

## Effect of vermicompost on yield, quality, and antibacterial activity of garlic

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We studied the influence of humus and different norms of vermicompost on the yield, nutritional value, and antibacterial properties of common garlic (*Allium sativum* L.). The use of the vermicompost caused an increase in the garlic yield by 1.7–3.9 t ha<sup>-1</sup> for cultivar ‘Prometei’ compared to the control ‘Sofiiskyi’ and by 2.2–5.2 t ha<sup>-1</sup> in relation to the control of cultivar ‘Prometei’. It was established that the calory content could increase up to 22.68 g 100 g<sup>-1</sup> of fresh weight with vermicompost manure 5 t ha<sup>-1</sup>, and the total content of sugar is increasing by 21.52–40.81% depending on the cultivar. The content of vitamins increased alongside with rate of vermicompost introduction.

We also revealed the influence of variety factor on the accumulation of vitamins. The antibacterial effect of the garlic essential oils against *Staphylococcus aureus*, *Escherichia coli* and *Bacillus subtilis* was significant; the diameters of the inhibition zone were for *S. aureus* 21.35–27.10 mm, for *E. coli* – 16.97–26.46 mm, and for *B. subtilis* – 16.42–25.36 mm. The number of *Mycobacterium smegmatis* colonies decreased by 23.96–43.44%. This study has been proved that garlic juice had considerable antibacterial effect on the studied bacteria (*S. aureus*, *E. coli* and *B. subtilis*); therefore, it can replace chemical antibiotics that have undesirable effects on the body, like allergy and antimicrobial resistance. Our data shows that using of vermicompost was more effective than humus.

**Key words:** antibacterial activity; garlic; nutritional value; vitamins

### Introduction

Garlic is one of the most effective phytoncidic-medicinal plants, characterized by bactericidal, fungicidal, anti-acidic, analgesic, and other properties (Viger, 2001; Martins et al., 2016). Plenty medicinal products are established on its basis and widely used such as allicin, sativin, alistat, and alohol. It is known that garlic cloves contain about 41.3% of dry matter, 6.7% of protein, 29.3% of carbohydrates, as well as vitamins C, B1, and substances of hormonal nature. Garlic is especially rich in mineral compounds. Its ash contains potassium (260 mg per 100 g of raw matter), phosphorus (140), sodium (120), calcium (90) and iron (1.5 mg). Garlic bulbs contain about 0.1% essential oils, which include organic sulphur compounds (allylpropyl disulfide, allyn, etc.) (Mardomi, 2017).

It has been proved that garlic extract at low concentration (1:32–1:40) inhibits the growth of pathogenic fungi such as *Coccidioides immitis*, *Auxarthron zuffianum* and *Uncinocarpus*, which are agents of coccidiosis. Other studies have shown that allicin is effective against *Histoplasma capsulatum*, a fungus that similar to the tuberculosis illness (Egbobor, 2007; Singh, Singh, 2008; Pure et al., 2017). Degwale et al. (2016) and Kenea & Gedamu (2018) have noticed a positive effect of vermicompost that it has been shown not only on the productivity of garlic, but also on its quality. Thus, the content of essential oil in garlic bulbs increased by 14.4–41.1% at introducing of vermicompost in rates from 5 to 25 t ha<sup>-1</sup> (Golmohammadzadeh et al., 2015). In some other research a significant positive impact of vermicompost on the quality of seedlings vegetables and other crops was registered (Atiyeh et al., 2000; Zaller, 2007; Arancon et al., 2008; Lazcano, Domínguez, 2010; Pour et al., 2013; Kwan et al., 2015). The reduction of fungicide usage and improvement of the phyto-sanitary condition of garlic crops could contribute to improving the quality of pharmaceutical industry products.

Thus, the aim of our study was to check the effect of the vermicompost on the yield of garlic cultivars, garlic chemical composition and nutritional value of garlic, antifungal and antibacterial properties of garlic essential oils.

### Material and methods

We have been studied the effect of vermicompost on the quality and antibacterial activity of common garlic (*Allium sativum* L.) during 2017–2019. The total area for the experiment was 400 m<sup>2</sup>, plot was 100 m<sup>2</sup>, and sampling plot was 10 m<sup>2</sup>. The plots were arranged in a systematic order with four replications. The predecessors were the early spring vegetables. Planting was carried out by the scheme of 45 × 6 cm in 5–10 of October, the location of the plots was regular.

**Determination of B-complex vitamins content.** Our sample preparation was as follows - all the vegetables and fruits were washed and dried, weighed 50 g, cut into small pieces and extracted with 0.1 NHCL (sodium chloride) on the water bath at suitable temperature and time. All extracts were filtered through 0.40 micron filter and taken into 100 mL volumetric flask and volume was add up for mobile phase (McCormick, 1989; 1996).

We used the common preparation - stock of standard (Sigma Aldrich Analytical grade Reagent) prepared by dissolving 0.01 g of each standard in 100 mL of mobile phase followed by successive dilutions.

**High-performance liquid chromatography (HPLC) analysis.** HPLC (Shimadzu, Model Prominence 20A) equipped with UV detector and Supelco Discovery Cis18 column (25 cm in length and 0.45 internal diameter) was used for analysis. Mobile phase was 50 m MK<sub>2</sub>HPO<sub>4</sub> and MeOH (70:30) at 1 mL min<sup>-1</sup> flow rate and 10 µL of each sample / standard was injected and monitored at UV 254 nm.

The antimycobacterial activity of garlic oil was estimated by the plant count method (Dibua et al., 2010). Solutions and extracts of the sterile medicinal product were prepared by dissolving in sterile water and then filtering through 0.22 µm nylon filter. The inoculum containing 1.5 × 10<sup>7</sup> CFU (colony-forming unit) mL<sup>-1</sup> of bacteria *Mycobacterium smegmatis* was used for research and was prepared by breeding 1:10 bacterial suspension having turbidity comparable to McFarland No. 0.5. One hundred micro litres of suspension of the test microorganism were sown and distributed using sterile cotton on a surface on an agar medium to obtain uniform growth (Moghaddam et al., 2011). The paper discs of 6 mm in size. Under aseptic conditions, empty sterilized disks were impregnated with a solution of rifampicin (3 mg mL<sup>-1</sup>) and garlic oil (50 mg mL<sup>-1</sup>). These disks are placed on an agar medium. The appropriate growth control, sterility and solvent were also maintained for 30 minutes at room temperature to allow for oil diffusion and then incubated at 37 °C for 21 days. The studies were conducted in three replicates, the obtaining results were presented as meaning values. The antibacterial activity of garlic oil was evaluated regards *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus subtilis* in the inhibition zone by the use of amoxicillin as a standard preparation (El-Mahmood, 2009; Ross et al., 2009).

**Nutritional value.** Proteins, fats, carbohydrates, and ash content were determined by standard methods described in the procedures of the American Organization of Analytical Chemists, AOAC International (Horwitz, Latimer, 2005). The crude fat was determined using a Soxhlet apparatus (Behr R 106 S, Germany) with petroleum ether, according to the AOAC 920.85 methodology (Horwitz, Latimer, 2016). The content of ash was determined by burning at 600 °C to constant mass in accordance with AOAS method 923.03 (Horwitz, Latimer, 2016).

The energy was calculated by the formula:

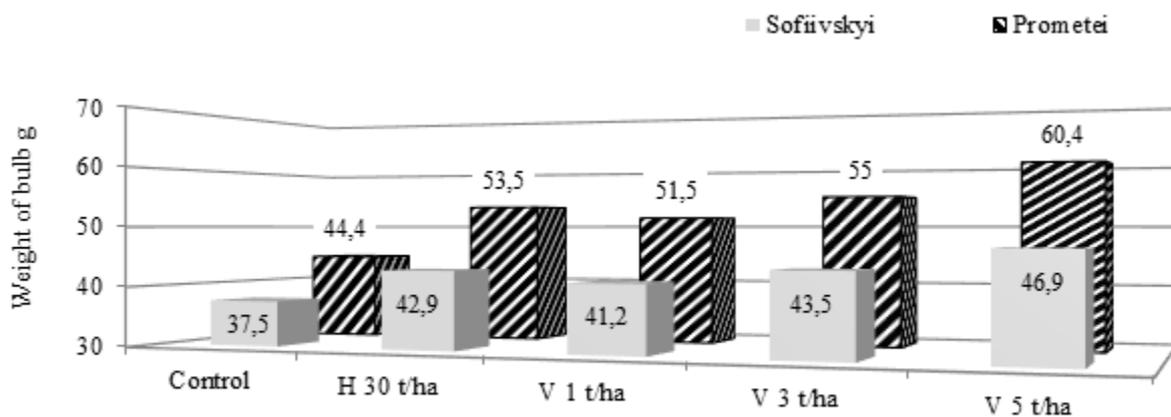
$$\text{Energy (kcal)} = 4 \times (\text{protein}) + 4 \times (\text{carbohydrate}) + 9 \times (\text{fat}) \quad (1).$$

The free sugar was determined by using HPLC, coupled with a refractive index detector using the internal standard methodology (mesostiosis) (Guimarães et al., 2013). For the food and chemical composition, three samples were analysed for each variety, and all analyses were performed in three replicates. The results were expressed as averages and standard deviation. The chemical composition were analysed using a one-way dispersion analysis, followed by the Tvxyi's Honesty Difference (TQ) test with = 0.05 using SAS software, V. 9.1.3 (IBM Corp., Armonk, NY, USA). All results were presented per 100 g of fresh weight (FW).

## Results

The bulb weight of garlic cultivar 'Sofiivskiyi' increased by 5.4 g with manure 30 t ha<sup>-1</sup> of humus; it also increased by 3.7, 6.0, and 9.4 g with vermicompost manure 1, 3 and, 5 t ha<sup>-1</sup> correspondingly (Fig. 1). The bulb weight of garlic cultivar 'Prometei' without the fertilizer was higher than control by 6.9 g. With the manure 30 t ha<sup>-1</sup> the weight increased by 16.0 g; this also increased by 14.0, 17.5, and 22.9 g with the manure 1, 3, and 5 t ha<sup>-1</sup> respectively.

The use of the vermicompost caused the increase in the yield of cultivar 'Prometei' by 1.7–3.9 t ha<sup>-1</sup> compared to the control and of cultivar 'Sofiskyi' by 2.2–5.2 1.7–3.9 t ha<sup>-1</sup> (Fig. 2).



**Fig. 1.** The bulb's weight of the garlic cultivars depending on the fertilizer by vermicompost (2017–2019). Here and in Fig. 2 H – humus, V – vermicompost

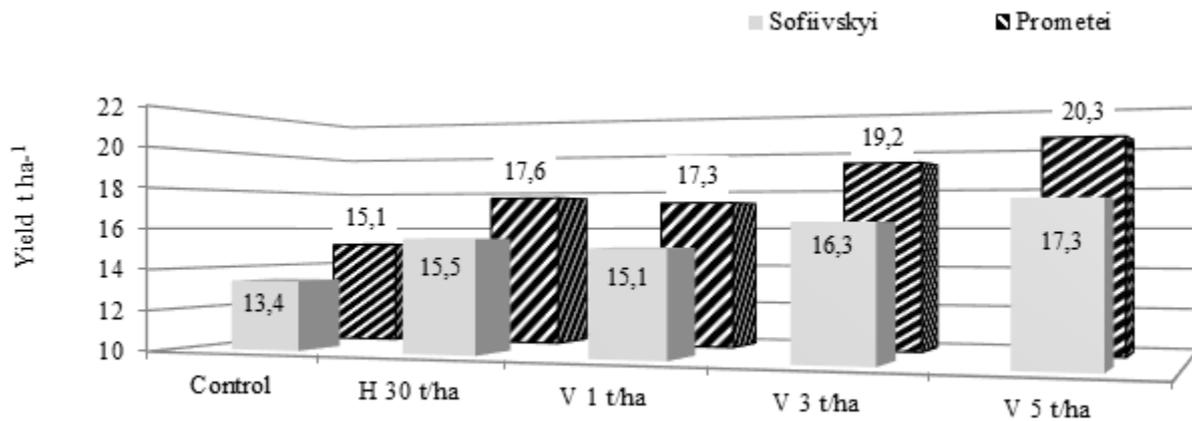


Fig. 2. The yield commodity of the garlic cultivars depending on the fertilizer by vermicompost (2017–2019)

The changes of the nutritional value of the studied garlic cultivars with the fertilizer of vermicompost are presented in Table 1. The significant differences were observed not only between cultivars, but also between fertilizer variants, indicating that the conditions of cultivation have a significant effect on the quality of garlic. Thus, the content of ash depending on the cultivar and the norm of vermicompost increased by 0.05–0.37 g 100<sup>-1</sup> g FW, the content of the protein increased significantly from 0.18 to 0.99 g 100 g<sup>-1</sup> FW (up to 16.26% relatively to control), the fat content increased by 0.02–0.16 g 100 g<sup>-1</sup> FW, the carbohydrate content increased by 0.70–4.32 g 100 g<sup>-1</sup> FW (3.50–17.85%). The calorie content with the fertilizer of vermicompost was increased from 3.70 g 100 g<sup>-1</sup> FW, with the fertilizer of 1 t ha<sup>-1</sup> of vermicompost in the cultivar ‘Sofiivskiyi’ up to 22.68 g 100 g<sup>-1</sup> FW, with the fertilizer of 5 t ha<sup>-1</sup> of vermicompost in the cultivar ‘Prometei’.

Table 1. The nutritional value of the garlic cultivars depending on the fertilizer (t ha<sup>-1</sup>) by vermicompost

Cultivar (factor A)	Fertilization (factor B)	Dry weigh %	Ash	per 100 g of FW			Energy kcal per 100 g of FW
				Proteins	Fat	Carbohydrates	
Sofiivskiyi	Control	36.49	1.15	6.2	0.18	20.00	106.42
	Humus 30	37.11	1.22	6.31	0.22	22.40	116.82
	Vermicompost 1	37.62	1.20	6.38	0.20	20.70	110.12
	Vermicompost 3	37.93	1.26	6.54	0.24	22.90	119.92
	Vermicompost 5	38.45	1.27	7.02	0.25	23.08	122.65
Prometei	Control	41.53	1.55	6.15	0.26	24.20	123.74
	Humus 30	42.51	1.70	6.32	0.32	26.80	135.36
	Vermicompost 1	42.78	1.65	6.35	0.30	26.00	132.10
	Vermicompost 3	43.09	1.84	6.6	0.39	27.70	140.71
	Vermicompost 5	43.94	1.92	7.14	0.42	28.52	146.42
LSD <sub>0.01</sub>	A	0.89	0.023	0.085	0.004	0.38	1.83
	B	1.41	0.037	0.134	0.006	0.61	2.89
	A×B	1.48	0.053	0.190	0.009	0.86	4.10

Here and further FW – fresh weight

The vitamins are indispensable, vital organic compounds that do not produce calories, but they are important for cellular metabolic responses. They are required in small amounts for normal growth and function of the body (Lee et al., 2018). The vitamin contained in fruits and vegetables can widely vary across the globe due to various environmental factors (Food and Nutrition Board, 1998; Scognamiglio et al., 2015; Combs, McClung, 2016).

Our results proved significant difference between B2 content regards garlic cultivars and fertilizer variants (Table 2). The obtained data shows that using of 1 t ha<sup>-1</sup> of vermicompost was more effective than 30 t ha<sup>-1</sup> of humus. The content of vitamins increased along the rate of vermicompost. The most significant increase was registered for vitamin B<sub>9</sub>, the content of which was at the lowest level. Thus, the amount of this vitamin with the introduction of vermicompost increased by 166.7–266.7% in cultivar of Sofiivskiyi, whereas in the cultivar ‘Prometei’ this indicator was lower than the control by 25.0% without fertilizer. The content of vitamin B<sub>9</sub> increased by 75.0–150.0% in variant with vermicompost, relative to the control and by 133.3–233.3% relative to variant without fertilizer.

The effect of variety factor on the accumulation of vitamins was revealed. The cultivar ‘Prometei’ varied significant by content of vitamin B<sub>1</sub>, but not much as cultivar ‘Sofiivskiyi’ with content of all other vitamins (B<sub>3</sub>, B<sub>6</sub>, B<sub>5</sub>, B<sub>4</sub>, B<sub>2</sub> and B<sub>9</sub>).

**Table 2.** The B-complex of vitamins of the garlic cultivars depending on the fertilizer (t ha<sup>-1</sup>) by vermicompost

Cultivar (factor A)	Fertilization (factor B)	Content of vitamins, mg / mcg 100 g <sup>-1</sup> FW						
		B <sub>3</sub> mg	B <sub>6</sub> mg	B <sub>5</sub> mg	B <sub>4</sub> mg	B <sub>1</sub> mg	B <sub>2</sub> mg	B <sub>9</sub> mcg
Sofiiivskiyi	Control	16.07	2.56	0.97	0.49	0.60	0.06	0.12
	Humus 30	18.12	3.09	1.16	0.61	0.72	0.10	0.27
	Vermicompost 1	18.16	3.14	1.18	0.58	0.65	0.10	0.27
	Vermicompost 3	20.05	3.19	1.22	0.64	0.74	0.12	0.32
	Vermicompost 5	23.03	3.19	1.26	0.72	0.77	0.12	0.44
Prometei	Control	15.11	2.36	0.86	0.43	0.86	0.05	0.09
	Humus 30	17.45	2.60	0.94	0.60	0.94	0.10	0.24
	Vermicompost 1	18.00	2.85	1.09	0.60	1.09	0.11	0.21
	Vermicompost 3	19.27	3.08	1.15	0.62	1.15	0.11	0.28
	Vermicompost 5	20.20	3.13	1.19	0.68	1.19	0.13	0.30
LSD <sub>0.01</sub>	A	0,34	0,056	0,018	0,013	0,022	0,003	0,009
	B	0,54	0,089	0,029	0,021	0,035	0,005	0,014
	A×B	0,77	0,126	0,041	0,030	0,050	0,007	0,020

**Table 3.** The free sugars of the garlic cultivars depending on vermicompost manure (t ha<sup>-1</sup>)

Cultivar (factor A)	Fertilization (factor B)	Free sugars g 100 g <sup>-1</sup> FW			
		fructose	glucose	sucrose	total sugars
Sofiiivskiyi	Control	0.12	traces	1.98	2.10
	Humus 30	0.16	0.15	2.15	2.46
	Vermicompost 1	0.21	0.18	2.27	2.66
	Vermicompost 3	0.22	0.22	2.34	2.78
	Vermicompost 5	0.25	0.23	2.71	3.19
Prometei	Control	0.10	traces	2.13	2.23
	Humus 30	0.13	0.10	2.35	2.58
	Vermicompost 1	0.19	0.15	2.37	2.71
	Vermicompost 3	0.27	0.24	2.46	2.97
	Vermicompost 5	0.31	0.29	2.54	3.14
	A	0.004	-	0.043	0.048
	B	0.006	-	0.068	0.076
	A×B	0.008	-	0.096	0.146

Among the sugars (Table 3), the dominant was sucrose, with content of 1.98–2.54 g 100 g<sup>-1</sup> FW, and the increase by 8.59–19.25% depending on the cultivar with vermicompost introduction. The most significant was the increase of fructose – this was 30–33% in humus manure 30 t ha<sup>-1</sup> and 75.0–210.0% in variants with various manure of vermicompost. Also, the content of glucose increased significantly with introduction of organic fertilizers, while in the control only traces were observed. The content of total sugar increased by 21.52–40.81% with vermicompost introduction.

According to our data (Table 4), it is evident that the essential oil of the garlic growth with the organic fertilizer rates, especially vermicompost. It has a more depressing effect relative to the control, which can be explained by increasing in the content of alliin and an improvement in its quality.

**Table 4.** The antibacterial activity of the garlic cultivars depending on the fertilizer

Cultivar (factor A)	Fertilization (factor B)	Colony count	Decrease in colony count %	Diameter of zone inhibition mm		
				<i>S. aureus</i>	<i>E. coli</i>	<i>B. subtilis</i>
	Amoxycillin (standard)	-	-	35.71	27.09	36.55
Sofiiivskiyi	Control	38.05	0	17.20	14.08	15.55
	Humus 30	27.92	26.62	25.34	17.55	18.45
	Vermicompost 1	28.75	32.34	21.85	16.97	22.00
	Vermicompost 3	24.61	35.32	26.35	22.30	24.25
	Vermicompost 5	21.52	43.44	27.10	26.46	25.36
Prometei	Control	39.42	0	15.43	14.00	15.12
	Humus 30	30.65	22.24	21.35	16.76	17.10
	Vermicompost 1	31.80	23.96	21.67	16.05	16.42
	Vermicompost 3	28.44	27.85	22.00	18.42	18.94
	Vermicompost 5	24.30	38.35	22.09	18.59	19.66

We also determined that the diameter of the inhibition zone of *E. coli*, *S. aureus*, and *B. subtilis* was significant but less weighty than standard amoxicillin.

## Discussion

In general, the investigated garlic varieties demonstrated a significant difference in their quality and nutritional value not only between genotypes but also between the variants of fertilization. This indicates that in addition to the genotype the growing conditions and methods of cultivation can considerably affect the chemical composition and nutritional value, and therefore the quality of the garlic.

We studied the antibacterial effect of garlic against *Mycobacterium smegmatis*, *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus subtilis* and revealed that the sensitivity of bacteria gradually increased with the rate of vermicompost, which indicates its positive effect on the quality of allicin (Table 4). The resistance to the bacteria is a global problem, because many bacterial species have become resistant to the antibacterial agents (Garau et al., 1994).

Thus, there is a need to evaluate the efficacy of plant chemicals concerning to the growth of bacteria by extracts of plants to be used with dichloromethane extraction (Laenger et al., 1996), maceration, and soxhlet fluid extraction with hexane (Vilegs et al., 1997).

Garlic is known to have antibacterial, antifungal and antiviral activity (Bakri et al., 2005). Our results are in concordance with previous data (Reuter et al., 1996), which reported that garlic inhibits the growth of staphylococcus and many other species. Abdon et al. (1972) registered that the raw garlic juice is highly active against *Escherichia coli* and *Typhoid salmonella*. Sasaki et al. (1999) reported the activity of garlic against methicillin of *Staphylococcus aureus* and *Candida albicans*. The extract of garlic has the antibacterial activity against *Helicobacter pylori* in a moderate concentration, so it has a protective effect against gastric ulcers (Satiawane et al., 2005).

## Conclusion

The use of the vermicompost for garlic promotes an increase in the yield by 1.7–3.9 t ha<sup>-1</sup> for cultivar 'Prometei' compared to the control 'Sofiivskiy' and by 2.2–5.2 in relation to the control of the 'Prometei'.

Our data showed that the cultivars and the conditions of cultivation (fertilization) significantly affect the chemical composition and nutritional value, and hence the quality of garlic.

Our results suggested that the use of organic fertilizers, especially vermicompost, improves significantly the antifungal and antibacterial properties of garlic essential oils, so natural herbs can replace the chemical antibiotics that have undesirable effects, such as allergy and antimicrobial resistance.

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