Testing of bio-organic fertilizer based on organic waste to improve the productivity of vineyards

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Abstract. The authors developed an environmentally safe technology for obtaining liquid organic fertilizer. The technology includes obtaining compost by applying microflora containing actinomycetes and microscopic fungi, populating the compost with vermiculture Eisenia foetida and obtaining biohumus. In 2018-2020 fertilizers obtained from organic waste were used on industrial plantings of technical variety Bastardo Magarachsky (planting scheme: 3 x 1.5 m, formation - double-shouldered cordon, rootstock - Kober 5 BB, non-irrigated culture) as foliar dressing. Climatic zone and place of experiment: South Coast agroclimatic area, sub-area - with subtropical winter (annual rainfall - 450-500 mm; hydrothermal coefficient of moisture - 0.5-0.6). Standard methods of agronomic observations of growth and development of grape plants were used in the work. Consumption rate 2 l/100 liters of water. The number of treatments - six, the terms of application: shoots growth; before flowering; after flowering; berry growth; beginning of softening; beginning of sugar accumulation (a month before harvesting). It was found that at the background of the same potential productivity of grape plants compared to the control, the yield increased by 15.9%; mass fraction of sugars in berry juice - by 7.1%, mash output - by 14.7%; technological stock of coloring and phenolic substances - by 7.6%.

1 Introduction

To date, all developed countries are striving to switch to organic fertilizers. This desire, according to some researchers, due to the fact that the use of inorganic pesticides and agrochemicals leads to a significant violation of the ecological balance [1, 2]. An important factor is the increased demand for organic products, the growth rate of consumption which is more than 2 times higher than the growth of the food market as a whole. The main demand for organic products is concentrated in several countries: the United States, Germany, France, China, Canada and Italy. Together they consume up to 77% of the world's organic products. The organic fertilizer market is expected to grow by 12.08% from 2017 to 2022, reaching a value of $11.16 billion [3]. In addition, organic fertilizers, being complex fertilizers, improve air nutrition of plants, as they enrich the ground air with carbon dioxide, neutralize soil

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The use of organic fertilizers derived from organic waste allows not only to introduce the necessary macro- and microelements into the soil, but also to solve the problem of disposal of organic waste, because when storing organic waste in landfills, the atmosphere emits greenhouse gas - methane, which can cause deterioration of human health and atmospheric air pollution. The main methods of processing organic waste include: processing of organic matter with obtaining biogas [4-11], the advantages of this method are: simple design and maintenance, low cost; disadvantages - low biogas release; long and incomplete processing of organic substrate; content of harmful flora in the processed biomass. Widely spread method of waste composting [12-17]. Advantages of this method are: low cost of obtained fertilizers; safety of compost for ecosystems; disadvantages of the method are the duration of the process, pungent smell. Vermicomposting method is also used [18-22], which is carried out in several ways. The first method is mainly horizontal movement (usually used on an industrial scale). The advantages of this method are: the possibility of mechanization of the process, use in the open air, with minimal initial costs; the disadvantages of this method are that it takes large areas, the need to mix the substrate for more uniform processing. The second - mainly by vertical movement. Advantages of this method are: the process is more natural - the worm intuitively looks for food at the top - where in nature the plant fallout is formed; use of compact structures; disadvantages of this method: high energy costs for lifting and moving weights, the process only in rooms with a constant plus temperature.

Cultivation of grapes, as well as any other agricultural crop, leads to the emergence of organic waste, which in turn poses to the producer the problem of their processing or disposal. The practice of viticulture shows that about 1200-1400 kg of organic waste per 1 hectare of cultivated crop is formed. It should be taken into account that organic waste takes away nutrients from the soil. Partially, the problem of return of organic waste to vineyards is solved by their mulching or creation of composting sites, but there are several negative factors: mulching does not always create conditions for the most optimal processing of mulch into biohumus; mulching and mulching operations and composting are expensive, which in turn leads to increased costs for the final product.

The authors developed an environmentally safe technology for obtaining liquid organic fertilizer from organic waste, which includes obtaining compost by applying microflora containing actinomycetes and microscopic fungi, populating the compost with vermiculture red Californian worm Eisenia foetida and obtaining biohumus, which at the final stage of production is dispersed in a cavitation unit. That allows to use as a raw material the organic waste affected by diseases and pests, as at cavitation processing the prepared solution is sterilized. The patent RU2654864C2 was received for this development. The proposed method, in addition to obtaining fertilizer solves the environmental problems - recycling and storage of organic waste due to the use as raw materials for the production of humic substances vineyard waste, as well as minimal production costs, the cost of fertilizer is 2-7 times lower than the analogues available in the market.

In 2018-2020 "Humic Fertilizers" obtained from organic waste were used on industrial vine plantations as foliar feedings. We studied their influence on the total yield of plants, yield structure, yield quality indicators, determination of growth force and degree of shoots ripening, the leaf surface area of the bush.

2 Research methodology

Climatic zone and place of experiment: South Coast of Crimea, South Coast agroclimatic area, sub-area - with subtropical winter (annual precipitation - 450-500 mm; hydrothermal
coefficient of moisture - 0.5-0.6). The tests were conducted on the vine plantations of the State Unitary Enterprise of the Republic of Crimea "Massandra". Branch "Livadia", Yalta.

South Coast agroclimatic region is moderately hot and arid. The period with temperatures above 10°C lasts 7 months, the frost-free period lasts 8-8.5 months, the average annual temperature is 13.20°C, the sum of active temperatures above 10°C reaches 3700-4200°C; annual precipitation is 450-700 mm, summer months account for 25-30%; hydrothermal coefficient of moisture - 0.5-0.6; soil carbonate-free, carbonate and typical subtypes of brown soils, from slightly (7.8%) to medium and strongly washed away (41.8%). The soil of the experimental plot is brown mountain non-carbonate, enriched with skeletal fraction (stones, rubble, etc.). Humus content - 1.48%, soil pH - 6.9. Active lime is absent, or its content along the profile is insignificant. The mechanical composition of the soil is loamy. Climatic conditions 2018-2020 were not favorable for growth and development of grape plants - high average daily temperatures and low humidity, under-rainfall compared to the average annual rates during bunches development and berry ripening had a negative impact on the overall condition of plants.

Culture - grapes, technical variety - Bastardo Magarachsky, year of vineyard establishment - 1989; tillage: autumn plowing in October-November, spring plowing in March, summer tillage (2-3 times); application of basic fertilizers (N90P45K45): after leaf fall, under autumn plowing (urea, superphosphate, potassium nitrate); planting scheme: 3 x 1.5 m, formation - double-shouldered cordon on the middle stem. The rootstock is Kober 5 BB. The crop is non-irrigated; plant care measures: pruning (March), dry garter (March), two pruning (May-June); protection against a complex of fungal diseases (oidium, midge, rot complex) and pests (plant-eating mites complex). Total number of pesticide treatments is 8-10 per vegetation.

The number of accounting plants in each variant is 60 (15 plants in four replications). The placement of the variants and replications was randomized. Standard methods of agrotechnical observations for growth and development of grape plants were used in the work; yield structure was determined by sampling method with subsequent weighing; product quality was determined by areometric, titrometric and colorimetric methods.

The foliar feeding was carried out by spraying the plants with a backpack sprayer "Solo 450". Consumption rate of the studied fertilizer - at the rate of 2 l/100 liters of water. The working solution was prepared immediately before the application. To prepare the working solution we measured the required amount of fertilizer for one treatment. Then, the sprayer was filled by half with water, the required amount of fertilizer was added, water was added to the calculated volume, and the solution was mixed.

The number of treatments was six, the terms of tested bioorganic "Humic fertilizer" application were according to the production practice and expected results: active shoots growth; before flowering; after flowering; active berry growth; beginning of softening; beginning of saccharification (a month before harvesting).

Agroaccounts were conducted during the period of active shoot growth, before flowering, and harvesting - during the onset of technical maturity of grapes.

Studies were conducted against the control (without foliar dressing with humic fertilizers)

3 Discussion of experimental results

The results obtained in agroaccounting indicate that all variants of the experiment were laid on the plants of the same growth strength and equal potential productivity. The difference between the indicators characterizing the number of normally developed and fruiting shoots per one accounting bush, the number of inflorescences, is not significant at 95% level of probability (Table 1).
Table 1. Agrobiological indicators, Bastardo Magarachsky variety, Branch "Livadia" - SUE RK "PJSC "Massandra", 2018-2020.

| Option of experiment | Total number of eyes pcs./bush | Normally developed shoots pcs./bush | Fruiting shoots pcs./bush | Inflorescences pcs./bush | Coefficients |
|----------------------|--------------------------------|------------------------------------|--------------------------|--------------------------|--------------|
|                      |                                |                                    |                          |                          | Fruiting. K1 | Fertilidad . K2 |
| I. Control           | 22.8                           | 17.6                               | 15.8                     | 30.2                     | 1.72         | 1.91           |
| II. "Humic Fertilizer." | 21.5                          | 18.3                               | 16.7                     | 30.0                     | 1.64         | 1.80           |
| HCP05                | 2.13                           | 2.41                               | 2.37                     | 4.11                     | -            | -              |

During the phytosanitary monitoring of grapes in the phases "flowering" - "bunch development" - "berry ripening", visual signs of Oidium (Erysiphecator Schwein) development were observed on leaves and inflorescences/thorns, respectively, 3.1-7.2 and 2.2-6.1% and had no negative impact on quantitative and qualitative indicators of grape plant development.

After harvesting, we determined the effect of Humic Fertilizer on yield structure, yield of grape plants per 1 ha, and yield quality indicators (Tables 2-3). The formation and ripening of the crop took place under hot and dry summer conditions.

On unwatered vineyards, improvement of plant growing conditions created by applying bioorganic "Humic Fertilizer" had a positive effect on bush yield increase. On the background of the same potential productivity of grape plants, the difference between the variants of experiment I and II was significant in terms of the indicators determining the average bunch weight and the yield collected from one plant (Tables 2, 3). Yield increase was obtained by increasing the weight of one berry and the number of berries in the bunch.

Table 2. Yield structure by variants of the experiment, Bastardo Magarachsky variety, Branch "Livadia" - SUE RK "PJSC "Massandra", 2018-2020.

| Option of experiment | Weight of 1 berry. g | Weight of 100 berries. g | Number of berries in bunch. pcs | average weight of the crest. g | Average weight of the bunch. g | Number of bunches. pcs/brush |
|----------------------|----------------------|--------------------------|---------------------------------|-------------------------------|-------------------------------|-----------------------------|
| I. Control           | 1.21                 | 120.6                    | 115.4                           | 12.89                         | 152.5                         | 30.2                        |
| II. "Humic Fertilizer." | 1.34              | 133.7                    | 124.0                           | 11.36                         | 177.5                         | 30.0                        |
| HCP05                | 3.65                 | 4.18                     | 1.07                            | 14.52                         | 4.6                           |

Compared to the indicators obtained on the control not treated with foliar dressing, the average weight of the bunch was higher by 16.4% on the variant II. The difference between the control and Variant II in terms of "weight of 100 berries" and the number of berries in the bunch was significant and was 10.8 and 7.5%, respectively.

There were no minor berries in all variants of the experiment.

The application of the preparation "Humic Fertilizer" contributed to the increase of grape yield per 1 ha (Table 3).

Table 3. Economic efficiency of the preparation "Humic Fertilizer" on grapes, Bastardo Magarachsky variety, Branch "Livadia" - SUE RK "PJSC "Massandra", 2018-2020.

| Option of experiment | Yield. kg / bush | Yield. tons/hectare (estimated) | Yield increase. tons/hectare | % |
|----------------------|------------------|---------------------------------|------------------------------|---|
| I. Control           | 4.60             | 10.22                           | -                            | - |
| II. "Humic Fertilizer." | 5.33            | 11.84                           | 1.62                         | 15.9 |
| HCP05                | 0.24             | -                               | -                            | - |
The yield collected from one accounting plant on the control was significantly lower compared with variant II (by 0.73 kg (15.9%)).

Root fertilization of plants with bioorganic fertilizer "Humic Fertilizer" six times, in the period: active shoots growth; before flowering; after flowering; active berry growth; beginning of softening; beginning of sugar accumulation (a month before harvesting), provided a significant increase in yield - by 1.62 tons/hectare, or respectively, by 15.9%, compared with control.

The harvested yield of variant II was higher than that of the control by quality indices (Table 4).

Significant differences in the mass fraction of sugars in the berry juice during the harvesting period between variant II and the control were confirmed by mathematical processing and were, respectively, 15.0 g/dm3 or 7.1%. The difference between the indicators of mass concentration of titratable acids between the experimental variants was not significant.

### Table 4. Yield quality by variants of the experiment, Bastardo Magarachsky variety, Branch "Livadia" - SUE RK "PJSC "Massandra", 2018-2020.

| Option of experiment | Mass concentration | Technological stock of colorants and phenolic substances, mg/dm³ | Glucoacidimetric index (GAI) |
|----------------------|---------------------|---------------------------------------------------------------|-----------------------------|
|                      | sugars. g/dm³       | titratable acids. g/dm³ | Mash yield. % |                           |                          |
| I. Control.          | 211.8               | 7.6                | 34.0          | 1695                       | 2.79                      |
| II."Humic Fertilizer." | 226.8              | 7.5                | 39.0          | 1823                       | 3.02                      |
| HCP₀₅                | 0.84                | 0.45               | -             | 29.47                      | -                         |

Mash yield is one of the main indicators characterizing the quality of technical grape varieties. Sixfold treatment with Humic Fertilizer increased this index for the variant II by 14.7% compared to the control.

Phenolic compounds are biologically active substances increasing dietary and therapeutic-and-prophylactic properties of wines. Phenol substances and products of their transformations influence the taste, aroma, color and transparency of wine materials and wines, they also play the role of antioxidants and prevent excessive oxidation of red wines. Phenols take an active part in the processes which take place at all stages of wine making.

Technological reserve of coloring and phenolic substances in the variants, six times treated with bioorganic fertilizer "Humic Fertilizer" at the rate of 2.0 l/100 liters of water, was significantly higher than the control, by 7.6, %, respectively.

Glucoacidimetric index (GAI) is the ratio of sugar content of berries to their acidity and is another important characteristic of the quality of the grape crop, which plays a crucial role in determining the economic value of the grape crop, the direction of its use. Different values of this ratio correspond to different types of wine products.

According to the GAI values (2.79-3.02), grapes harvested from variants I and II correspond to the requirements for grapes intended for the production of quality red table wine materials.

The results of the experiments showed that foliar vine treatment with bioorganic fertilizer "Humic Fertilizer" contributed to the strengthening of the vegetative power, as well as positively affected the formation of the leaf surface of the bush (Table 5).
Table 5. Biometric indicators of grape plants by variants of experience, Bastardo Magarachsky variety, Branch "Livadia" - GUP RK "PJSC "Massandra", 2018-2020.

| Option of experiment | Leaf surface area. cm²/stem (% of control) | Average shoot length. cm (% of control) | Length of matured part. cm (% of control) | Percentage of shoot maturation. % |
|----------------------|------------------------------------------|----------------------------------------|---------------------------------------|----------------------------------|
| I. Control.          | 2415.13                                  | 147.9                                  | 126.5                                 | 85.5                             |
| II."Humic Fertilizer." | 2983.25 (123.5)                          | 181.6 (122.8)                          | 171.2                                 | 94.3 (110.3)                     |
| HCP05                | 111.76                                   | 11.9                                   | 9.1                                   | -                                |

Leaf surface area of the bush treated with "Humic Fertilizer" options (in recalculation cm²/stem) increased compared to the control by 23.5%, the average length of the shoot - by 22.8%.

4 Conclusions

As a result of the research, it was found that the sixfold application of bioorganic fertilizer "Humic Fertilizer" to grapes during the following periods: active shoot growth; before flowering; after flowering; active berry growth; beginning of softening; beginning of saccharification (one month before harvesting), at the rate of 2 l/100 liters of water, provided a significant increase in yield - by 1.62 t/ha, or, respectively, by 15.9%, compared to control.

Against the background of the same potential productivity of grape plants, the average weight of the bunch on the variant with the use of "Humic Fertilizer" was higher than on the control by 16.4%. The yield increase was obtained by increasing the weight of one berry (10.8%) and the number of berries in the bunch (7.5%).

The yield harvested in the variant treated with "Humic Fertilizer" was higher in qualitative indices than that of the control: the mass fraction of sugars in the berry juice increased by 15.0 g/dm³ (7.1%); the yield of must increased by 14.7%; the technological stock of coloring and phenolics increased by 7.6%.

The values of GAI (2.79-3.02) of grapes harvested from varietals I and II meet the requirements for grapes intended for the production of quality red table wine materials.

Leaf surface area of a bush on the variants treated with "Humic Fertilizer" (in recalculation cm²/stem) increased compared to the control by 23.5%, the average length of a shoot - by 22.8%.

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