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RESEARCH PAPER

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The Effects of Liquid Biogas Digestate on Yield and Mineral Nutrition of Cucumber Growing in Greenhouse

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Abstract

This study aimed to investigate the effects of a liquid fraction of digestate obtained from different biogas plants on the growth and mineral nutrition of cucumber plants under greenhouse conditions. For this purpose, Liquid Biogas Digestates (LBD) obtained from two different plants (A-B) with different properties were applied to pots with 10 kg of soil in 5 different doses (0, 20, 40, 60, and 80 t ha^{-1}) and the effects of the treatments were observed. As a result of the research, the highest yields increased 24.6% for digestate A in A5 (80 t ha^{-1}) and 29% for digestate B in B3 (40 t ha^{-1}) compared to control. While LBD contributed to the increase of N, Ca, Zn, Cu, and Mn concentrations in the leaf samples, it was observed that the dose increase did not have a linear effect on N, Ca, Zn, Cu, and Mn concentrations in the leaf samples. It is thought that liquid biogas wastes produced in biogas plants have positive effects on fruit yield, agricultural practices can be taken as the basis for the disposal of these wastes and the use of liquid biogas residues in soils by eliminating potential risks can provide significant benefits.

1. Introduction

Biogas is a colorless, odourless, lighter-than-air and flammable gas mixture that is the end product of the decomposition of organic waste and residues by various bacteria in an anaerobic environment (Weiland, 2010). Its composition includes 50-75% methane, 25-50% carbon dioxide, hydrogen sulphide (H_2S), hydrogen (H_2), ammonia (NH_3) (1-2%) and trace other gases as oxygen and nitrogen (Atelge et al., 2020). The waste that is released after biogas generation can be converted into a significantly more valuable fertilizer that is required for organic farming, so preventing pollution of the environment. Environmental health benefits from this conversion, especially in rural regions (Chang et al., 2011). The amount of solid and liquid digestate produced daily by an average-sized plant during the biogas production phase is approximately 1500 m^3 and approximately 95% of this waste is liquid fraction of digestate. It becomes quite difficult to dispose of such a large amount of liquid digestate. As the amount of these liquid biogas digestates, which are usually stored in lagoons or pools, increases, problems such as flies and bad odours cause environmental pollution. These wastes can seep through the soil and mix with groundwater and contaminating groundwater resources. For these reasons, the accumulation of these wastes cannot be continued for a long time. Although the composition of liquid biogas digestates is generally 93-99% water and 1-7% dry matter (Lukehurst et al., 2010), it contains significant amounts of mineral elements, enzymes and amino acids, as well as significant amounts of organic matter (OM) with a relatively low C/N ratio (Alburquerque et al., 2012).

There are some studies on the use of liquid biogas digestate and sludge in agriculture. The application of biogas sludge increases the amount of N-P-K in the soil, has a positive effect on parameters such as protein, soluble sugars and βcarotene in the plant, and also plays an important role in increasing the number of culturable bacteria and actinomycetes in the soil (Yu et al., 2010). Application of biogas sludge to plants increased plant height, root length, chlorophyll content, stomatal conductance and water use (Xu et al., 2013). Studies have shown that liquid biogas digestate and sludge application increased to plant growth, yield and nutrient uptake (Abubaker et al., 2012; Ferdous et al., 2018; İbil, 2019; Yaylacı and Erdal, 2021; Adamovics and Sivicka, 2023). Liquid biogas digestate and sludge had positive effects on the number of spikes per square meter, thousand grain weight, number of grains per spike, flag leaf area and grain yield, hectolitre weight, ash and protein content in cereals (Yaraşır et al., 2018; Karaman and Türkay, 2022).

This study was conducted to determine cucumber plant height, fresh and dry weight, fruit length, fruit diameter, yield and mineral nutrition status of the digestate fraction obtained from different biogas plants. Thus, it was aimed to reveal the possibilities of using problematic waste in the agricultural sector.

2. Material and Method

This research was carried out in the greenhouses of Akdeniz University Faculty of Agriculture in 2022. In the experiment, which was conducted under the pot conditions in the greenhouse, 5 different doses (0, 20, 40, 60 and 80 t ha^{-1}) of Liquid Biogas Digestate (LBD) obtained from two different biogas plants (A and B) were applied to the soils. The effects of the treatment doses of liquid biogas digestate on growth, yield and mineral nutrition were attempted to be determined (Table 1). LBD-A is a biogas plant located in Aksaray and produces biogas with a capacity of 1.067 MW using all agricultural waste and animal manure in the immediate vicinity of the plant. LBD-B is a biogas plant located in Malatya and produces biogas with a capacity of 3.12 MW using poultry manure, broiler manure and solid manure.

Greenhouse cultivation was carried out between September 15 and December 13, 2022, and the temperature change in the greenhouse during the cultivation period was recorded (Figure 1). It was observed that the day-night temperature differences increased due to the autumn growing season, but this situation did not reach levels that would prevent production.

Some soil properties in experiment were as follows: pH: 6.99, $CaCO_3$: 27.12%, loamy loam in texture, EC: 0.31 dS m^{-1}, organic matter content: 0.87%, total N: 0.30%, available P: 38.23 mg kg^{-1}, exchangeable K: 0.18 meq 100 g^{-1}, exchangeable Ca: 33.18 meq 100 g^{-1}, exchangeable Mg: 7.06 meq 100g^{-1}, available Zn: 0.38 mg kg^{-1}, available Mn: 4.53 mg kg^{-1} and available Cu: 1.48 mg kg^{-1}.

Table 1. Treatment rates of Liquid Biogas Digestates (LBD) from different biogas plants.

Treatment	Dose	Treatment	Dose
A1	0 t ha^{-1} LBD	B1	0 t ha^{-1} LBD
A2	20 t ha^{-1} LBD	B2	20 t ha^{-1} LBD
A3	40 t ha^{-1} LBD	B3	40 t ha^{-1} LBD
A4	60 t ha^{-1} LBD	B4	60 t ha^{-1} LBD
A5	80 t ha^{-1} LBD	B5	80 t ha^{-1} LBD

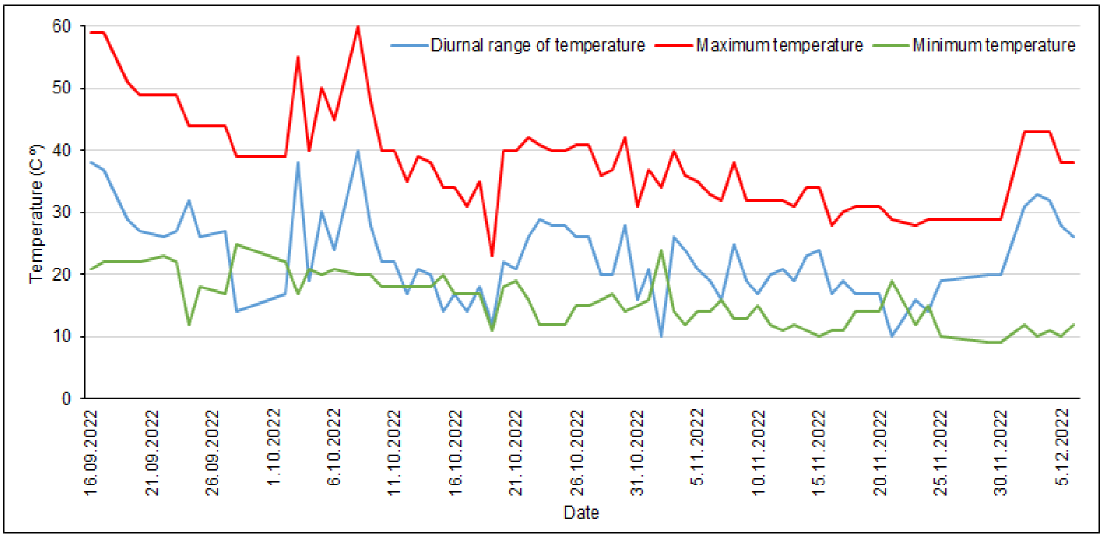

Figure 1. Temperature change in the greenhouse during the growing period.

The test plant used in the study was the cucumber variety Silor type YT-195. Silor type cucumber (YT-195) has short internodes, productive, dark green, long stem, high quality, 10-12 cm heigh, very good taste and flavour, long shelf-life. The experiment was designed according to the randomized block design with 4 replications, seedlings were planted separately for 2 different liquid biogas digestates in pots with 10 kg soil, with 1 plant in each pot, and all cultural procedures (irrigation, spraying, plant protection etc.) were applied equally to all pots during the cultivation process. During the growing period, 160 kg ha^{-1} N, 140 kg ha^{-1} P_2O_5, 290 kg ha^{-1} K_2O were applied equally to all pots 1-2 times a week with irrigation. Other plant nutrients were not applied to observe the effect of nutrient content of liquid biogas digestate. The application of liquid biogas digestates to the soil started 1 week after the seedlings were transplanted to the soil and was applied a total of 4 times, once every 14 days. In the control treatment, only water was applied. Some analytical results of the liquid biogas digestate used as treatment material are given in Table 2.

Plant height, plant fresh and dry weight, fruit length (cm), fruit diameter (mm) and fruit yield (g $plant^{-1}$) were determined in cucumber plants. Cucumber fruit length was measured using a ruler from one end to another, while fruit diameter was measured in three different locations on the fruit with caliper. Fruit weight was measured by placing it on an electronic scale and recording the weight.

In the experiment, leaf and fruit samples of cucumber plants were collected and after the necessary physical measurements, taken to the laboratory, washed, dried at 65°C to constant weight, then ground and prepared for analysis (Kacar and İnal, 2008). For plant analyses, total Nitrogen (N) was determined in cucumber leaf samples using the modified Kjeldahl Method (Bremner, 1965). In addition, for phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), zinc (Zn) and copper (Cu) analyses, plant samples were wet combusted and read by ICP-OES (Perkin Elmer-Optima 7000 DV) as reported by Soltanpour and Workman (1981).

Soil samples were analysed for pH (Jackson, 1967), lime ($CaCO_3$) (Evliya, 1964), electrical conductivity (Anonymous, 1988), composition (Bouyoucos, 1955), organic matter (Black, 1965), total N (Black, 1957), available P (Olsen and Sommers, 1982), extractable K, Ca and Mg, available Zn, Cu and Mn (Lindsay and Norvell, 1978; Knudsen et al., 1982).

In liquid biogas digestates, pH and EC were determined by pH-meter and EC-meter, and organic matter was determined by dry combustion at 550°C (Kacar, 1972), the dry matter content was measured by keeping it at 70°C until reaching stable weight, total nitrogen by devarda (Liao, 1981), P, K, Ca, Mg, Zn, Mn and Cu were determined by treating 1 g of fertilizer sample with 50 ml of water and 1 ml of concentrated nitric acid, adding to 100 ml, filtering and reading in an ICP-OES (Inductively Coupled Plasma-Atomic Emission Spectrometry-Perkin Elmer 700DV).

The results obtained from the laboratory analyses and measurements were subjected to Duncan's multiple comparison test by analysis of variance in the SPSS 17.0 package program (Yurtsever, 1984).

3. Results and Discussion

Some measurements and analyses were carried out on the leaf and fruit samples of the cucumber plant. The effects of two different liquid biogas digestates on plant height and plant fresh weight of cucumber plants were found to be statistically significant (Table 3), while plant dry weight values were not affected by the treatments.

LBD-A treatment A4 (60 t ha^{-1}) together with control produced the highest plant height, while the A5 (80 t ha^{-1}) produced the highest fresh weight. In the LBD-B treatment, the highest values for plant height and fresh weight were obtained with B3 (40 t ha^{-1}). There was no linear relationship between increasing doses and changing fresh and dry weights. LBD-A and LBD-B materials have different properties and show different changes in fresh and dry weight values. Plant height is

Table 2. Some analyses properties of Liquid Biogas Digestates (LBD) used in the experiment.

Parameter	LBD-A	LBD-B
pH	9.17	8.58
EC (dS m^{-1})	22.2	14.53
Organic matter (%)	1.46	3.7
Dry matter (%)	5.51	2.08
N (%)	1.47	2.48
P (%)	0.022	0.019
K (mg kg^{-1})	446.94	338.91
Ca (mg kg^{-1})	97.20	60.20
Mg (mg kg^{-1})	23.16	5.76
Zn (mg kg^{-1})	2.63	2.96
Mn (mg kg^{-1})	3.88	1.63
Cu (mg kg^{-1})	0.80	2.20

EC:Electrical conductivity, N:Nitrogen, P:Phosphorus, K:Potassium, Ca:Calcium, Mg:Magnesium, Zn:Zinc, Mn:Manganese, Cu:Copper

Table 3. Effects of different Liquid Biogas Digestates (LBD) on plant height, fresh and dry weight of cucumber plants.

Treatment	LBD-A			LBD-B		
	Plant height (cm)	Fresh weight (g)	Dry weight (g)	Plant height (cm)	Fresh weight (g)	Dry weight (g)
1	151.5±8.06[a]	229.3±7.93[b]	9.3±1.66	147.8±2.84[b]	198.6±6.33[c]	7.87±0.87
2	122.3±4.03[b]	167.0±6.34[c]	6.1±1.10	156.5±7.67[ab]	241.8±5.87[b]	7.85±1.95
3	129.3±3.07[b]	233.9±4.66[b]	7.7±1.03	170.3±4.77[a]	279.8±5.24[a]	7.61±2.47
4	144.3±4.09[a]	163.9±7.38[c]	5.9±0.58	151.0±3.81[b]	150.5±7.06[d]	5.83±1.22
5	123.3±2.02[b]	271.0±7.81[a]	8.6±2.38	145.5±4.56[b]	214.4±4.90[c]	8.45±0.66
F value	7.72***	44.69***	1.03[ns]	3.91*	66.28***	0.39[ns]

*p<0.05, ***p<0.001, ns: not significant

Table 4. Effects of different Liquid Biogas Digestates (LBD) on macro element concentrations in in cucumber leaf samples.

Treatment	LBD-A (%)				
	N	P	K	Ca	Mg
A1	2.55±0.15[ab]	0.30±0.01[a]	2.58±0.05[a]	2.26±0.02[c]	1.18±0.06
A2	2.32±0.73[b]	0.24±0.01[b]	2.23±0.07[b]	2.47±0.17[ac]	1.17±0.11
A3	2.66±0.04[a]	0.24±0.01[b]	2.12±0.02[b]	2.29±0.09[bc]	1.16±0.18
A4	2.67±0.09[a]	0.24±0.02[b]	2.26±0.06[b]	2.60±0.01[ab]	1.01±0.01
A5	2.85±0.09[a]	0.25±0.01[b]	2.22±0.09[b]	2.75±0.10[a]	0.99±0.08
F value	4.13**	7.68***	8.81***	4.21**	0.80[ns]
Treatment	LBD-B (%)				
	N	P	K	Ca	Mg
B1	4.09±0.11[a]	0.22±0.01	2.65±0.19	2.48±0.16	0.95±0.13
B2	4.16±0.21[a]	0.21±0.01	2.47±0.08	2.56±0.21	1.10±0.15
B3	4.60±0.13[a]	0.26±0.03	2.51±0.13	3.12±0.19	0.92±0.11
B4	2.80±0.26[b]	0.27±0.03	2.61±0.19	3.10±0.37	1.03±0.13
B5	2.71±0.11[b]	0.21±0.01	2.54±0.08	2.64±0.25	0.91±0.11
F value	24.90**	2.10[ns]	0.25[ns]	1.54[ns]	0.40[ns]

**p<0.01, ***p<0.001, ns: not significant. N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium.

Table 5. Effects of different Liquid Biogas Digestates (LBD) on microelement concentrations in cucumber leaf samples.

Treatment	LBD-A (mg kg^{-1})			LBD-B (mg kg^{-1})		
	Zn	Mn	Cu	Zn	Mn	Cu
1	6.72±0.65[a]	33.27±3.41	2.14±0.32[b]	5.49±0.28[b]	22.62±1.92	2.73±0.27
2	6.26±0.32[a]	29.31±1.31	4.61±0.69[a]	8.17±0.82[a]	26.24±3.25	2.33±0.15
3	4.67±0.40[b]	29.42±3.12	1.73±0.32[b]	8.45±0.70[a]	27.55±2.55	1.95±0.29
4	4.89±0.39[b]	25.73±1.34	2.42±0.18[b]	8.34±0.56[a]	28.54±4.06	2.24±0.47
5	4.70±0.18[b]	27.99±6.48	1.85±0.30[b]	5.62±0.38[b]	25.83±0.55	1.66±0.22
F value	5.37***	0.56[ns]	8.78***	6.87**	0.67[ns]	1.79[ns]

**p<0.01, ***p<0.001, ns: not significant. Zn: Zinc, Mn: Manganese, Cu: Copper.

increased by biogas liquid digestate and sludge, according to Ferdous et al. (2020) and Ronga et al. (2019). Baştabak (2019) found that biogas-fermented waste increased root and stem length in lettuce. Abubaker et al. (2012) reported that biogas sludge contributed to the increase in fresh weight of plants. Kouřimská et al. (2012) reported that the use of biogas liquid digestate improved the quality and yield of vegetables.

The effects of different liquid biogas digestates on macro element concentrations (%) in cucumber plants are shown in Table 4. Regarding the effect of LBD-A treatments on macro-element concentrations in cucumber leaf samples, the effect of treatments on all elements except Mg was found to be statistically significant. The highest values for N in cucumber leaf samples were obtained from A3, A4 and A5 treatments, while the control treatments gave the maximum value for P and K contents. The liquid biogas digestate had no effect on the P and K contents of the leaves. It was observed that the effect of LBD-B treatments on macroelement contents of cucumber leaf samples was only on N concentration and B1, B2 and B3 treatments gave maximum values. LBD-A material was more effective than LBD-B material for N and Ca in cucumber leaf samples. Biogas sludge is a readily available source of ammonium nitrogen in soil, which can increase plant N concentration and contribute to growth (Moller et al., 2008; Yu et al., 2010; Nkoa, 2014; Koszel and Lorencowicz, 2015). Applying biogas sludge to the soil improves its organic matter content, nutrient concentrations, water-holding capacity, and nitrogen use efficiency (Akanbi et al., 2010).

The effects of different liquid biogas digestates on micro-element concentrations (mg kg^{-1}) in cucumber leaf samples are shown in Table 5. The effects of LBD-A treatments on Zn and Cu in microelement concentrations in cucumber leaf samples were found to be statistically significant. In cucumber leaf samples, the highest values for Zn

Table 6. Effects of different Liquid Biogas Digestates (LBD) on fruit length, fruit diameter, yield per plant in cucumber.

Treatment	LBD-A			LBD-B		
	Fruit height (cm)	Fruit diameter (mm)	Yield (g plant^{-1})	Fruit height (cm)	Fruit diameter (mm)	Yield (g plant^{-1})
1	11.7±0.25	28.8±0.95	210.1±2.98^{c}	12.4±0.66	38.1±1.46^{a}	198.6±4.94^{cd}
2	12.9±0.42	29.2±0.52	194.2±2.99^{c}	12.1±0.16	29.1±0.76^{c}	245.4±6.87^{b}
3	12.2±0.33	30.6±1.62	254.2±7.39^{b}	13.1±0.39	34.0±2.15^{ab}	279.8±5.24^{a}
4	13.5±0.56	33.3±1.65	193.8±4.18^{c}	11.8±0.48	36.7±0.85^{ab}	195.5±5.50^{d}
5	13.0±0.57	33.1±2.29	278.5±8.90^{a}	11.8±0.36	33.5±0.91^{b}	214.4±6.69^{c}
F value	2.68^{ns}	1.88^{ns}	43.29***	1.39^{ns}	6.77**	36.52***

**p<0.01, ***p<0.001, ns: not significant.

Table 7. Effects of different Liquid Biogas Digestates (LBD) on macro element concentrations in cucumber fruits.

Treatment	LBD-A (%)				
	N	P	K	Ca	Mg
A1	1.56±0.09^{ab}	0.43±0.02^{b}	2.79±0.07^{b}	0.61±0.07^{bc}	0.32±0.02^{b}
A2	1.63±0.03^{a}	0.55±0.06^{a}	3.68±0.22^{a}	0.71±0.01^{ab}	0.41±0.01^{a}
A3	1.41±0.04^{b}	0.42±0.01^{b}	2.86±0.05^{b}	0.54±0.03^{c}	0.32±0.01^{b}
A4	1.42±0.03^{b}	0.48±0.02^{ab}	3.49±0.29^{a}	0.78±0.03^{a}	0.34±0.02^{b}
A5	1.54±0.05^{ab}	0.55±0.03^{a}	3.61±0.15^{a}	0.68±0.02^{ab}	0.35±0.01^{b}
F value	3.56*	3.40*	5.67**	6.04**	6.69**
Treatment	LBD-B (%)				
	N	P	K	Ca	Mg
B1	1.53±0.03^{b}	0.41±0.02^{b}	3.40±0.13	0.59±0.03	0.31±0.03
B2	1.31±0.02^{d}	0.45±0.03^{b}	3.41±0.20	0.61±0.03	0.33±0.03
B3	1.69±0.02^{a}	0.56±0.03^{a}	3.83±0.20	0.59±0.01	0.37±0.03
B4	1.42±0.04^{c}	0.49±0.02^{a}	3.43±0.15	0.55±0.04	0.33±0.02
B5	1.30±0.03^{d}	0.46±0.02^{b}	3.31±0.08	0.60±0.01	0.36±0.02
F value	30.76***	5.04**	1.62^{ns}	0.87^{ns}	0.97^{ns}

**p<0.01, ***p<0.001, ns: not significant. N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium.

were obtained from the A1 and A2 treatments, while the highest values for Mn were obtained from the A2 treatment. The effect of treatments on Mn content was not found to be significant. The effect of LBD-B treatments on the microelement concentrations of cucumber fruit was found to be substantial with respect to Zn content, with the B2, B3, and B4 treatments providing the highest values of Zn content. Liquid biogas digestates are rich in plant nutrients and organic contents that can be used in agricultural production (Bauer et al., 2009), and can increase macro and microelement contents in soils and plants (Chiew et al., 2015).

The effects of different liquid biogas digestates on cucumber fruit length, fruit diameter and yield per plant are shown in Table 6. Although the LBD-A treatments had no effect on cucumber fruit length and fruit diameter, the yield per plant values were found to be statistically significant. The highest yield values were produced from A5 (80 t ha^{-1}), which was the maximum dose and A5 increased yield by 24.6% compared to the control (A1). Fruit diameter and yield values in the LBD-B treatment were found to be statistically significant; in contrast, the control treatment had the highest fruit diameter value. B3 (40 t ha^{-1}) had the highest yield value per plant, and it increased yield by 29% when compared to treatment B1. The effect of LBD-B material is more effective than LBD-A material on fruit characteristics. Biogas digestates had a significant effect on cucumber yield (Adamovics and Sivicka, 2023). Yaraşır et al. (2018) and Różyło et al. (2017) reported that liquid biogas digestates had a significant effect on wheat yield. Makadi et al. (2008) reported that the use of liquid biogas digestates increased the yield, protein and amino acid content of soybean. Li et al. (2023) reported that biogas sludge applied at 3% (V/W) had the best ability to promote growth and suppress disease without the risk of soil salinization.

The effects of the different liquid biogas digestates on the concentrations of the macro-elements (%) in the cucumber fruit are shown in Table 7. The effect of LBD-A treatments on macro-element concentrations in cucumber fruit was found to be statistically significant. A2 had the highest concentrations of N, P, and Mg in the cucumber leaf samples; A2, A4, and A5 had the highest concentrations of K, and A4 had the highest concentrations of Ca. LBD-B treatments were effective only on N and P concentrations in cucumber macroelement, B3 was effective on N concentration and B3 and B4 were effective on P concentration. Fruit's nutrient content was enhanced by the of liquid biogas digestates, which provided enough nutrients for the plants. The use of liquid biogas digestates increases plant biomass, magnesium content and photosynthetic efficiency (Xu et al., 2013). Liquid biogas digestates contribute to plant N recovery, and this contribution is higher for liquid waste than for biogas slurry (Lukehurst et al., 2010). This nitrogen-rich material contributes to plant growth and nitrogen balance. Liquid biogas digestates can have similar effects to chemical

Table 8. Effects of different liquid biogas digestates on micro element concentrations in cucumber fruit.

Treatment	LBD-A (mg kg^{-1})			LBD-B (mg kg^{-1})		
	Zn	Mn	Cu	Zn	Mn	Cu
1	7.08±0.14^{d}	3.32±0.39^{b}	2.11±0.12^{c}	14.83±0.42^{c}	7.95±0.33^{b}	11.78±0.66
2	11.84±0.51^{c}	5.02±0.49^{b}	3.00±0.35^{c}	16.41±0.47^{c}	8.04±0.50^{b}	11.76±0.77
3	12.77±1.20^{c}	7.81±0.29^{a}	8.49±0.69^{b}	29.06±0.86^{a}	10.02±0.13^{a}	13.80±0.72
4	16.60±0.38^{b}	8.73±0.44^{a}	12.29±0.21^{a}	19.70±0.84^{b}	8.47±0.41^{b}	12.96±0.60
5	23.92±1.14^{a}	8.80±1.11^{a}	12.80±0.44^{a}	16.71±0.84^{c}	8.65±0.27^{b}	12.59±0.76
F value	62.84***	15.80***	148.39***	63.76***	5.69**	1.49^{ns}

**p<0.01, ***p<0.001, ns: not significant. Zn: Zinc, Mn: Manganese, Cu: Copper.

fertilizers on shoot and root dry mass and nutrient content (C, N, and P) (Barbosa et al., 2014). Biogas digestates provided high levels of P, K, and Mg in kohlrabi (Losak et al., 2014). Liquid biogas digestates provided the highest levels of macronutrients and unsaturated fatty acids in winter oilseed rape (Koszel et al., 2020).

The effects of different liquid biogas digestates on the concentrations of micro-elements (mg kg^{-1}) in cucumber fruits are shown in Table 8. The effect of the LBD-A treatments on the concentrations of microelements in the cucumber fruit samples was found to be statistically significant. The highest value for Zn content in cucumber fruit samples was obtained from A5, while the highest values for Mn content were obtained from A3, A4 and A5. A4 and A5 had the highest values for Cu content of fruits. It has been determined that the effect of LBD-B applications on the microelement contents of cucumber fruits was significant, and that B3 had the maximum values for Zn and Mn contents in the fruits. LBD treatments provided microelement enrichment in the fruit due to the microelement concentrations in their compositions. Liquid biogas digestate contains sufficient levels of plant nutrients (Yadav and Garg, 2016). Baştabak and Koçar (2020) stated that the contents of liquid biogas digestates are rich in nutrients useful for plants. Yaraşır et al. (2018) reported that liquid biogas digestates can be used as an alternative fertilizer for soil fertility and plant growth.

4. Conclusion

Liquid biogas digestates, which are anaerobic fermentation products of organic wastes used in biogas production facilities, are usually accumulated in large lagoons and ponds and these materials carry some environmental risks (odour, disease transmission by vectors, leakage into groundwater, etc.). Researches conducted in this context show that liquid biogas digestates can be used in agricultural areas by taking the necessary precautions. In this study, it was determined that treatment doses of 40-80 t ha^{-1} were effective on plant growth (plant height, fresh and dry weight, fruit length, fruit diameter), yield and some mineral nutrient values of fermented liquid digestates obtained from different biogas plants and dose increases did not have a linear effect on the studied parameters. It was observed that liquid biogas digestates do not have a homogeneous structure and may have different properties due to the fact that the materials produced in each biogas plant consist of materials with different contents. In order to prevent the environmental risks of liquid biogas digestates, alternative methods of management and treatments that contribute to production should be planned in advance. Pasteurization can be done against possible pathogen risks and can be used with dilution to reduce the risk of salinity. Product-based research should be carried out on the use of these products in agriculture and possible risks should be determined.

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