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Original article

THE INFLUENCE OF WINTER GREEN MANURES ON THE FERTILITY OF THE SOIL UNDER THE VINEYARD

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The paper presents data on the effect of phytoremediation: the use of a mixture of winter vetch and wheat as green manure [GM] and their combination with the microbial preparation Azotobacterin [AB] (GM +AB) in vineyard rows on soil fertility on piedmont carbonate chernozems. A variant with overgrowing of row spacing with segetal vegetation served as a control. The studies were conducted in 2018–2019 in the foothill zone of the Crimea in a vineyard founded in 2002, on grapes of cultivar 'Bastardo Magarachsky'. Also, GM cultures were sown in November and plowed in May next year. It was found that 0.19–0.21 kg/m^2 of organic matter dry mass got into the soil during the plowing with GM, 1.6 times more than in the control. Thus, GM leads to the accumulation of moisture in the layer 60–100 cm, 13.4% higher than the control, and an increase in pH_{H2O} and active carbonates content within the permissible values for grapes. There was an accumulation of organic carbon by 0.31–0.45%, mobile forms of nutrients in the soil: NO_3 - by 18%, P_2O_5 - by 3.2 times, K_2O - by 39% in the 0–60 cm layer under the influence of GM.

Keywords: *Vitis vinifera L.; green manure; phytoremediation; microbial preparations; soil fertility*

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Научная статья

ВЛИЯНИЕ ОЗИМЫХ СИДЕРАТОВ НА ПЛОДОРОДИЕ ПОЧВЫ ПОД ВИНОГРАДНИКОМ

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В работе представлены данные о влиянии фиторемедиации – применения смеси озимой вики и пшеницы в качестве сидерата [СД] и их сочетания *с микробным препаратом Азотобактерин [АБ] (СД + АБ) в рядах виноградников – на плодородие почвы на предгорных карбонатных черноземах. Контролем служил вариант с зарастанием междурядий сегетальной растительностью. Исследования проводились в 2018–2019 гг. в предгорной зоне Крыма на винограднике, заложенном в 2002 г., на винограде сорта Бастардо Магарачский. Сидеральные культуры были посеяны в ноябре и запаханы в мае следующего года. Установлено, что при запахивании сидератов в почву поступило 0.19–0.21 кг/м² сухой массы органического вещества, что в 1.6 раза больше, чем в контрольном варианте. Таким образом, сидераты приводят к накоплению влаги в слое 60–100 см, что на 13.4% выше контроля, увеличению* pH_{H2O} *и содержания активных карбонатов в пределах допустимых значений для винограда. Под влиянием сидератов в слое 0–60 см отмечено накопление органического углерода на 0,31–0,45% и подвижных форм элементов питания в почве:* NO_3 *– на 18%,* P_2O_5 *– в 3.2 раза,* K_2O *– на 39%.*

Ключевые слова: *Vitis vinifera L.; сидераты; фиторемедиация; микробные препараты; плодородие почвы*

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Introduction

Intensive technologies for growing perennial crops, including grapes, without sufficient amounts of organic fertilizers, lead to a sharp decrease in organic matter content in soils, especially in the south, where the traditional system of row spacing is autumn fallow. The use of mineral fertilizers in large quantities leads to soil contamination, causing a decrease in the productivity of the agrocenosis and the quality of products.

Currently, the application of an ecological approach in the process of managing agrocenoses and the implementation of the main provisions of the Concept of sustainable development in the agricultural industry are relevant [14; 20]. In this regard, the development and application of environmentally friendly technologies characterized by high efficiency and environmental safety are relevant. These technologies include the use of green-manured fallow or a long-term grassing-down of grape row spacing with herbs [16; 17; 18]. In the south, with insufficient natural moisture supply and warming and aridization of the climate, the cultivation of vineyards is possible only with irrigation. Without irrigation, the traditional method of increasing the fertility of the soil of a grape plantation is the use of green fertilizers: green manure [GM] [6]. Currently, several methods of applying GM were developed: short-term seasonal grassing-down of grape row spacing in each four-year agrotechnological cycle, various triticale variety types, and their use with effective microorganisms [4]. At the same time, the inflow of organic matter into the soil increases; conditions are created for the natural process of reproduction of soil fertility, improving its physical and chemical properties and bringing high-quality products [12]. The use of legume GM enriches soil with nitrogen, increases the content of mobile humic substances, and positively influences the crop and its quality [21]. However, in some cases, the use of vetch and clover leads to a decrease in the grape harvest due to competition for water with the vines [14; 15]. In the Crimea, on irrigated vineyards, the positive effect of long-term grassing-down of row spacing with perennial grasses and their combined use with microbial preparations on soil fertility and grape quality was shown [10; 23]. Ya. A. Volkov and his coauthors [3] investigated the influence of various annual cereal and legume GM in the vineyard on the composition of soil microorganisms for the development of organic viticulture techniques. The effect of growth-stimulating microorganisms on different plants was studied separately [1; 2; 19], resulting in increased growth, productivity, and quality of fruits and seeds. However, the effect of GM and their combination with effective microorganisms on the properties in carbonate soils of Crimea has not been studied.

Materials and methods

The paper aims to evaluate the effect of a grain-legume mixture of winter GM and their combination with the microbial preparation [MP] Azotobacterin07-Agro [AB] on the agrochemical parameters of the soil in a vineyard in the foothill zone of the Crimea. The research tasks were estimating the biomass of GM, selecting and analyzing soil samples according to the variants of the experiment, and determining active carbonates, pH, organic carbon, and nutrients. The research was conducted in 2018–2019 in a small-scale field experiment on a vineyard in the foothill experimental farm of All-Russian National Research Institute of Viticulture and Winemaking of the RAS "Magarach" (Vilino village, Bakhchisarai district, Republic of the Crimea). The experiment was carried out on grapes (*Vitis vinifera* L., 1753) of 'Bastardo Magarachsky' cultivar (2002 year of planting), rootstock Kober 5 BB and planting scheme 3.0 x 1.5 m. In November 2018, the seed was sown with a mixture of winter vetch (*Vicia* L., 1753) (40% in the mixture) and winter wheat (*Triticum aestivum* L., 1753) (60%). The seeding rate of the seed mixture was 90 kg $ha^{-1.}$

Seeds of GM were treated with an MP: AB, the bio-base strain of which *Azotobacter* (Beijerinck, 1901) strain 10702 was a nitrogen fixator and plant growth promoter. This strain has been included in the Unique Scientific Installation “Crimean Collection of Microorganisms” [13]. The norm of the preparation was 2% of the weight of the seeds. The preparation was developed and provided by the Department of Soil Microbiology of the Research Institute of Agriculture of Crimea.

The experimental design was as follows:

- Control – a natural overgrowth of row spacing with weed vegetation;
- GM without MP treatment;
- GM + AB.

The primary plot was 1 row of the vineyard (two spaces on both sides of the row). The area of the primary plot was 600 m^2, the area of the experiment was 1800 m^2.

The plowing of GM and segetal grasses (control) was carried out in June. Before plowing, the selection of herbs with roots for biomass was performed on trial sites with an area of 1 m^2 in three-fold repetition. Mineral fertilizers were not applied in the vineyard.

Soil samples were collected for analysis in the original soil in October 2018 and in May 2019 (before GM plowing) in 20-cm layers up to a depth of 100 cm in three-fold repetition. In the soil, moisture, organic matter (**C_{org}**), pH water (**pH water**), and mobile forms of nutrition elements were determined using conventional methods [11]. Active carbonates were establishedusing Druino-Galais method [17]. The soil at the experimental plot was Calcic Skeletal Chernozem-Loamic on loamy-pebble deposits. The soil was quite suitable for growing wine grape cultivars; it hadthe following characteristics in a layer of 0–60 cm: pH of water 8.14–8.28, C_{org} 1.48–2.07%, $CaCO_3$ 9.5%–18.6%, active carbonates 5.5%–11.0%; NO_3 and P_2O_5 – 2.8–9.3 and 1.1–8.8 mg kg^{-1}, respectively; K_2O – 444–610 mg kg^{-1}. The content of silt particles (<0.01 mm) was 27.9%–31.0%, physical clay (<0.1 mm) – 52.5%–61.2%. The soils were not saline with easily soluble salts; the amount of salts was 0.054%–0.064%. Data were statistically processed using the ANOVA Statistica 07 and Excel 2010 programs.

Results

The biomass of GM that enters the soil after plowing replenishes it with fresh organic matter. Therefore, it is essential to determine the optimal amount of biomass entering the soil to avoid competition between the grape plant and GM for moisture. The research results indicate that the dry biomass of segetal vegetation in the control at 'Bastardo Magarachsky' was 0.20 kg m^{-2} (Fig. 1). When plowing GM, the biomass was 1.6 times higher than in the control (the differences were significant at the level of 5%). Thus, GM treated with AB produced lower biomass, exceeding the control by 0.03 kg m^{-2} (15%); the differences with the control were significant ($p = 0.05$).

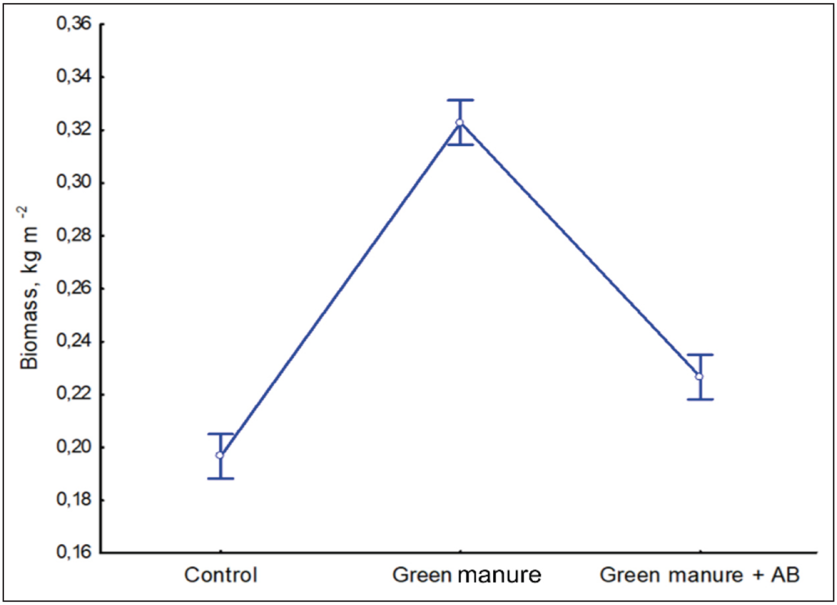

Fig. 1. Biomass (dry mass) of GM in the vineyard. Here and further in the figures: Vertical bars denote 0.95 confidence intervals.

The influence of GM on the properties of the soil under the grapes wasanalyzed. We found that the total soil moisture in the control was insignificant and amounted to 13.5%–13.7% in the layer of 0–40 cm; in the layer of 40–60 cm, it decreased slightly with a maximum at a depth of 60–100 cm: 14.3% (Fig. 2).

The use of GM contributed to an increase in soil moisture in the 40-80 cm layer by 6-8 relative percent. Therefore, GM treated with AB reduced soil moisture, particularly significantly at depths of 0–20 cm and 80–100 cm.

Studies of soil properties showed that the pH value of water in the control was 8.0-8.1 and did not change much with depth (Fig. 3). The combined use of GM and AB only slightly increased the pH of the soil in the layers of 20–40 and 60–80 cm compared to the control.

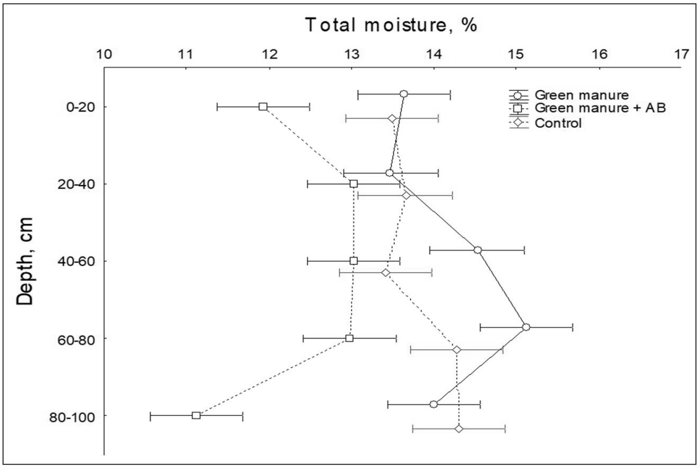

Fig. 2. Changes in total soil moisture under the influence of GM. Wilks lambda = 0.446, F (32.101) = 0.77440, p = 0.793.

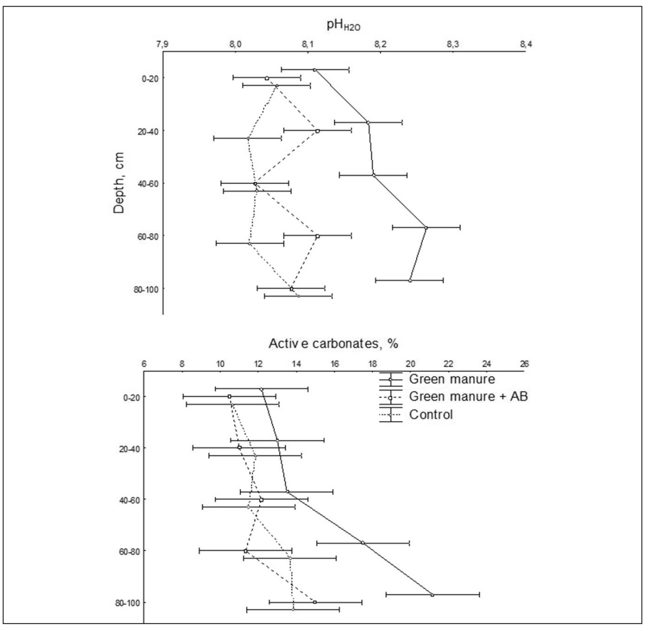

Fig. 3. Effect of GM on the pH value of water and the content of active lime in the soil.

The content of active carbonates in the control soil was low in the 0–60 cm layer: 10%–13% (Fig. 3). In the lower layers, it gradually increased to 14%–16% due to the carbonate content of the soil-forming rock. When sowing GM, the content of active carbonates in the 0–60 cm layer slightly increased compared to control (the differences are insignificant at the level of 5%). However, in a 60–100 cm layer, their content increased sharply to 16%–22%.

The content of organic matter (**C_{org}**) in the control soil was low and decreased with depth (Table 1). The GM significantly increased it in the 0–40 cm layer by 0.31%–0.45%, and at most in the 0-20 cm layer. During the treatment with AB, GM seeds did not significantly change the humus content in the soil compared to the control. There was a tendency for its increase in the layer of 20-40 cm by 0.15% or 10 relative percent.

Table 1.

Influence of ampelocenosis biologization techniques on the content of C_{org} and mobile forms of nutrients in the soil, 2019.

Variant	Depth, cm	C_{org} (%)	$N\text{-}NO_3$	P_2O_5	K_2O
			mg kg $^{-1}$		
Control (natural grassing down)	0–20	2.00	12.4	4.0	428
	20–40	1.48	16.5	2.4	359
	40–60	1.40	13.7	1.3	330
Average	0–60	*1.63*	*14,2*	*2.6*	*373*
GM	0–20	2.45*	18.7*	18.2*	627*
	20–40	1.79*	14.0	5.2	462
	40–60	1.38	13.8	1.7	466*
Average	0–60	*1.87*	*15.5*	*8.4*	*518*
GM + AB	0–20	2.00	12.8	5.4	472
	20–40	1.63	14.6	1.4	362
	40–60	1.38	12.1	1.4	334
Average	0–60	*1.63*	*13.2*	*2.7*	*389*
MSD_{05}	-	0.28	5.7	9.7	121

*Note**: The difference with the control was significant ($p < 0.05$).

The content of nitrate-nitrogen ($N\text{-}NO_3$) in the soil under the grapes was low in the control, with the maximum profile in the layer of 20–40 cm. The cultivation of GM contributed to a significant increase in the content of nitrates in the 0–20 cm layer by 50%, in the 40–60 cm layer – by 33% of the control. On average, the $N\text{-}NO_3$ content in the 0–60 cm layer increased by 18% with GM. The combined use of GM with AB did not change the NO_3 content compared to the control in the 0–20 cm layer and slightly reduced it in the 20–60 cm layer (Table 1).

The concentration of mobile phosphorus (P_2O_5) in the control soil was very low (Table 1). The use of GM significantly increased this factor in the 0–20 cm layer by 4.5 times. On average, in the 0–60 cm layer, its amount increased by 3.2 times compared to the control. The use of AB in combination with GM did not change the content of P_2O_5 in the soil.

The concentration of K_2O in the soil under the grapes was high and varied in the control from 330 to 428 mg kg^{-1}, gradually decreasing with depth. Moreover, GM contributed to a significant increase in its content in the 0–20 and 40–60 cm layer compared to the control by 199 (46%) and 136 (41%) mg kg^{-1}, respectively. The combined use of GM and AB caused a slight increase in K_2O content in the soil. On average, in a layer of 0–60 cm, it exceeded the control by 16 mg kg -1 (4%).

Discussion

The data obtained indicate that the replenishment of the soil with fresh organic matter during the plowing of GM led to an increase in the content of C_{org} and mobile forms of nutrients, which is associated with an increase in its microbiological activity [7; 8]. Winter GM growing in the autumn-winter period protect the soil from evaporation and delay snow cover. After mowing the green mass of GM and embedding them in the soil, a mulching layer is formed on the surface, protecting the soil surface from evaporation and contributing to the accumulation of moisture [9]. This situation indicates the preservation of moisture by GM plants in winter. Treatment of GM seeds before sowing AB in a dose of 2% dilute suspension from the seed weight did not significantly increase the amount of plowed biomass and soil moisture.

When growing GM in the rows of the vineyard, there was a slight increase in the pH of the soil, which, in our opinion, is associated with an increase in the content of active carbonates (r = 0.65, n = 45, the correlation is significant at the 5% level). The content of active carbonates in the soil under the GM also increased due to an increase in soluble forms of carbonates with an increase in soil moisture under the action of GM (r = 0.885). However, this increase was within limits allowed for the vine crop.

It was found that GM had a more positive effect on the content of organic matter and mobile forms of nutrients in the soil than their mixture with AB. The bacteria of the applied strain may have contributed to the additional absorption of nutrients from the soil by GM plants during their active development in spring [5]. In addition, on a soil poor in nitrogen, nitrogen fixation by introduced diazotrophs and absorption of either nitrogen from the soil may be inhibited [22]. However, it was previously established that using MP against the background of grassing down with perennial grasses significantly increased the yield and quality of grape products [10]. Further research will be devoted to studying the influence of green-manured crops and MP on the productivity and quality of grape products.

Conclusion

Because of the conducted studies, it was found that the use of winter GM (vetch-wheat mixture of 95 kg ha^{-1}) led to an increase in soil fertility in the vineyard. The cultivation of GM increased the dry organic mass entering the soil by 64% compared to the natural weed vegetation. This step contributed to the accumulation of moisture in the soil of a non-irrigated vineyard in the spring period in a layer of 40-80 cm by 2-8 relative %, which caused an increase in the content of active carbonates and the pH value of water in this soil layer. In this case, it was within limits allowed for grapes on the rootstock Kober 5BB. GM significantly increased the content of C_{org} in the 0-40 cm layer by 0.31-0.45%, increased the concentration of mobile forms of nutrients in the soil: N-NO_3 by 18%, P_2O_5-by 3.2 times, K_2O-by 39% in the 0-60 cm layer relative to the control (segetal vegetation).

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