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VEGETABLES CROPS NUTRITION MANAGEMENT USING DRIP FERTIGATION AND SHADING MESH

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Abstract

The main objective of our case study was related to a comparative assessment of chemical and organic fertilizers on yield and quality of vegetables in arid conditions. The highest yield of two pepper hybrids was fixed in the trial fertigated with liquid digestate fraction and equipped with sunlight protective mesh.
The fresh red tomato yield was highest after foliar spraying treatment with vermicompost tea (6.95 kg/m^2) and carbamide (7.23 kg/m^2) in the second field experiment. The relative additional yield of aubergine fruits (11.6-12.1%) and pepper (12.0-12.7%) was higher in case of drip fertigation. The aubergine fruits have a high peroxidase activity. The high activity of peroxidase was especially observed in fruits when using vermicompost tea. The use of drip fertigation proved to be a more efficient operation of the peroxidase system in pepper fruits compared to foliar spraying. The study of molecular forms of peroxidase in tomato seeds showed their small number (six components) and variability of expression under different growing conditions. Significant inhibition of isoperoxidase activity was observed in carbamide treatment after foliar spraying of tomato plants.

Key words*: digestate, drip fertigation, shading mesh, vegetables crops, vermicomposting tea.*

INTRODUCTION

Pre-conditions to organic farming of vegetables growing. During last decades agriculture in the steppe zone of Ukraine is in most cases caused by changing weather conditions and the diversity of soil fertilizers cover. Precipitation is less than 350 mm in dry years i.e. dry steppe zone, in damp years more 550mm in forest-steppe zone (average perennial value 470 mm).
Recently, Ukrainian private farms have used very little fertilizer. Generally speaking, farms have been forced into this situation because they do not have enough money to buy expensive mineral fertilizers.
Vast quantities of nutrients exist in agri-wastes that can potentially be utilized as fertilizers or soil amendments to subsidies the tremendous demand for synthetic chemical fertilizers and to reduce the economic and environmental costs associated with fertilizer production and waste disposal.

Soild and liquid fractions of digestate prospects. The market value of digestate products is usually estimated at the equivalent market value of nutrient analogues (N, P, and K) in mineral fertilizers. Therefore, both solid and liquid fractions of bio-digestate are prospect products to use it following famous agricultural practices (Tambone et al., 2017; Logan & Visvanathan, 2019). As a rule, biogas plants use a mixture of different types of raw materials. The results of a study conducted by KTBL (KTBL, 2008) showed that any further processing of 'raw' digestate, regardless of the type of derivatives thereof, leads to a decrease in the equivalent net value of digestate by the NPK complex, and therefore for most biogas plants simple soil application of digestate is more economically attractive than digestate processing. The ultrafiltered dairy manure digestate biofertilizer had the highest yield of red tomatoes (7.13 tons/ha) followed by the concentrated food waste digestate biofertilizer and mineral N fertilizer treatments with 6.26

and 5.98 tons/ha, respectively. The digestate provided a significant amount of ammonium N, which is rapidly nitrified and therefore available directly to crops in the short term (Alburquerque et al., 2012). Furthermore, the addition of digestate led to an increase in the amount of P available in the soil. The subsurface fertigation of digestate can be useful in decreasing the volatilization of ammonia in fields after digestate application (Lili et al., 2016). Meanwhile, this liquid digestate application technology may be a cost-effective option compared to chipper surface drip fertigation (Nkoa, 2014). In this sense, the use of poultry digestate liquid fraction for irrigation and fertigation appears very promising as well. However, attention must be paid to avoid overapplication of digestate in the soil, including several negative environmental effects including leaching, phytotoxicity, soil salinity, pathogen exposure, and increased gaseous NH_3 emissions (Barzee et al., 2019).

Vermicomposting as main component of organic farming in horticulture. It is known that vermicomposting is the product of accelerated biodegradation of organic matter by earthworms through mesophilic decomposition (Márquez-Quiroz et al., 2014). Vermicomposts are finely divided peat-like materials with high porosity, aeration, drainage, water-holding capacity, and microbial activities, which make them excellent soil amendments or conditioners (Atiyeh et al., 2000). These composts result from a non-thermophilic biodegradation and stabilization of organic materials because of earthworms and microorganisms' interactions (Agnieszka et al., 2013). The composition of vermicompost-based growth substrates includes 25-30% vermicompost, peat, sand, gravel and perlite (Olle, 2016). During the mean time certain proportions of vermicompost and natural soil from 1: 1 to 4: 1 can be prepared as well (Abduli et al., 2013). Four levels of vermicompost (0, 5, 10 and 15 tons/ha) were applied in the field experiment as an easy bio-treatment to improve pepper antioxidant compounds, fruit quality and yield (Aminifard & Hassan, 2016). Vermicompost provided pepper plants with the highest growth rate during the nursery period, especially under salinity stress conditions (Kaciu et al., 2011). Vermicompost and chicken manure compost more effectively promoted tomato plant growth, including stem diameter and plant height compared to other fertilizer treatments, in all three types of soil (Wang et al., 2017). The rate 0.5-0.6 g/g of vermicompost added to soil provided tomato growth similar to the standard inorganic fertility program (Zucco et al., 2015). The production of solanaceous crops can be improved also with vermi-tea fertigation (Aslam et al., 2020).

Vermicomposting tea is a mixture of aerobic microbes present in vermicomposting with aerated water (Arosha & Sarvananda, 2022). Incorporation of aerated compost tea obtained from organic compost based on the mixture of rice straw compost, vermicompost, and Hinoki cypress bark compost in the root zone increased shoot and root growths and yield of red leaf lettuce (Kim et al., 2015). Vermicompost tea can be irrigated, sprayed plants or sprinkled on leaves, as it contains many useful nutrients, growth regulators, and enzymes (Alkobaisy et al., 2021). Low concentrations of vermi-compost tea at rates of 1.6% and 3.2% for lettuce significantly increased lettuce yields (Arancon et al., 2019). Even lower concen-trations of vermicompost tea significantly increased tomato yields as a supplement in reduced nutrient solutions of 50%.

Isoperoxidase activity as index of fruits quality. It is known that such enzyme as isoperoxidaze may influence the quality of fruits and vegetables (Muftugil, 1985). Products with high peroxidase activity must be blanched or treated with antioxidants to decrease isozyme activity (Prestamo & Manzano, 1993). Those vegetables that exhibit low peroxidase activity and mainly contain low-molecular-weight isozymes need not be blanched, but can be treated with antioxidants if needed.

The main objective of our research was related with effect of liquid fraction of digestate, carbamide and vermi-tea on yield and quality of tomato, pepper and aubergine fruits in arid conditions.

MATERIALS AND METHODS

Site location and soil conditions.This research work was carried out at the Pokrov research and educational station located in the southern

part of Ukraine (47º39'N, 34º08'E). The annual rainfall and evaporation are 465 mm and 650 mm accordingly. The black soil used for the experiment has loess like loam texture.

Experimental design. The layout of the two field experiments was designed in a completely randomized design with three replicates at 2018 and 2021.

First field experiment. Two pepper varieties (Monolite and Turmaline) were selected to examine the effectiveness of different trials: **a)** control (water); **b)** treatment with drip fertigation using the liquid fraction of digestate (LFD) dissolved by water in ratio 1:200; **c)** with and without sun protective mesh (SPM) and **d)** LFD+SPM (Figure 1).

Figure 1. Pepper drip fertigation under sun protective mesh

Fertilization in first field experiment. Poultry litter digestate was obtained from MHP Oril-Leader farm involved with all aspects of poultry agriculture. In 2012, it commissioned an anaerobic digester in Yelyzavetivka village for poultry manure and slaughterhouse waste using technology from Nijhuis Industries.

Three liquid fraction of poultry litter digestate injection with drip irrigation system were made during vegetation period. The protective mesh was applied as a second test with the intention of reducing the impact of exposure to sunlight on the volatilization of ammonia.

Second field experiment. Three varieties of tomato (Bobkat), aubergine (Nadir) and pepper (Ayvengo) were tested to compare foliar spraying and drip fertigation.

The treatments were: (**1**) no fertilizer (water), (**2**) mineral N fertilizer (carbamide), (**3**) vermicompost tea (vermi-tea). The dose of 20 kg of carbamide was dissolved in 10 litres of water. The vermicompost tea was dissolved by water in a 1: 100 using an injector (Figure 2).

Figure 2. Fertilizer delivery with injection system

The fertilization rate was taken following recommendations for artificial ammonium liquid fertilizers to obtain optimal growth of drip irrigation vegetables in Dnipropetrovsk province (Kharytonov et al., 2019).

Fruit determinations. The mass of the vegetable fruits was recorded for each plot. For the determination of the dry vegetable yield, five of the fruits of each treatment plot were randomly sampled, cut, and weighted in kg/m^2. The nitrogen content in fruits was analyzed with the Kjeldahl method. The fruits of pepper,aubergine fruits and tomato seeds (0.3 g) were homogenized in 6 mL of 0.05 M Tris-HCI buffer, pH 7.4 with 0.5% polyvinylpyrrolidone (PVP) for the isolation of the benzidine peroxidase. The extraction was carried out at +40^{0}C for 1 hour. The extract was centrifuged for 15 min at 14,000 rpm. The supernatant was selected to determine the isoenzyme composition of benzidine peroxidase (BPx). The isoenzyme composition of BPx was determined by the isoelectric focus (IEF) method on a 5% horizontal polyacrylamide gel (PAAG) on an "Ultrophor" device (LKB, Bromma, Sweden), pH range 3.5-6.5. The benzidine method was used to detect enzymatic activity in a polyacrylamide gel (Guikema & Shermen, 1980).

Data analyses. The data obtained were processed using statistical methods using the StatGraphics Plus software package at a significance level of 0.95 % (P-value < 0.05).

RESULTS AND DISCUSSIONS

Pepper fruits yield and quality in experiment with liquid fraction of digestate
The highest yield of two pepper hybrids was fixed in the LFD + SPM trial fertigated with liquid digestate fraction and equipped with sunlight protective mesh (Figure 3).

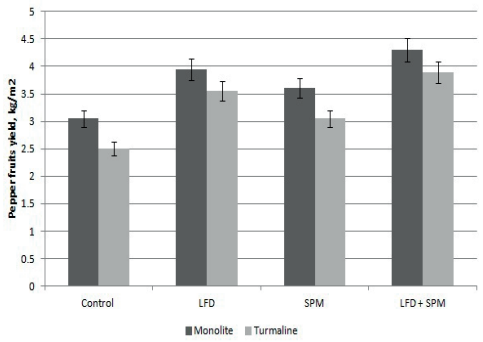

Figure 3. Pepper fruits yield, kg/m^2

In the meantime, the lowest data on dry matter in pepper fruits was fixed in the LFD + SPM trial as well (Figure 4).

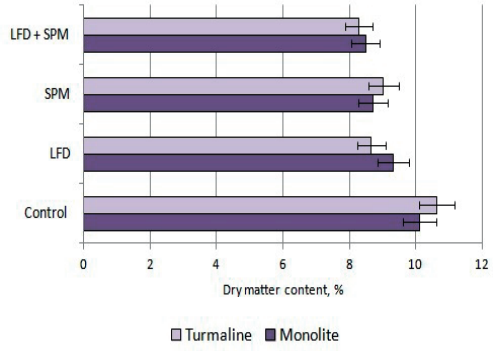

Figure 4. Dry matter content, %

The data on nitrogen content in pepper fruits is shown in Figure 5. The maximum level of nitrogen content in Monolite (1.85%) and Turmaline (2.13%) pepper hybrids fruits was found after drip fertigation with liquid fraction of poultry litter digestate.

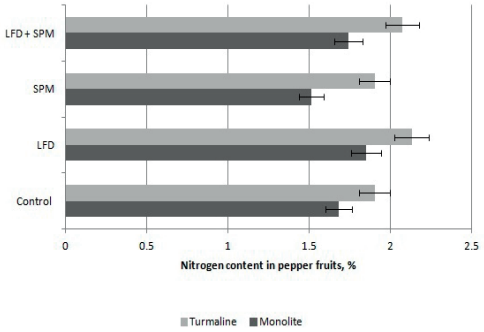

Figure 5. Nitrogen content in pepper fruits, %

Comparative presentation of tomato, pepper and aubergine fruits yield
The yield data obtained in the field experiments with tomato, aubergine and pepper are shown in the Figure 6 and Figure 7. The fresh red tomato yield was highest after foliar spraying treatment with vermicompost tea (6.95 kg/m^2) and carbamide (7.23 kg/m^2).

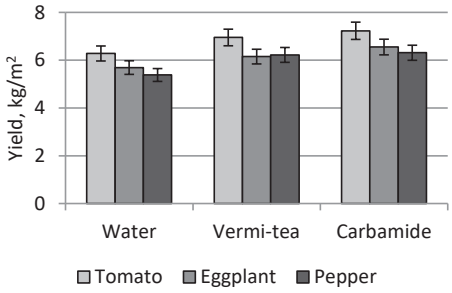

Figure 6. Foliar spraying fertilization effect on vegetables yield

The relative additional yield of aubergine (11.6-12.1%) and pepper (12.0-12.7%) was higher in the case of drip fertigation (Figure 7).

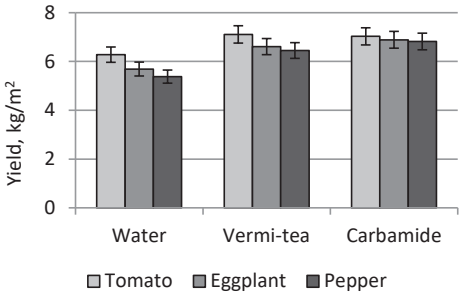

Figure 7. Drip fertigation effect on vegetables yield

Meantime, the tomato drip fertigation with vermicompost tea provided maximum yield (7.11 kg/m^2) or 11.3% comparative to control.

Drip fertigation and foliar spraying impact on tomato, pepper and aubergine enzymatic antioxidant system.

The study of the expression of redox enzymes occupies a special place in the evaluation of the adaptation capabilities of various plant tissues. These enzymes directly or indirectly affect the concentration of reactive oxygen species in tissues (Clemens, 2001; Mittler et al., 2004). It was shown that aubergine fruits have a high peroxidase activity. The structure of the aubergine fruits IEF spectra of peroxidase was similar both under drip irrigation and under foliar spraying (Figure 8).

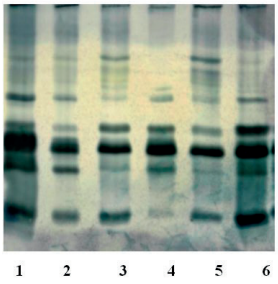

Figure 8. Changes in the polyacrylamide gel isoelectric focusing (IEF) profiles of benzidine-peroxidase from aubergine fruits are grown using two methods of plant treatment with different types of fertilizers: Drip irrigation: 1 - Vermi-tea; 2 - Water; 3 - Carbamide; Foliar spraying: 4 -Water; 5 - Carbamide; 6 - Vermi-tea

The highest activity was found for four enzyme isoforms with pI 4.00, 4.12, 4.20 and 4.30. Especially high activity of peroxidase was registered in fruits when using vermicompost tea. Isoperoxidase with a pI of 4.20 showed consistently high activity in all treatments. Significant fluctuations were observed in the activity of components with a pI of 4.00, 4.12 and 4.30. Isoperoxidase with a pI of 4.00 showed the highest activity in the treatment with vermi-tea, and the lowest - after foliar spraying with water. The component with pI 4.12 showed high activity after foliar spraying with vermi-tea. Treatment with carbamide leads to inhibition of this isoform. This has also been observed with drip fertigation. The highest activity of the enzyme isoform with a pH of 4.30 was recorded in the vermi-tea trial with both methods of aubergine treatment. The lowest activity of the isoenzyme was fixed in the trial with water during drip irrigation. The average intensity of the component with a pI of 4.30 was observed in treatments with carbamide after foliar spraying. Minor forms (range of pI values 4.60-5.05) of peroxidase also showed variability in activity in different approaches with different types of fertilizers. Research on the antioxidant activity of pepper fruits was also carried out based on the study of the isoenzyme composition of benzidine peroxidase (Figure 9). The use of drip fertigation proved a more efficient operation of the peroxidase system in pepper fruits compared to foliar spraying.

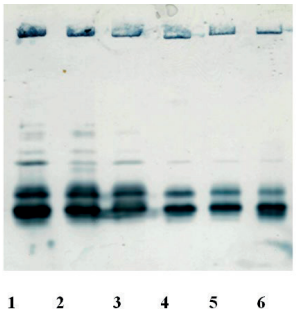

Figure 9. Changes in the polyacrylamide gel isoelectric focusing (IEF) profiles of benzidine-peroxidase from pepper fruits are grown using two methods of plant treatment with different types of fertilizers: Drip irrigation: lanes 1 - Vermi-tea; 2 - Water; 3 - Carbamide; Foliar spraying: lines 4 -Water; 5 - Carbamide; 6 - Vermi-tea

The treatment with vermi-tea stood out in particular. The study of molecular forms of peroxidase in tomato seeds showed their small number (six components) and variability of expression under different growing conditions (Table 1).

Table 1. The polyacrylamide gel isoelectric focusing (IEF) profiles of benzidine-peroxidase from tomato seeds

pI	Foliar spraying			Drip irrigation		
	vermi-tea	water	carbamide	water	carbamide	vermi-tea
4.00	+++	+	++	+	++	+++
4.10	++++	+	+	+	++	+++
4.15	+	-	-	-	-	+
4.95	+	-	-	-	-	+
5.10	trace					+
5.95	trace	trace	trace	trace	trace	trace

Components with a pH of 4.00 and 4.10 showed high activity in the vermi-tea treatment both during drip irrigation and foliar spraying. Significant inhibition of isoperoxidase activity is observed in carbamide treatment after foliar spraying of tomato plants. Therefore, the results of studying the composition of the isozyme showed significant changes in the number of molecular forms of peroxidase. The variation in its level of its expression along their distribution in the spectrum confirms the polyfunctionality of this enzyme depending on the conditions of plant growth (Shupranova et al., 2019). Such changes may be caused by post-translational modifications, increased synthesis of the enzyme, or the appearance of its new isoforms (Kumar et al., 2014). The results obtained showed a high activity of the peroxidase system with the use of vermi-tea extract in pepper and aubergine fruits. This may be related to the neutralization of active forms of oxygen formed when the intensity of respiration in ripe fruits increases. A strong correlation between respiration intensity and peroxidase activity was also shown in plum fruits (Serdyuk et al., 2017).

A change in the activity ratio of the molecular forms of peroxidase in the pepper, aubergine fruits, and tomato seeds is one of the consequences of the treatment of the plant with different types of fertilisers.

CONCLUSIONS

The main objective of our study was related to a comparative assessment of chemical and organic fertilizers on yield and quality of vegetables in arid conditions. The layout of the field experiments was designed with three replications in 2018 and 2021.The liquid fraction after liquid/solid separation of biogas digestate has a high potential as a fertilizer as a result of its high nutrient concentration. The highest yield of two pepper hybrids was observed in the trial fertigated with liquid digestate fraction and equipped with sunlight protective mesh. The maximum nitrogen content in the fruits of Monolite (1.85%) and Turmaline (2.13%) pepper hybrids was determined after drip fertigation with the liquid fraction of poultry litter digestate. The fresh red tomato yield was highest after foliar spraying treatment with vermicompost tea (6.95 kg/m^2) and carbamide (7.23 kg/m^2). The relative additional yield of aubergine (11.6-12.1%) and pepper (12.0-12.7%) was higher in the case of drip fertigation. Meanwhile, tomato drip fertigation with vermicompost tea provided maximum yield (7.11 kg/m^2) or 11.3% compared to the control.

The use of drip fertigation proved to be a more efficient operation of the peroxidase system in pepper fruits compared to foliar spraying. Significant inhibition of isoperoxidase activity is observed in carbamide treatment after foliar spraying of tomato plants.

Sunlight protective mesh is only one way to decrease ammoniac evaporation using a liquid fraction of digestate for fertigation. The incorporation of some natural adsorbents (biochar and zeolites) into the topsoil seems very promising to decrease negative consequences connected with NO_x emission, nitrates, mobile phosphates leaching, etc.

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