Agronomy Research **18**(S4), 2742–2751, 2020
https://doi.org/10.15159/AR.20.223

Influence of vermicompost on strawberry plant growth and dehydrogenase activity in soil

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Abstract. Vermicompost is increasingly becoming popular as an organic fertiliser used for different crops. Effects of vermicompost on strawberry plant growth and soil properties were studied in this investigation. The research was performed in LatHort from 2015 to 2017. Strawberry was grown on open field in rows. Two trials were established. In Trial 1, the application of vermicompost with a dose of 50 mL per plant was compared to growing without any fertilization. In Trial 2, several treatments were used: 1) only inorganic mineral fertilization applied; 2) vermicompost applied with a dose of 100 mL per plant in planting holes, later mineral fertilization applied; 3) vermicompost applied with a dose of 100 mL per plant in planting holes, no additional fertilization applied; 4) vermicompost applied two times per season on the ground around plants with dose of 50 mL per plant, no mineral fertilization applied. The plant growth was assessed two times per season by evaluating the amount of leaves and plant height. Soil dehydrogenase activity was evaluated during all growing seasons as indicator of soil microbial activity. The application of vermicompost positively influenced plant growth in comparison to growing without fertilization. In Trial 2, plant growth varied among years. During first two growing seasons better plant growth was observed for plants fertilized by inorganic mineral fertilizers, while later the growth levelled off for all treatments applied. The application of vermicompost had positive influence on the soil dehydrogenase activity in contrary to fertilization by mineral fertilizers.

Key words: *Fragaria x ananassa* Duch., fertilization, vegetative growth, dehydrogenase activity.

INTRODUCTION

Strawberry is one of the most widely grown small fruits in Latvia with a tendecy to slowly increase area. In 2019, the plantations of strawberry reached 553 ha (Central Statistical Bureau of Latvia, 2019). Nowadays from the side of customers there is increased interest on fruits that are grown organically or with reduced use of chemical products. Chemical fertilizers are widely used to increase the yield and fruit quality, while at the same time they can reduce soil fertility over the years (Sinha et al., 2009). To replace chemical fertilizers, different organic materials can be used, and vermicompost is one of the possibilities. Vermicompost is the excreta of earthworm, where biodegradable wastes such as farm wastes, kitchen wastes, market wastes, bio-wastes of agro based industries, live- stock wastes etc. are converted passing through the worm-gut to nutrient rich compost (Adhikary, 2012). It is described as improver of soil health and nutrient status (Adhikary, 2012), the miracle plant growth promoter

(Sinha et al., 2009). It increases germination, growth, flowering, fruit production and accelerates the development of a wide range of plant species (Lazcano & Domínguez, 2011). The addition of compost improves soil physical properties by decreasing bulk density and increasing the soil water holding capacity (Weber et al., 2007). Further, soil application of vermicompost as supplementary dose has ability to improve availability of soil nitrogen, phosphorus and potassium (Singh & Sharma, 2016). Vermicomposts are rich in microbial populations and diversity and have large particulate surface areas that provide many microsites for microbial activity as well (Arancon et al., 2004). However, the effects of vermicompost on plant-soil systems are not yet fully understood when mechanism of enzymatic activities is concerned. Besides, the most of research is done in the USA and southern countries, while it is a less known organic fertilizer for northern European climate. The current study is confined to the response of plant growth in strawberry and dehydrogenase activity in soil after application of vermicompost alone or in combination with mineral fertilizers.

MATERIALS AND METHODS

Field experiments and treatments

The experiments were carried out at the Institute of Horticulture (LatHort) in Pūre, Tukums region, Latvia (57°02` N and 22°52` E). The experimental site was situated on a sandy loam soil with dolomite mother rock, pH_{KCl} - 5.9, organic matter - 2.5%, K_2O - 151 mg kg^{-1}; P_2O_5 - 194 mg kg^{-1}; Mg - 195 mg kg^{-1}; Ca - 1,050 mg kg^{-1}. Due to low potassium content, potassium sulphate was applied as a basic fertilizer for all field in a dose 26 g m^{-2} in the spring of 2015. Later soil analysis were performed within treatments in the autumn of 2015 and 2016. Results are shown in the Table 1.

Table 1. Results of soil analysis in Trials 1 and 2 in years 2015 and 2016

Indicator, sampling time / treatment		Trial 1		Trial 2			
		Unfertilized	Vermi-compost, 50 mL $plant^{-1}$	Only mineral fertilizers	Mineral fertilizers + vermi-compost, 100 mL $plant^{-1}$	Vermi-compost, 100 mL $plant^{-1}$	Vermi-compost, 50 mL $plant^{-1}$, 2x
Soil pH (KCl 1 n)	2015	6.0	6.0	6.0	5.9	6.0	5.9
	2016	6.3	6.2	5.9	6.0	6.3	6.4
Organic matter, %	2015	2.9	2.8	3.2	3.1	2.8	3.7
	2016	1.9	2.1	2.0	2.0	2.1	2.1
P_2O_5, mg kg^{-1}	2015	161	153	168	138	166	167
	2016	102	114	125	101	130	144
K_20, mg kg^{-1}	2015	90	106	124	91	121	107
	2016	170	196	248	383	156	230
Ca, mg kg^{-1}	2015	1,150	1,120	1,140	1,200	1,080	1,160
	2016	890	904	910	813	918	920
Mg, mg kg^{-1}	2015	231	243	274	231	243	249
	2016	177	168	170	151	185	203

Strawberries were planted on May 20, 2015 in rows with a planting distance 1.0 m between rows and 0.3 m between plants in rows. Cultivar 'Induka' was used in the investigation. Two trials were established. In Trial 1, two treatments were evaluated: 1) no fertilization was used during strawberry growth; 2) the vermicompost was applied with a dose of 50 mL per plant in planting holes before planting. In Trial 2, following treatments were used: 1) only inorganic mineral fertilization applied; 2) vermicompost was applied with a dose of 100 mL per plant in planting holes, later inorganic mineral fertilization applied; 3) vermicompost was applied with a dose of 100 mL per plant in planting holes during planting, no additional fertilization applied; 4) the vermicompost applied two times per season (in spring and at the end of summer) on the ground around plants with a dose of 50 mL per plant, no mineral fertilization applied. In both trials, treatments were replicated four times with the 15 plants per plot.

In Trial 2, in treatments with application of mineral fertilizers, 1.2 g plant^{-1} of N was applied in 2015 during season, 3.0 g plant^{-1} of N and 3.7 g plant^{-1} of K_2O were applied in 2016 and 2.6 g plant^{-1} of N and 1.9 g plant^{-1} of K_2O were applied in 2017 as inorganic fertilizers. In 2017, the doses were reduced because plants were not grown full season. The vermicompost used in both trials was produced by BIOEC (Bioorganic Earthworm Compost) Ltd from cattle manure and green grass using Californian earthworms. According to producer, it contains at minimum 0.5% N, 0.3% P_2O_5, 0.5% K_2O, microelements Fe, Ca, Mn, Mg, Zn, Cu, B, pH 7–8; organic matter - at minimum 30%.

Drip irrigation was used in the plantations. Plants were irrigated six times (from the middle of June to the end of August) in 2015, four times in 2016 (during May, June) and one time in 2017 (July). One liter of water per row meter was applied every irrigation time. Weeds were controlled mechanically and by hand weeding. During fruit ripening time the straw mulch was applied between rows. No chemical plant protection products were used in the trials. To prevent spreading of pests and diseases, all leaves and runners were cut and removed from the field after finishing of fruit harvesting in 2016.

Measurements and dehydrogenase activity analysis

The evaluations were performed for three growing seasons: 2015 to 2017. The plant growth was assessed in August of 2015, May and July of 2016 and May and August of 2017 by evaluating the amount of opened leaves and measuring plant height. Randomly selected 20 plants per treatment were evaluated.

Soil dehydrogenase activity (DHA) was evaluated during seasons 2016 and 2017 as indicator of soil microbial activity. The soil samples from every treatment were collected 6 times per season from the beginning of June till the end of August.

DHA activity was detected according to Kumar et al. (2013) method as modified by Dane & Šterne (2016). One gram of soil sample was exposed to 0.2 mL of 0.4% INT (2-p-iodophenyl-3-p-nitrophenyl-5-phenyltetrazolium chloride) and 0.05 mL of 1% glucose in 1 mL distilled water for at least 6 hours. The formed INTF (p-iodonitrotetrazolium formazan) is extracted by adding 10 mL methanol and actively shaking for 1 min. INTF is measured spectrophotometrically at wave length 485 nm. DHA activity (amount of INTF) was calculated by formula:

$$\text{Amount of INTF } (\mu\text{L} \times L^{-1} \times \text{h}) = \frac{(-3a^2 + 4a) \times 86{,}400}{(60 \times h) + min}$$

where a – reading from spectrophotometer; h – incubation time in full hours; min – minutes over full hour.

Meteorological data

Meteorological data were obtained from an automatic field meteorological station (Luft) located at Pūre. Data from each year were different (Table 2). The season of 2015 characterized by very low amount of precipitation in June and hot and dry weather in August. In 2016, the average air temperature during the vegetation period was somewhat higher than in 2015 and there were more precipitation in this year than in previous. July was the hottest and wettest month in the season, while the lowest amount of precipitation was in September.

In season of 2017, the average temperature was lower than in previous years. Spring frosts were observed even at the beginning of June and there were large temperature fluctuations in May. While August was the warmest month of the season according to average air temperature. Almost all season was rather dray, while in September there were heavy rainfalls, though experiments were already finished on that time.

Table 2. Average air temperature and amount of precipitation during vegetation periods of 2015–2017

Month	Year	Precipitation, mm	Air temperature, °C		
			min	max	average
April	2015	34	-2.5	18.8	6.2
	2016	38	-5.5	16.7	6.2
	2017	35	-8.2	19.5	4.6
May	2015	39	-1.5	21.3	10.4
	2016	52	0.1	27.3	13.8
	2017	12	-5.1	32.3	10.7
June	2015	5	0.1	26.2	14.3
	2016	38	1.6	33.0	16.5
	2017	45	-0.4	28.6	15.0
July	2015	81	6.0	30.4	16.7
	2016	75	8.3	30.7	18.4
	2017	20	3.6	27.7	16.7
August	2015	15	3.2	32.3	18.0
	2016	70	4.5	28.3	16.6
	2017	12	4.1	31.7	17.0
September	2015	33	-1.0	26.6	13.2
	2016	18	1.9	27.6	13.4
	2017	174	0.5	22.4	12.7

Data analysis

Descriptive statistics, analysis of variance, followed by Fisher`s *LSD* (least significant difference) test ($P \leq 0.05$) and Pearson`s correlation were used for data analysis. The statistical analyses were performed using the MS Excel 2013.

RESULTS AND DISCUSSION

Plant growth

During investigation period strawberry plant growth changed within years mainly due to plants aging. It was also influenced by fertilizers applied. Changes were observed for both investigated parameters - amount of leaves and plant height.

Leaves are a very important part of a plant as they are the primary sites of photosynthesis and manufacture food for plants. The amount of leaves increased with the age of plants in all treatments and both trials. Some slight decrease was observed in the summer of 2017, which was influenced by cutting off all leaves in the previous summer to improve phytosanitary situation in the plantation. In Trial 1, application of vermicompost with the dose 50 mL per plant at planting increased the amount of leaves compared to growing without any fertilization (Fig. 1). While significant difference was observed only in the first growing seasons.

According to previous research, the vermicompost can contain significant quantities of plant growth hormones and humic acids, which act as plant regulators and can increase plant growth, and contains enzymes, which can break down the organic matter in the soil to release the nutrients and make it available to the plant roots that can succeed plant growth too (Nielson, 1965; Arancon et al., 2006b; Adhikary, 2012). Besides, vermicompost provides all nutrients in readily available form and enhances uptake of nutrients by plants (Adhikary, 2012). Research has shown that vermicompost has an effective role in improving growth of different field crops, including vegetables, ornamentals, cereals, nuts and fruit plants (Buckerfield & Webster, 1998; Reddy & Ohkura, 2004; Basheer & Agrawal, 2013; Kaur et al., 2015; Raha, 2015; Joughi et al. 2018; Dechassa et al., 2019). Several studies have also been done on it for strawberries (Arancon, et al., 2003; Arancon et al., 2004; Arancon et al., 2006a; Arancon et al., 2006b; Ameri et al., 2012; Singh et al., 2015; Zuo et al., 2018).

In the Trial 2, where different applications of vermicompost were compared to mineral fertilization, the amount of leaves significantly did not differ among treatments, except in May of 2016, when, in the treatment with application of vermicompost with dose 100 mL per plant, the amount of leaves was significantly lower than in the treatment with only mineral fertilization (Fig. 2). Later the amount of leaves increased in this treatment.

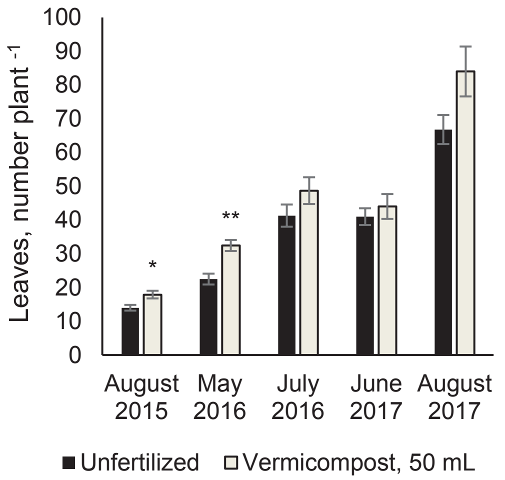

Figure 1. Number of leaves per plant in unfertilized plots and fertilized with vermicompost, dose 50 mL plant^{-1}, during three growing seasons and standard error bars. * – the difference among treatments significant at $P \leq 0.05$; ** – the difference among treatments significant at $P \leq 0.01$.

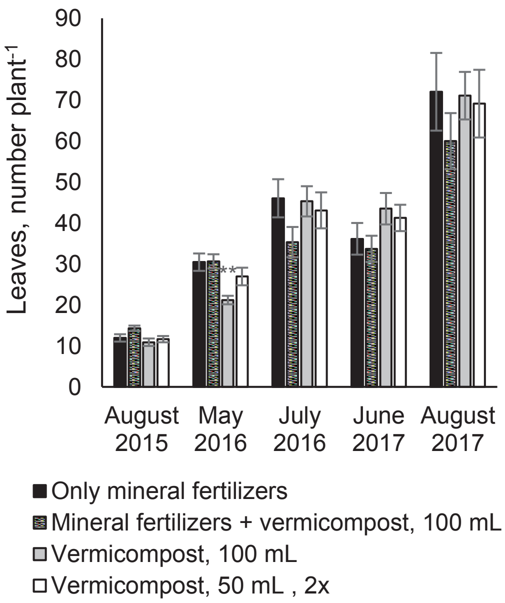

Figure 2. Number of leaves per plant in plots fertilized by mineral fertilizers and/or vermicompost during three growing seasons and standard error bars. ** – the difference among treatments significant at $P \leq 0.01$ compare to treatment with application of only mineral fertilizers.

The amount of leaves significantly correlated with the plant height ($P < 0.01$) in both trials. During growing years, the highest plant height was observed in the second growing season (Figs. 3, 4).

In the Trial 1, the application of vermicompost had positive effect on the increase of plant height compared to the unfertilized plots which might be associated with ability of vermicompost to improve photosynthesis rate, free radical scavenging and soil enzymatic activity as complemented by Zuo et al. (2018). While significant difference was observed only during the first growing seasons that was similar to the situation with leaf amount. The lower growth in the third season can be explained by utilising nutrients and plant growth stimulators provided, as vermicompost was given only at the planting, and increased plant age.

In Trial 2 in total, the biggest plant height was observed in the treatment with only mineral fertilization applied. In August 2015 and May 2016, in all other treatments the plant height was significantly lower ($P < 0.01$) than in the treatment with only mineral fertilization (Fig. 4). In July 2016, it was significantly lower in treatments with application of both - mineral fertilizers and vermicompost, and treatment with only vermicompost application two times per season with a dose of 50 mL per plant. Later plant growth levelled off in all treatments.

Vermicompost and inorganic fertiliser combination increased strawberry growth significantly in trials in the USA, Ohio, where vermicompost-treated plots were supplemented with appropriate

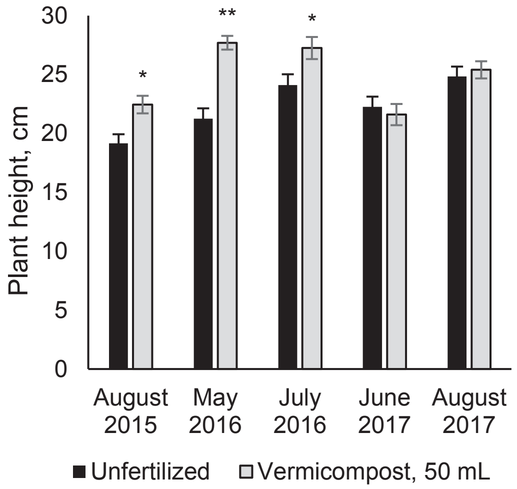

Figure 3. Plant height in unfertilized plots and fertilized with vermicompost, dose 50 mL plant^{-1}, during three growing seasons and standard error bars. * – the difference among treatments significant at $P \leq 0.05$; ** – the difference among treatments significant at $P \leq 0.01$.

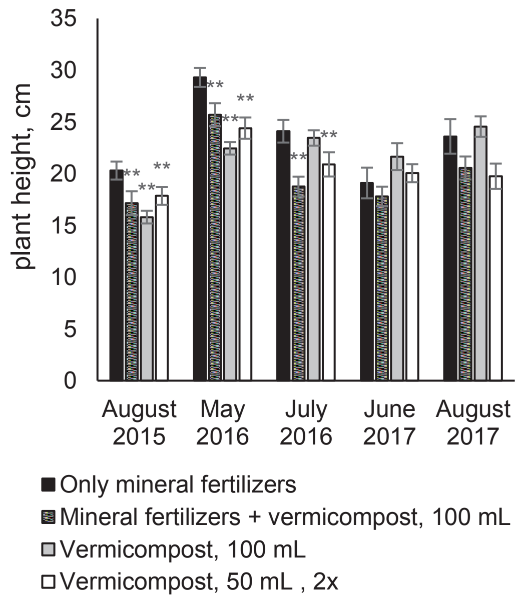

Figure 4. Plant height in plots fertilized by mineral fertilizers and/or vermicompost during three growing seasons and standard error bars. ** – the difference among treatments significant at $P \leq 0.01$ compare to treatment with application of only mineral fertilizers.

amounts of inorganic fertiliser to equalize the total recommended full rate of main macronutrients (Arancon et al., 2003; Arancon et al., 2004). In our trial, the vermicompost was given additionally to recommended doses applied by inorganic mineral fertilisers and the positive effect of combination of inorganic fertilization and vermicompost on strawberry plant growth was not observed, probably because of too high concentration of mineral nutrients. There was observed high increase of plant available potassium content in the soil in this treatment (Table 1).

Dehydrogenase activity in soil

The dehydrogenase enzyme activity was measured, as these enzymes are considered to be good indices of overall microbial activity (Nannipieri et al., 1990). According to Arancon et al. (2006a), levels of dehydrogenase activity are correlated positively and significantly with amounts of soil microbial biomass.

In our Trial 1, where application of vermicompost with dose 50 mL per plant at planting was compared to without fertilization, no significant difference was observed between treatments in dehydrogenase activity (data not shown). Probably the dose applied was too small to influence soil microbiota. Albiach et al. (2000) have reported about non-effectiveness of low doses of vermicompost on the increase of microbial biomass content and enzymatic activities after the application to a horticultural soil.

In Trial 2, where different applications of vermicompost were compared to mineral fertilization, significant differences were observed between treatments in the second (Fig. 5.) and third (Fig. 6) growing year, as well as significant differences were observed between sampling dates. In 2016, the lowest dehydrogenase activity was at the beginning of June and the highest it was at the end of July. While in 2017, it increased in June and decreased in July. It can be explained by different weather conditions during growing years. In 2016, the end of May and beginning of June were very dry, while in 2017, July and August were dry and it was not possible to irrigate sufficiently.

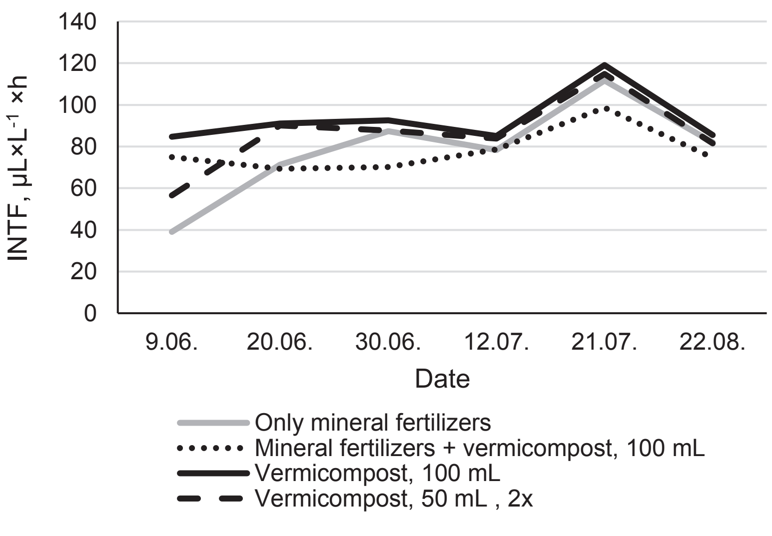

Figure 5. Soil dehydrogenase activity in plots fertilized by mineral fertilizers and/or vermicompost in the second growing year (2016). INTF, µL× $L{-}1$ × h

In the second growing year in general, both treatments with application of only vermicompost showed significantly higher ($p = 0.001$) soil microbial activity compared to treatments where mineral fertilizers were applied. In the treatment with split application of vermicompost (50 mL plant^{-1} two times per season), at the beginning of June the dehydrogenase activity was low, while later it increased. Whereas in the treatment with vermicompost application 100 mL per plant at planting, already at the beginning of June the activity was high and was the highest during all season. It shows that 100 mL of vermicompost is an amount big enough to be adequate for successful microbiota life cycle.

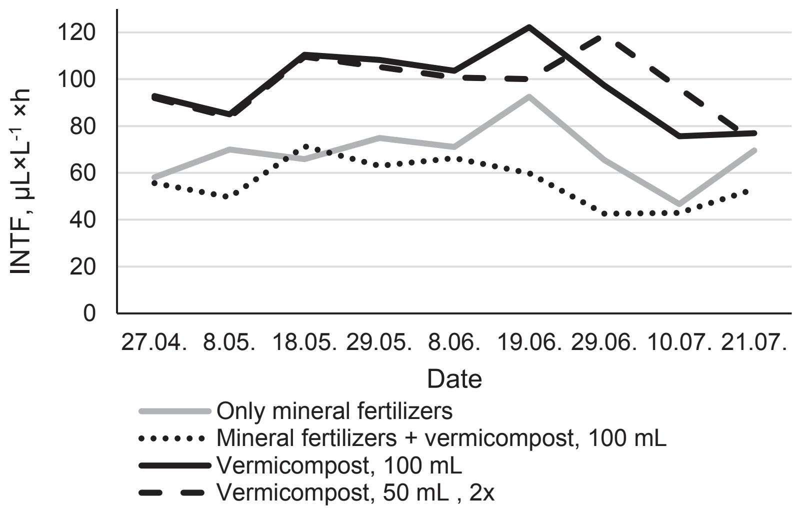

Figure 6. Soil dehydrogenase activity in plots fertilized by mineral fertilizers and/or vermicompost in third growing year (2017).

The same trend can be seen in the third growing year, where both treatments with application of only vermicompost showed significantly higher ($p < 0.001$) soil microbial activity compared to treatments where mineral fertilizers were applied, and the gap between mineral fertilized and only vermicompost fertilized treatments had become bigger. There have been several other reports that vermicompost fertilizers can increase soil microbiological activity (Atiyeh et al., 2001; Arancon et al., 2006a; Sinha et al., 2009), while mineral fertilizers adversely affect beneficial soil microorganisms and soil chemistry (Sinha et al., 2009).

CONCLUSIONS

Obtained results confirm that vermicompost has a positive effect on strawberry plant growth compare to non fertilization and can be used as organic fertiliser ir strawberry plantations. The dose 50 mL per plant at planting maintained positive effect for the first two growing seasons, while this dose did not influence overall microbial activity in soil. The application of only mineral fertilizers had a higher effect on strawberry plant growth than vermicompost, and combined fertilization (vermicompost and mineral fertilizers) during the first two growing seasons, while later this effect decreased. The application of mineral fertilizers reduced soil microbial activity compared to only vermicompost application that could negatively influence soil fertility in the future. More investigations on doses and application times for vermicompost are necessary.

ACKNOWLEDGEMENTS. This work was supported by the Latvia Ministry of Agriculture Project ‘Evaluation of Small Fruit Cultivars Perspective for Integrated Production in Different Regions of Latvia and Development and Improvement of Growing Technologies’.

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