlova O.V. [13], it was also found that soybean yield largely depends on the climatic conditions of the year.

In our studies, the soybean yield in the variants without incorporation of green mass of oats ranged from 1.2 to 1.4 t/ha, in the first and second years after incorporation - within 1.5-2.1 t/ha, in the third year after incorporation of green manure - 1.7-2.3 t/ha, in the fourth year after green manure, soybean yield was 2.1-2.4 t/ha, after five years after green manure, the yield was in the range of 2.0-2, 4 t/ha and in the sixth year after oat embedding, the yield was 2.3-2.4 t/ha.

During the years of research, the yield had a different degree of dependence on the determined indicators of agrochemical properties. In unfavorable weather conditions in 2018 and 2019, the strongest direct dependence was traced on the content of mobile phosphorus in the soil. At the same time, in 2019, an increase in the content of exchangeable potassium in the alluvial meadow soil had a significant impact on the yield of the main crop in the crop rotation - soybeans. In different years, the soybean yield was characterized by a high strength of connection with the reaction of the soil environment.

5 Conclusion

In a five-field crop rotation, annual green manure contributed to a change in the reaction of the environment to more optimal values for growing soybeans - close to neutral (6.80-6.93 units pH). The content of mobile phosphorus, determined by the method of A.T. Kirsanov, decreased with each year of research, while the minimum values of the content of this element were recorded in 2022 (11-87 mg / kg of soil), when the maximum soybean yield was obtained in the production experiment (1.9-2.4 t / ha) . Green manure of oats had a positive effect on the content of exchangeable potassium, while an increase in the content of this element was noted only in 2019 by 12-73 mg/kg of soil, and after 3 years, the indicators were lower by 37-73 mg/kg of soil relative to 2019 values. Further research in this area should be aimed at studying changes in the physical and biological properties of the soil in dynamics under the conditions of the Amur Region.

The yield of soybeans of an early maturing variety without green manure was 1.2-1.4 t/ha. For six years of systematic incorporation of green mass of oats in a five-field crop rotation, the yield increased to 1.9-2.4 t/ha. The strongest direct dependence of soybean yield was traced on the content of mobile phosphorus in the soil, the pair correlation coefficients were 0.913-0.942. It is advisable to continue research in this direction to determine the effect of green manure on the chemical composition of soybean seeds.

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