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Proceeding Paper

Impact of Solid Grain Waste Digestate on Biometrics and Photosynthetic Parameters of Tomato (L. *Lycopersicon esculentum*) Seedlings †

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Abstract: Anaerobic digestate has been commonly used for the cultivation of vegetable seedlings and as one of the measures for improving peat substrate. Studies have shown that there has been further research conducted on the effect of anaerobic digestate on greenhouse vegetable seedlings. The main objective was to investigate the effect of the additional insertion of different rates of solid grain waste digestate into peat substrate on tomato seedling quality. The results showed that 10% of solid grain waste digestate (peat digestate) application with transplanted seedlings had better biometrical measures and photosynthetic parameters for tomato seedlings compared with the control variant.

Keywords: biometrics; photosynthetic parameters; seedlings; solid grain waste digestate; tomato

1. Introduction

The cultivation of qualitative vegetable seedlings is important in agriculture because planting healthy seedlings not only reduces the use of pesticides and chemical fertilisers but also ensures a higher vegetable yield [1]. The quality of vegetable seedlings is characterised by morphological features, and physiological and biochemical indicators [2]. The morphological characteristics of quality greenhouse plant seedlings are that they are not elongated, are compact, with short internodes, dark green leaves, and white roots, and are intact, covering the entire peat substrate in the pot. Many factors can affect the quality of seedlings, such as light, temperature, humidity, fertilisers, substrate, etc. [3]. Studies have shown that the best and most sustainable way to use various biological wastes is to turn them into organic fertilisers. In recent years, the use of biosubstrate (digestate) obtained during the biogas and bioethanol production process in agriculture has been increasing. Biogas digestate is rich in essential elements and nutrients, nitrogen (N), phosphorus (P), potassium (K), amino acids, vitamins, and some beneficial microorganisms [4], and has a positive effect on soil properties and plant nutrition [5]. According to Jain and other scientists [6], digestate could replace about 7% of inorganic fertilisers that are currently used worldwide. It has also been proven that digestate has better properties as a fertiliser than manure does [7]. The latest agro-environmental requirements, and the challenges of soil degradation and decreasing plant productivity encourage farms to produce agricultural products with limited use of synthetic and chemical fertilisers. The development of resource-efficient fertilisers for horticultural crops is an important step toward more sustainable food production, which is necessary to meet the challenges of the future.

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2. Materials and Methods

2.1. Research Conditions

This investigation was carried out at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry, in unheated greenhouses covered with double polymer film. Two factors were investigated, the different seedling establishment methods (transplanted and directly sowed in the pod) and different substrates: control (peat, Profi 1), peat +10% peat digestate, and peat +20% peat digestate (Figure 1). The transplanted tomatoes were sown in the middle of February and seedlings directly sowed in the pod were sown at the end of February; both were kept under the same conditions in a heated nursery. The plants were watered when necessary. The seedlings were cultivated for 60 days. The investigation object was the variant "Brooklyn H". At the beginning of May, the seedlings were transported to unheated greenhouses. Three replications were performed in a randomised block design.

Figure 1. Tomato seedlings (authors photos) grown in solid grain waste digestate (peat-digestate) and peat substrate mixtures: control (peat), peat +10% peat digestate, and peat +20% peat digestate.

2.2. Biometric Measurements

The biometrical measurements were carried out at when the seedlings were fully developed. The seedling height was measured to the tip of the youngest leaf. The leaf area of seedlings was measured using the "WinDias" leaf area metre (Delta-T Devices Ltd., Cambridge, UK).

2.3. Non-Destructive Measurements

Non-destructive measurements of leaf chlorophyll (CHL), nitrogen balance (NBI) and flavanoid (FL) indexes were performed using the Dualex 4 Scientific® (FORCE-A, Orsay, France) metre. Tomato seedling leaves, stems, and roots, and all-plant fresh mass were also evaluated by calculating their weight (g) [8–10].

2.4. Determination of Photosynthetic Parameters

Photosynthetic rate (Pr, μmol CO_2 m^{-2} s^{-1}), transpiration rate (Tr, mmol H_2O m^{-2} s^{-1}), stomatal conductance (g_s, mol H_2O m^{-2} s^{-1}), and the ratio of intercellular to ambient CO_2 concentration (C_i/C_a) was determined at 9:00–11:00 amusing an LI-6400XT portable open-flow gas exchange system (Li-COR 6400XT Biosciences, Lincoln, USA). Measurements were chosen from the two most developed leaves from the plant; tree plants were measured for one minute. The reference air concentration (CO_2) (400 μmol mol^{-1}), light intensity (1000 μmol m^{-2} s^{-1}), and flow rate of the gas pump (500 mmol s^{-1}) were set [11].

2.5. Statistical Analysis

Research data were obtained via two-factor analysis of variance (ANOVA) using the computer program STATISTICA (STATISTICA 10) for statistical and data analysis [12]. The data were presented as the mean of three replicates (n = 3) linked to the sampling points.

The statistical reliability of the differences between means was assessed using Tukey's significant difference test ($p < 0.05$).

3. Results and Discussion

The mixture with solid grain waste digestate (peat digestate) with peat substrate and the seedling establishment method influenced the biometric parameters of the seedlings. The results showed that 10% peat digestate application with transplanted seedlings had a significant effect on the plant height, leaf number, leaf area, and all-plant fresh mass of tomato seedlings compared with the control variant (Table 1). Comparing seedlings directly sown in the pod with transplanted seedlings showed that the largest area of leaves, significantly, was formed by transplanted seedlings. These transplanted seedlings were more developed, compact, and not elongated, and had a significantly larger plant height.

Table 1. The effect of the solid grain waste digestate (peat digestate) and peat substrate mixture on biometric parameters of tomato seedlings.

Treatment	Plant Height, cm	Hypocotyl Length, cm	Stem Diameter, mm	Number of Leaves, Unit	Leaf Area, cm^2
			Direct seeding		
(Control/Peat Substrate)	24.50 d	3.40 b	4.37 c	5.27 a	189.01 d
Peat + 10% peat digestate	19.20 a	2.90 ab	3.77 a	4.40 d	97.04 b
Peat + 20% peat digestate	12.67 c	2.73 ab	2.70 b	3.80 c	29.51 a
			Transplanting		
(Control/Peat Substrate)	40.30 b	1.63 c	5.90 e	7.33 b	667.56 e
Peat + 10% peat digestate	38.67 b	2.40 a	5.37 d	7.50 b	699.04 f
Peat + 20% peat digestate	18.47 a	1.47 c	3.73 a	5.67 a	177.63 c

Means with different letters are significantly different at the $p < 0.05$ level according to Tukey's significant difference test.

The chlorophyll and NBI index of transplanted tomato seedlings were much affected by these substrates. The addition of more peat digestate to the peat substrate increased the chlorophyll index to 10.5–21.1% in the seedlings compared with peat without the digestate (Figure 2). The NBI in transplanted seedlings with 20% peat digestate and the peat mixture was 40.4% higher compared with that of other variants (Figure 2). The seedling establishment method had a significant an effect on seedlings; however, the total flavonoid content in tomato seedlings showed no significant difference (Figure 2).

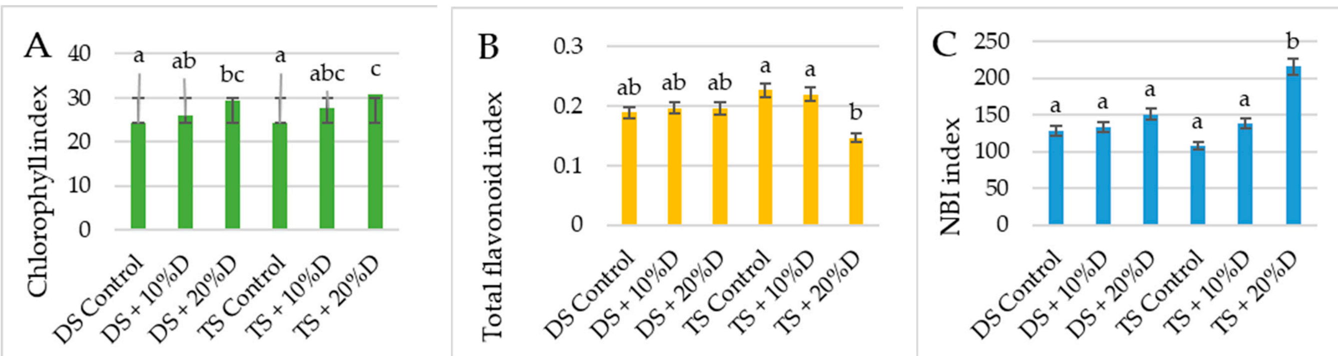

Figure 2. The effect of the solid grain waste digestate (peat digestate) and peat substrate mixture on tomato seedlings' chlorophyll (**A**), total flavonoid (**B**) and NBI values (**C**): DS Control—direct seeding (Control/Peat); DS + 10%D—direct seeding + 10% peat digestate; DS + 20%—direct seeding + 20% peat digestate; TS—transplanting (Control/Peat); TS + 10%D—transplanting + 10% peat digestate; TS + 20%D—transplanting + 20% peat digestate. Means with different letters are significantly different at the $p < 0.05$ level according to Tukey's significant difference test. Error bars are shown as percentages.

The transplanted control variant and the mixture with 10% solid grain waste digestate (peat digestate) and peat substrate had a 2.2–2.4-fold higher fresh leaf mass compared with seedlings directly sown in the pod (Figure 3).

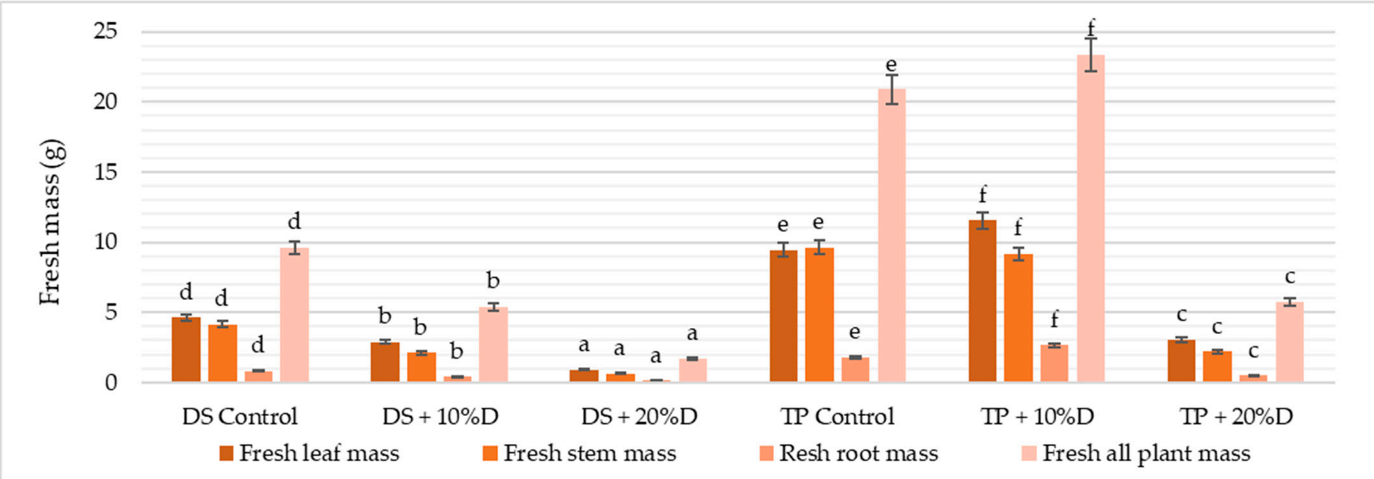

Figure 3. The effect of the solid grain waste digestate and peat substrate mixture on tomato seedlings' fresh leaves, stems, roots and all-plant mass. DS Control—direct seeding (Control/Peat); DS + 10% D—direct seeding + 10% peat digestate; DS + 20%—direct seeding + 20% peat digestate; TS—transplanting (Control/Peat); TS + 10%D—transplanting + 10% peat digestate; TS + 20% D—transplanting + 20% peat digestate. Means with different letters are significantly different at the $p < 0.05$ level according to Tukey's significant difference test. Error bars are shown as percentage.

The highest photosynthetic parameters were found in the leaves of transplanted seedlings + 10% peat digestate. The photosynthetic rate was increased by up to 31.9–50.3% and the concentration of intercellular CO_2 was 1.7 times higher compared with that for other experimental variants. Transplanted seedlings showed higher stomatal conductance (19.5–37.3%) and a 3.4–6.9-fold better transpiration rate (Table 2).

Table 2. The effect of the solid grain waste digestate and peat substrate mixture on photosynthetic parameters of tomato seedlings.

Treatments	Photosynthetic Rate, (μmol CO_2 m^{-2} s^{-1})	Stomatal Conductance, (H_2O mol m^{-2} s^{-1})	Intercellular CO_2, (μmol CO_2 mol^{-1})	Transpiration Rate, (Mmol H_2O m^{-2} s^{-1})
		Direct seeding		
(Control/Peat substrate)	7.18 b	0.021 a	166.76 c	0.81 a
Peat + 10% peat digestate	5.62 ab	0.014 a	248.71 a	0.58 a
Peat + 20% peat digestate	4.50 a	0.011 a	278.83 ab	0.48 a
		Transplanting		
(Control/Peat substrate)	9.73 d	0.41 d	339.74 b	2.83 c
Peat + 10% peat digestate	14.77 c	0.29 c	288.54 ab	2.36 b
Peat + 20% peat digestate	14.31c	0.22b	265.32a	1.93b

Means with different letters are significantly different at the $p < 0.05$ level according to Tukey's significant difference test.

4. Conclusions

The insertion of solid grain waste digestate (peat digestate) into peat substrate influenced the biometric parameters of tomato seedlings, their physiological parameters, and non-destructive measures. Transplanted seedlings grown in peat digestate were higher, had more leaves, and had a larger leaf area, as well as a larger fresh all-plant mass. The addition of peat digestate to the peat substrate resulted in better chlorophyll and nitrogen balance index (NBI) parameters in the tomato seedlings. The positive effect of the mixture of peat digestate and peat substrate on the photosynthetic parameters in the tomato seedlings was observed. A higher amount of peat digestate in the peat substrate increased the photosynthetic rate and intercellular CO_2. Transplanted seedlings showed a significantly higher transpiration rate and increased stomatal conductance in the leaves of seedlings. Furthermore, they showed the best development and the best results from all the experiment variants.

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References

1. Feng, J.; Xiangpei, H. An IoT-based Hierarchical Control Method for Greenhouse Seedling Production. *Procedia Comput. Sci.* **2021**, *192*, 1954–1963. [CrossRef]
2. Aragão, V.P.M.; Navarro, B.V.; Passamani, L.Z.; Macedo, A.F.; Floh, E.I.S.; Silveira, V.; Santa-Catarina, C. Free amino acids, polyamines, soluble sugars and proteins during seed germination and early seedling growth of *Cedrela fissilis* Vellozo (Meliaceae), an endangered hardwood species from the Atlantic Forest in Brazil. *Theor. Exp. Plant Physiol.* **2015**, *27*, 157–169. [CrossRef]
3. Paul, L.C.; Metzger, J.D. Impact of vermicompost on vegetable transplant quality. *Hort-Science* **2005**, *40*, 2020–2023. [CrossRef]
4. Chong, C.C.; Cheng, Y.W.; Ishak, S.; Lam, M.K.; Lim, J.W.; Tan, I.S.; Show, P.L.; Lee, K.T. Anaerobic digestate as a low-cost nutrient source for sustainable microalgae cultivation: A way forward through waste valorization approach. *Sci. Total Environ.* **2022**, *803*, 150070. [CrossRef] [PubMed]
5. Panuccio, M.R.; Attinà, E.; Basile, C.; Mallamaci, C.; Muscolo, A. Use of recalcitrant agriculture wastes to produce biogas and feasible biofertilizer. *Waste Biomass Valorization* **2016**, *7*, 267–280. [CrossRef]
6. Jain, S.; Newman, D.; Nzihou, A.; Dekker, H.; Le Feuvre, P.; Richte, H.; Gobe, F.; Morton, C.; Thompson, R. Global Potential of Biogas. Ph.D. Thesis, World Biogas Association, London, UK, 2019.
7. Lind, P.O.; Hultberg, M.; Bergstrand, K.-J.; Larsson-Jönsson, H.; Caspersen, S.; Asp, H. Biogas digestate in vegetable hydroponic production: pH dynamics and pH management by controlled nitrification. *Waste Biomass Valorization* **2021**, *12*, 123–133. [CrossRef]
8. Hüner, P.A.; Dahal, K.; Bode, R.; Kurepin, L.V.; Ivanov, A.G. Photosynthetic Acclimation, Vernalization, Crop Productivity and 'the Grand Design of Photosynthesis. *J. Plant Physiol.* **2016**, *203*, 29–43. [CrossRef] [PubMed]
9. Sala, F.; Arsene, G.G.; Iordănescu, O.; Boldea, M. Leaf Area Constant Model in Optimizing Foliar Area Measurement in Plants: A Case Study in Apple Tree. *Sci. Hortic.* **2015**, *193*, 218–224. [CrossRef]
10. Merzlyak, M.N.; Gitelson, A.A.; Chivkunova, O.B.; Rakitin, V.Y. Non-destructive optical detection of pigment changes during leaf senescence and fruit ripening. *Physiol. Plant.* **1999**, *106*, 135–141. [CrossRef]
11. Laužikė, K.; Uselis, N.; Kviklys, D.; Samuolienė, G. Orchard planting density and tree development stage affects physiological processes of apple (*Malus domestica* Borkh.) tree. *Agronomy* **2020**, *10*, 1912. [CrossRef]
12. Sakalauskas, V. *Duomenų Analizė su STATISTIKA*; Margi Raštai: Vilnius, Lithuania, 2003; p. 235.