The effect of vermicomposts on tomato productivity in the conditions of Yakutia

D I Stepanova¹, M F Grigorev¹, A I Grigoreva² and T G Dmitrieva¹

¹ Yakut State Agricultural Academy, 3, Sergelyakh Str., Yakutsk, 677007, Republic of Sakha (Yakutia), Russia
² North-Eastern Federal University named after M.K. Ammosov, 48, Kulakovskogo Str., Yakutsk, 677013, Republic of Sakha (Yakutia), Russian Federation

E-mail: grig_mf@mail.ru

Abstract. The article presents the research results of the effect of vermicompost based on horse and cattle manure on the productivity of tomatoes in Yakutia. The conducted experiments have established that only half of the manure (50%) is converted into biohumus from all processed raw materials. Fertilizing with the obtained vermicompost helps to improve the properties of greenhouse soil mixtures. It was found that fertilizers help to optimize the physical properties of soils, while increasing the microbiological activity in the soil. The vermicompost derived from horse manure in the composition of greenhouse fertile soils contributed to better development of tomato seedlings. When fertilizing with the vermicompost the best development of seedlings up to 10-30% is noted. Further increase of biofertilizers application inhibits the development of plants, reducing their biometric indicators. The experiment also studied the effect of increasing doses of vermicompost from 100 to 500 g / plant when applied locally. The efficiency of the lowest application dose of vermicompost 100 g / plant (6.2 kg / m²), which corresponds to increasing tomato productivity by 8.8%. Further increase in the rate of biofertilizers does not give a significant increase in productivity. Thus, it justifies the vermicompost application for the enrichment of the greenhouse soil and increasing tomato productivity in conditions of Yakutia.

1. Introduction
In the Republic of Sakha (Yakutia), agriculture is practiced in the Central and Southern regions of Yakutia, where the amount of frost-free days is more than 100 days. These zones include areas located along the banks of the Lena, Amga and Aldan rivers. These areas produce relatively high yields of vegetable crops compared to other areas of the republic. It should be noted that the entire territory of the republic is located in the permafrost zone. The climate type is sharply continental, with cold winters and hot summers. July is considered the warmest month and the ambient temperature reaches up to 32°C. In the territories between the rivers Lena and Vilyui the first autumn frosts occur in the middle and at the end of August. For this reason, to be ready for the negative temperatures onset the appropriate measures are taken. It is known that sharp temperature changes have a negative effect on the productivity of vegetable crops [1, 2].

It is also known that vermicompost improves soil properties [3, 4]. At the same time, the soil mixture is enriched with macro- and microelements, and the reaction of the medium becomes neutral, the amount of humic acids increases [5, 6]. It should be noted that vermicompost contains a large amount of soil saprophytic microbiota. This contributes to an increase in the share of microorganisms actively
participating in the cycle of substances that decompose protein substances, and the share of pathogenic microflora decreases [7, 8, 9]. It is also noted that adding vermicompost to greenhouse soils increases the aeration capacity [10]. Vermicompost contains nitrogen-fixing, ammonium-fixing, nitrifiers and cellulose-destroying bacteria, so this type of fertilizer can be considered microbial and when they are applied to soils, the available nutrients for the plant increase accordingly, which is relevant in conditions of repeated use of soils [11, 12].

It is noted that the use of vermicompost in the cultivation of vegetable crops contributes to a stable yield while improving their quality. The content of dry matter, vitamin C and sugars increases, while reducing nitrates [13, 14]. Also, vermicomposting allows to solve the environmental problem of agricultural production, recycling waste from livestock and poultry. The chemical, mineral and microbiological components of vermicompost depend on the initial substrate (manure, bird droppings, etc.). Vermicompost are safe biofertilizers, they are considered a preventive tool that reduces the incidence of plant diseases during the entire growing season [15].

Studies of the all-Russian Research Institute of Organic Fertilizers and Peat have proven the effectiveness of vermicompost from cattle manure and sewage sludge in the cultivation of vegetable crops. According to their data, the obtained biofertilizers based on the processing of manure by the worm Eisenia fetida contained up to 80% of coprolites. The resulting biofertilizers contained more humic acids. This affects the optimization of the humus state of soils. Also, biofertilizers contain a greater amount of nitrate nitrogen, mobile forms of potassium and phosphorus. Comprehensive studies of the all-Russian Research Institute of Agrochemistry named after D.N. Pryanishnikov have proved the effectiveness of biofertilizers (vermicompost) produced from different substrates and production technology using earthworms in the cultivation of vegetables and cereals [16].

In conditions of low-productivity soils of Yakutia, vermicomposting can become an effective way to produce biofertilizers in the region's crop production system. Currently, to improve the agrochemical properties of soils, untreated farm animal manure is used, which contains a large amount of undigested large plant residues of feed and weed seeds. At the same time, the sanitary situation deteriorates. Therefore, there is a need to improve and create new biofertilizers used in unheated greenhouses [17].

The effectiveness of applying (bio-fertilizing) vermicompost produced from different substrates when growing vegetable crops in low-fertility soils has been proved. There are many reports on the norms for adding vermicompost to soil when growing crops. However, there is no strictly accepted rules for their application. Mixed data on the efficiency and application rates were obtained in different geographical zones. This was the basis for this research.

2. Research purpose
Until now the effective methods of vermicomposting of organ-containing waste and their application in the vegetable growing system of Yakutia have not been developed yet. Research purpose is to study the effect of biofertilizers (vermicompost) created from local raw materials in the cultivation of tomatoes in Yakutia. Research objectives are the next:

- the effect of biofertilizers on tomato growth and development;
- the effect of fertilizers on tomato productivity.

3. Research materials and methods
Scientific experiments on the effectiveness of various biofertilizers (vermicompost based on local substrates) in cultivating tomatoes are organized on the basis of the greenhouse complex of the experimental production farm "Pokrovskoe" Khangalassky district. To prepare vermicompost from local substrates (horse manure), a hybrid of the red California worm was chosen (Eisenia fetida).

The study of the effectiveness of vermicompost based on horse manure in cultivating tomato included the following study groups: control group (greenhouse soil mix), I experimental group (greenhouse soil mix + 100 g/vermicompost plant), II experimental group (greenhouse soil mix + 300 g/vermicompost...
Small-scale farming experience (the area of the plot is 3.3 m²). At the end of the scientific experiment, the effect of vermicompost on the agrochemical properties of soil and its microbiological activity was studied.

Tomato plants were planted on June 5 in a permanent place in the greenhouse. Seedlings at the time of planting had an average height of 35-40 cm, with 7-8 leaves, with an area of photosynthetic apparatus of 200-300 cm², and with well-developed roots.

4. Research results and discussion
To study the effect of biofertilizers with increasing application rates of vermicomposts from local raw materials (manure Yakut horses) on the productivity of tomatoes Verlioka held in a greenhouse complex of experimental production farm "Pokrovske" Khangalassky district of Central Yakutia. The use of biofertilizers (vermicompost from Yakut horse manure) affected plant growth (table 1).

Table 1. The effect of vermicompost produced from horse manure on plant height, cm.

| Groups                                      | Years    | Beginning of flowering | Beginning of fruiting | Fruiting  |
|---------------------------------------------|----------|------------------------|-----------------------|-----------|
| control group (greenhouse soil mix)         | 1st year | 22.5                   | 110.7                 | 167.0     |
|                                             | 2nd year | 35.0                   | 120.3                 | 128.4     |
|                                             | 3rd year | 26.7                   | 64.5                  | 130.6     |
| I experimental group (greenhouse soil mix + 100 g/vermicompost plant) | On average for 3 years | 28.1                   | 98.5                  | 140.0     |
|                                             | 1st year | 22.8                   | 115.1                 | 168.3     |
|                                             | 2nd year | 47.4                   | 125.0                 | 133.0     |
|                                             | 3rd year | 32.0                   | 86.2                  | 149.6     |
| II experimental group (greenhouse soil mix + 300 g/vermicompost plant) | On average for 3 years | 34.1                   | 107.3                 | 150.6     |
|                                             | 1st year | 23.2                   | 116.6                 | 171.7     |
|                                             | 2nd year | 47.0                   | 127.3                 | 134.1     |
|                                             | 3rd year | 38.6                   | 101.7                 | 182.3     |
| III experimental group (greenhouse soil mix + 500 g/vermicompost plant) | On average for 3 years | 36.3                   | 114.7                 | 162.7     |
|                                             | 1st year | 23.0                   | 115.8                 | 169.7     |
|                                             | 2nd year | 44.0                   | 128.0                 | 132.8     |
|                                             | 3rd year | 37.2                   | 91.9                  | 181.6     |
|                                             | On average for 3 years | 34.7                   | 112.2                 | 161.4     |

The maximum height of the tomato plant was 162.7 cm in the II experimental group, where the use of biofertilizers in the norm of their application was 300 g per well. With an increase in the doses of applying biofertilizer to soil up to 500 g per well, the plant height decreased by 1.3 cm.

When studying the effect of different norms for applying biofertilizers, a difference in the assimilation surface of tomatoes was found. In the II experimental group, the maximum indicator for the leaf surface of tomatoes was set at 4537.5 cm². It should be noted that with increasing rates of application of biofertilizers, the leaf area decreased by 154.3 cm² (table 2).

Table 2. The effect of vermicompost produced from horse manure on the assimilation surface of tomato, cm².

| Groups                                      | Years    | Beginning of flowering | Beginning of fruiting | Fruiting  |
|---------------------------------------------|----------|------------------------|-----------------------|-----------|
| control group (greenhouse soil mix)         | 1st year | 714.2                  | 2701.1                | 4842.3    |
|                                             | 2nd year | 696.3                  | 2204.3                | 3569.7    |
The relationship between the assimilation apparatus and tomato productivity is determined (table 3).

**Table 3.** The effect of vermicompost produced from horse manure on tomato productivity, kg / m².

| Groups                                              | Productivity kg /m² | On average for 3 years |
|-----------------------------------------------------|---------------------|------------------------|
| control group (greenhouse soil mix)                 | 5.8                 | 5.5                    |
| control group (greenhouse soil mix)                 | 5.7                 | 5.7                    |
| control group (greenhouse soil mix)                 | 5.7                 |                        |
| I experimental group (greenhouse soil mix + 100 g/vermicompost plant) | 6.2                 | 6.0                    |
| II experimental group (greenhouse soil mix + 300 g/vermicompost plant) | 6.4                 | 6.1                    |
| III experimental group (greenhouse soil mix + 500 g/vermicompost plant) | 6.5                 | 6.0                    |

Within 3 years the experiment convinced that a small application of biofertilizers (of vermicompost) had the maximum effect on tomato productivity (100 g / plant - 6.2 kg /m²). The increase in the rate of biofertilizers application did not significantly increase the productivity (the difference is reliable). For 3 years, the trend in results was repeated.

**Table 4.** The effect of vermicompost produced from horse manure on tomato development.

| N  | The periods of plant development | Date of onset of plant development | Duration of the plant development period |
|----|----------------------------------|-----------------------------------|------------------------------------------|
|    |                                  | without bio-fertilizer with bio-fertilizer | without bio-fertilizer with bio-fertilizer |
| 1  | Crop                             | -                                 | 25.03                                    |
| 2  | Shoots                           | 2.04                              | 02.04                                    | 6-7 | 6-7 |
| 3  | The first true leaf              | 16.04                             | 14.04                                    | 14  | 12  |
| 4  | The fourth true leaf             | 10.05                             | 30.04                                    | 38  | 28  |
During the experiments, the optimal dose of applying biofertilizer (vermicompost from horse manure) to the soil was established and amounted to 100 g/plant. At this rate, the collection of tomato fruits from 1 m² was at the level of 6.0-6.5 kg.

### 5. Conclusion

The research results allowed to conclude that in the conditions of Yakutia, the use of biofertilizers (vermicompost based on local substrates – horse manure) contributes to early production. Also, the use of biofertilizers in tomato cultivation contributes to the full fruiting of plants and the development of up to 12 brushes on two stems from one plant. We note that applying small doses of biofertilizers in the soil provides optimal growth, development and productivity of tomatoes. At the same time, it should be noted that with increasing doses of biofertilizers over 300 g per well, there is a delay in growth and inhibition of plant development, reducing the productivity of tomatoes. Thus, the research conducted to determine the optimal dose of biofertilization produced from horse manure found that vermicompost of 100 g/plant contributed to an increase in tomato productivity by 8.8%.

### References

[1] Gavrilova M K 1973 *Climate of Central Yakutia* (Yakutsk: Yakut Book Publishing House) p 53
[2] Bogushevsky A A 1974 *Land Reclamation in the Permafrost Zone* (Moscow: Kolos) p 254
[3] Zhao H T, Li T P, Zhang Y, Hu J, Bai Y C, Shan Y H and Ke F 2017 Effects of vermicompost amendment as a basal fertilizer on soil properties and cucumber yield and quality under continuous cropping conditions in a greenhouse *Journal of Soils and Sediments* 17(12) 2718-30
[4] Goswami L, Nath A, Sutradhar S, Bhattacharya S S, Kalamdhad A, Vellingiri K and Kim K H 2017 Application of drum compost and vermicompost to improve soil health, growth, and yield parameters for tomato and cabbage plants *Journal of Environmental Management* 200 243-52
[5] Saeid A and Jastrzębska M 2017 Agronomic biofortification as a key to plant/cereal fortification in micronutrients *Food Biofortification Technologies* 1-60
[6] Sharma K and Garg V K 2018 Solid-State Fermentation for Vermicomposting: A Step Toward Sustainable and Healthy Soil *Current Developments in Biotechnology and Bioengineering* 373-413
[7] Ordoñez-Arévalo B, Guillén-Navarro K, Huerta E, Cuevas R and Calixto-Romo M A 2018

|   | Planting seedlings in a greenhouse | Beginning of flowering | The formation of the second stem | Beginning of fruiting | The first harvest (101 days from germination) | Fruiting 6-7 racemes | Stop the growth points of the plant | The last harvest |
|---|----------------|----------------------|--------------------------------|----------------------|--------------------------------------------|-------------------|-------------------------------|-----------------|
| 5 | 18.05 | 18.05 | 75 | 47 |
| 6 | 22.06 | 28.05 | 82 | 56 |
| 7 | 26.06 | 02.06 | 86 | 61 |
| 8 | 29.06 | 04.06 | 89 | 63 |
| 9 | 05.08 | 11.08 | 126 | 101 |
| 10 | 10.08 | 16.07 | 131 | 105 |
| 11 | 10.08 (with 7-8 brushes) | 10.08 (with 11-12 brushes) | 131 | 131 |
| 12 | 19.09 | 19.09 | 171 | 171 |
Enzymatic dynamics into the Eisenia fetida (Savigny, 1826) gut during vermicomposting of coffee husk and market waste in a tropical environment *Environmental Science and Pollution Research* **25**(2) 1576-86

[8] Ogunlade M O, Bello O S, Agbeniyi S O and Adeniyi D O 2019 Microbiota Assay of Cocoa Pod Husk–Based Compost as Organic Fertilizer *Int. J. Curr. Microbiol. App. Sci* **8**(3) 3182-92

[9] Ali Q, Ashraf S, Kamran M and Ijaz M 2019 Affirmative Plant-Microbe Interfaces Toward Agroecosystem Sustainability *Microbiome in Plant Health and Disease* 145-70

[10] Barthod J, Rumpel C and Dignac M F 2018 Composting with additives to improve organic amendments *Agronomy for Sustainable Development* **38**(2) 17

[11] Kumar V and Singh K P 2001 Enriching vermicompost by nitrogen fixing and phosphate solubilizing bacteria *Bioresource Technology* **76**(2) 173-5

[12] Huang K, Xia H, Cui G and Li F 2017 Effects of earthworms on nitrification and ammonia oxidizers in vermicomposting systems for recycling of fruit and vegetable wastes *Science of The Total Environment* **578** 337-45

[13] Chaudhary D R, Bhandari S C and Shukla L M 2004 Role of vermicompost in sustainable agriculture *Agricultural Reviews* **25**(1) 29-39

[14] Singh R, Sharma R R, Kumar S, Gupta R K and Patil R T 2008 Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (Fragaria x ananassa Duch) *Bioresource Technology* **99**(17) 8507-11

[15] Kalinina O Yu, Chertov O G and Popov A I 2002 Changes in the composition and agroecological properties of animal waste in the process of composting with the participation of earthworms Eisenia foetida *Soil Science* 1072-80

[16] Sychev V G, Merzlaya G E, Petrova G V, Filippova A V, Popov V I and Mishchenko V N 2007 *Ecological and Agrochemical Properties and Efficiency of Vermi- and Bio compost* (Moscow)

[17] Perlov I A, Perlova T A, Pavlov N P and Grevtseva V D 1984 *Handbook of Vegetable Growing in Yakutia* (Yakutsk: Yakut Book Publishing House)