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Research Article

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Effect of Treated Sewage Sludge on Heavy Metal Content of Vetch + Barley Mixture

Seda Rajabi Khiabani, Ahmet Esen Celen*

Ege University, Faculty of Agriculture, Dept. of Field Crops, Bornova, İzmir, TURKEY
*Corresponding author: esen.celen@ege.edu.tr

Abstract This study was carried out to determine the effect of vetch + barley mixture of treated sewage sludge on heavy metal content. The research was conducted in Randomized Complete Block Design with four replicates in experimental fields of Department of Field Crops, Faculty of Agriculture, Ege University for two years between 2015-2017. In the trial 10, 20 and 30 t ha^{-1} sewage sludge was applied in addition to the control and mineral fertilizer application. Copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni) and cadmium (Cd) contents were investigated in vetch + barley mixture. As a result of the research, it was found that sewage sludge applications had no significant effect on Cu, Mn and Ni content of mixture, but caused a decrease in Zn and Cd contents.

Keywords Heavy metal, sewage sludge, vetch + barley mixture

Introduction

In many countries, various projects are carried out for the recycling of urban wastes, vegetable wastes are converted into compost, and the number of wastewater treatment plants is increasing day by day. Research and studies for the evaluation of stabilized wastes in agricultural areas have recently gained momentum all over the world [1]. Increasing soil pollution caused by heavy metals has become a serious environmental problem for the world due to agricultural and industrial activities [2]. The presence of heavy metal presence in sewage sludge used as agricultural fertilizer is a major problem for soil and product quality. Therefore, sewage sludge should be used carefully and limit values should not be exceeded. Sewage sludge contains some nutrients and organic substances and can be used as a substitute for commercial plant fertilizers [3]. Considering the preservation and improvement of the structural properties of the soil, it is necessary to mix organic and inorganic materials into the soil at the right time and in an effective manner, to control the environmental conditions and to perform the interventions required by the conditions [4-5].

The use of sewage sludge in agriculture is a worldwide practice and is a very effective sludge disposal technique [6-7-8]. The rate of use of sewage sludge as fertilizer varies between 10–80% in European countries. What makes it possible to use sewage sludge as fertilizer is that it contains high organic matter in addition to the plant nutrients it contains. However, if the sewage sludge is to be used as fertilizer, these values should be under the limits of laws and regulations, considering that it may contain toxic substances and disease factors. In this regard, the Solid Waste Control Regulation and the Soil Pollution Control Regulation specified in the Turkish Environmental Legislation give benchmark values for the use of treatment sludge in agriculture [5-9].

The fact that sewage sludge is not free of pathogens also threatens human health. The sludge resulting from the treatment system process in treatment sludge may contain salt, pH, heavy metals and toxic substances. The occurrence of heavy metal accumulation in the soil where these sewage sludges are applied should be considered as limiting factors in the use of these organic material resources [10]. In developed countries, sewage sludge is analyzed and its negative effects are reduced by many processes and used as fertilizer in agriculture [11-12-13].

Working with sewage sludge, [14] stated that the content of heavy metals (Cd, Pb, Cu, Zn) in soil and plants may be low depending on the sludge application, and this may be caused by the low bioavailability of heavy metals. Researching the fertilizer requirement of winter wheat by giving treatment sludge, [15] reported that sludge application increased the yield of wheat and the nutrient elements of the grain such as N, P, Zn and Cu. [16] pointed out that the application of sewage sludge in agricultural areas is a widely accepted method, and it is necessary to be careful in terms of heavy metal levels as well as increasing productivity. [17] reported that Cd, Cu, Zn concentrations increased significantly in sludge treated maize.

Material and Method

This study was established in the trial areas of Ege University Faculty of Agriculture, Department of Field Crops in 2015-2016 and 2016-2017The sewage sludge used in the research was obtained from Izmir Metropolitan Municipality IZSU Cigli Wastewater Treatment Plant. The Alper variety of vetch and Sancak variety of barley, which were obtained from the Aegean Agricultural Research Institute, constituted the material of our study. The soil of the experimental area has a clay loam texture and is slightly alkaline. Lime soil is poor in organic matter. The amount of available Cu, Zn and Mn of the trial soil is sufficient, while the Fe content is low. Some physical and chemical properties and plant nutrient content of the soil sample taken from the trial area are given in Table 1.

Table 1: Some physical and chemical properties of the soil of experimental area

Analysis	**Result**	**Evaluation**	**Method**
Ph	7,51	slightly alkaline	[18]
EC (µS cm^{-1})	920	no risk of salinity	[18]
Organic Matter (%)	1,17	Low	[18]
Lime (%)	9,91	Limy	[19]
Sand (%)	40,80		[20]
Clay (%)	34,94	clay loam	
Shaft (%)	24,26		
Total N (%)	0,094	Middle	[21]
Available P (mg kg^{-1})	21,12	Enough	[22]
Available K (mg kg^{-1})	352	High	[23]
Available Ca (mg kg^{-1})	6875	very high	
Available Na (mg kg^{-1})	30,8	very low	
Available Mg (mg kg^{-1})	304,2	High	
Available Fe	4,39	Missing	[24]
Available Mn	7,58	Enough	
Available Zn	1,38	Enough	
Available Cu	1,66	Enough	

Table 2: Climate data for the research years and long years average of the trial area (IARTC., 2012)

	long years average (1970-2013)		**2015**		**2016**		**2017**	
	AT (°C)	**TP (mm)**	**AT (°C)**	**TP (mm)**	**AT (°C)**	**TP (mm)**	**AT (°C)**	**TP (mm)**
January	9.0	112.2	8.9	125.1	8.5	161	6.3	237.6
February	9.2	99.7	9.5	101.9	13.6	76.5	10.4	55.6
March	11.8	82.9	11.7	75.6	13.8	103	13.3	72.2
April	16.1	46.4	15.9	46.4	18.9	12.8	16.6	15.7

May	21.0	25.4	20.8	30.9	21.2	28.2	21.7	27
June	26.0	7.5	25.6	9.8	27.7	9.2	26.5	1.8
July	28.3	2.1	28.0	1.8	29.9	1.2	29.8	1.4
August	27.9	1.7	27.7	2.6	29.4	3.0	29.4	0.3
September	23.9	19.9	23.7	15.0	25.1	6.4	24.6	0.9
October	19.1	43.2	18.8	45.3	19.2	1.4	18.8	45.7
November	13.8	109.7	14.0	94.8	14	101	13.3	62.1
December	10.5	137.9	10.6	141.1	6.8	15.2	11.8	73.9
Av./Total.	**18.1**	**688.9**	**17.9**	**690.3**	**19.0**	**518.6**	**18.5**	**594.2**

AT: Average Temperature

TP: Total Precipitation

Treated sewage sludge (TSS) used in the experiment has a high organic matter content and is rich in organic carbon. The heavy metal values it contains are below the limit values specified in the regulation (Table 4). As a result of the analysis made before the experiment in the parcels where traditional fertilizer application was made, the nutrients in the soil were completed by giving 15-15-15 compound fertilizers as 60 kg N ha^{-1}, P_2O_5 and K_2O. In the parcels where treated sewage sludge was applied, 10, 20 and 30 t ha^{-1} [25] of treated sewage sludge was mixed into the soil before planting. In this study, hand sowing was carried out with 150 kg ha^{-1} vetch and 50 kg ha^{-1} barley [26].

Table 3: Analysis results of the sewage sludge used in the experiment

pH (1/10)		7.18	**Na**	Mg kg^{-1}	1390.5
EC (1/10)	µS cm^{-1}	1945	**Fe**	Mg kg^{-1}	12754.96
organic matter	%	51.20	**Cu**	Mg kg^{-1}	176.5
Organic C	%	29.66	**Zn**	Mg kg^{-1}	1376.59
Lime	%	5.35	**Mn**	Mg kg^{-1}	350
N	%	2.99	**Ni**	Mg kg^{-1}	69.73
P	%	0.2275	**Pb**	Mg kg^{-1}	17.44
K	%	0.34	**Cr**	Mg kg^{-1}	112.53
Ca	%	6.36	**Cd**	Mg kg^{-1}	2.83
Mg	%	2.04	**B**	Mg kg^{-1}	16.1

Table 4: Heavy metal limit values in the soil where sewage sludge will be used

Heavy metal (Total)	**6≤pH<7 mg kg^{-1} Oven Dry Soil**	**pH≥7 mg kg^{-1} Oven Dry Soil**
Lead	70	100
Cadmium	1	1.5
Crom	60	100
Copper	50	100
Nickel	50	70
Zinc	150	200
Mercury	0,5	1

Regulation on the Use of Domestic and Urban Sewage Sludge in Soil (Official Gazette Number: 27661, 2010)

The study was carried out in the experimental areas of the Ege University, Faculty of Agriculture, Department of Field Crops, in a randomized block design with 4 replications. Sowing was done by hand on 08.12.2015 in the first year and on 12.12.2016 in the second year. In the experiment, parcel size was 2 m x 5 m = 10 m2 and there were 10 rows with 20 cm apart in each parcel. Since study was carried out during the winter period, no irrigation was applied. Weeds were removed by hand as needed. Since yield and yield-related characters of the experiment were used in another article, only heavy metal contents of vetch+barley mixture were given in this article. Some physical and chemical properties and nutrient contents of the soil sample taken from the experimental area are given in Table 1.Data from the trial was performed analysis of variance by using PASW statistics package program, and the LSD (0.05) test was used to compare the significant means [27].

Results and Discussion

The results regarding the effects of the applications on the copper, zinc and manganese content of the vetch+barley mixture are given in Table 5. As it can be seen in Table 5, while there was no difference between the applications in both years on the copper and manganese content of the mixture, there was a difference on the zinc content only in the first year. While the copper content of the mixture varied between 9.02-10.24 mg kg^{-1} in the first year, it varied between 7.70-10.45 mg kg^{-1} in the second year. Considering the zinc content of the mixture, the highest zinc content was obtained from the control application with 29.73 mg/kg in the first year. Also, the lowest zinc contents were obtained as 24.59 and 23.99 mg/kg from 10 t ha sewage sludge and mineral fertilizer applications respectively. The manganese content of the mixture varied between 29.48-34.52 $mgkg^{-1}$ in the first year and between 29.64-32.62 $mgkg^{-1}$ in the second year.

Table 5: The effect of the applications on Cu, Zn and Mn content of vetch + barley mixture

Applications	Cu		Zn		Mn	
	2015	2016	2015	2016	2015	2016
Control	10.24	7.70	29.73 a	23.15	34.52	32.62
10 $t.ha^{-1}$ TSS	9.67	9.65	24.59 b	23.17	31.33	29.64
20 $t.ha^{-1}$ TSS	9.46	9.94	27.49 ab	25.39	30.62	31.21
30 $t.ha^{-1}$ TSS	9.16	10.45	27.03 ab	25.78	32.39	31.92
mineral fertilizer	9.02	9.62	23.99 b	23.43	29.48	31.0
LSD (0.05)	n.s.	n.s.	3.72	n.s.	n.s.	n.s.

*: $P < 0.05$ There are significant differences at the 0.05 level between the means in the same column.

The effect of sewage sludge and mineral fertilizer applications on the nickel and cadmium content of barley + vetch mixture is shown in Table 6. As can be seen in Table 6, the effect of the applications on the Nickel content appeared insignificant in both years, while there were differences in the cadmium content between the applications in the first year, and the applications did not have a significant effect on the cadmium content in the second year. The nickel content of the mixture varied between 2.06-2.63 mg kg^{-1} in the first year, and between 1.73-2.11 mg kg^{-1} in the second year. Considering the cadmium content of the mixture, the highest Cd content was obtained from the mineral fertilizer application with 0.99 mg kg^{-1} in the first year, while the lowest Cd content was taken 0.87 mg $kg^{-1}$from the sewage sludge application of 20 t ha^{-1}. In the second year Cd contents varied between 1.11-1.22 mg kg ha^{-1}.

Table 6: The effect of the applications on Ni and Cd content of vetch + barley mixture

Applications	Ni		Cd	
	2015	2016	2015	2016
Control	2.38	1.97	0.95 ^{ab}	1.14
10 $t.ha^{-1}$ TSS	2.41	2.11	0.93 ^{abc}	1.11
20 $t.ha^{-1}$ TSS	2.16	1.76	0.87 ^{c}	1.17
30 $t.ha^{-1}$ TSS	2.06	1.89	0.91 ^{bc}	1.22
mineral fertilizer	2.63	1.73	0.99 $_{a}$	1.15
LSD (0.05)	n.s.	n.s.	0.07	n.s.

*: $P < 0.05$ There are significant differences at the 0.05 level between the means in the same column

In our study, it was observed that the treatment sewage sludge application had different effects on heavy metal content of the vetch+barley mixture. While the sewage sludge had no effect on Cu, Mn and Ni contents of vetch+barley mixture, Zn and Cd contents were affected from sewage sludge only first year. But, many researchers working on similar fields stated that the content of many heavy metals in plants increased with treatment sludge application [28-29-30]. [28] stated that, in parallel with the increase in the amount of sewage sludge used, the concentrations of Ni, Cd, Cu, Cr, Pb and Zn increased, while the amount of Mn decreased. Researchers attributed this decrease to the antagonistic effect between Cd and Mn. Indeed, [31] also found lower Mn in the presence of high Cd in lettuce grown on agricultural soil to which composted sewage sludge was added. The Cd limit value in the soil where the treatment sludge will be used is between 1.0-1.5 at different pH levels, as seen in Table 4. The amount of Cd in the sewage sludge used is 2.83 (Table 3), which can be considered high. Low Mn values in our study can be considered compatible with the results of these researchers.

Vigerust and [32] found a tendency to accumulate heavy metals such as Zn, Cd, Ni, Cu, Pb and Cr in plants grown in sludge modified soil. The researchers stated that not all heavy metals in the soil are equally absorbed by plants and that even absorption is not a concentration-dependent phenomenon for all heavy metals. [28] stated that the ability of plants to transport heavy metals from roots to shoots is measured by calculating the translocation factor (TF), and they mentioned that if TF value is less than 1 more heavy metals accumulated in the root. [33] attributed less heavy metal accumulation in shoots to the complexation of heavy metals with sulfhydryl groups in roots. [34] also reported Cr, Zn and Mn accumulation in all parts of B. juncea grown at increasing sludge change rates, but all heavy metals were maximum in the roots. In our study, heavy metal analysis was not performed on the roots. Therefore, it can be said that the absence of significant heavy metal differences in the aerial parts of the plant compared to the control is consistent with the results of these researchers.

Conclusion

In this study, in which the effect of treated sewage sludge on the heavy metal contents of the vetch + barley mixture was investigated, when the results were evaluated in general it was found that although sludge applications had no significant effect on Cu, Mn and Ni contents of the plant it decreased the Zn and Cd contents. It can be said that 2 t/da of treated sewage sludge can be used in this and similar mixtures, considering both the necessity of soil analysis before planting and the heavy metal pollution that the treatment sludge may cause in soil and groundwater.

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References

[1]. Yalcin G, Yavuz R, Yilmaz M, Taspinar K, Ates O. (2010). Evaluation of sewage sludge on agricultural lands, Journal of Engineering Sciences. Eskisehir Soil and Water Resources Research Institute, Eskisehir. 156-164.

[2]. Li F, Zeng XY, Wu CH, Duan ZP, Wen YM, Huang GR, Long XL, Li MJ, Li MJ, Xu JY. (2013). Ecological risks assessment and pollution source identification of trace elements in contaminated sediments from the Pearl River Delta, China. Biol Trace Elem Res 155: 301-313. DOI: http://dx.doi.org/10.1007/s12011-013-9789-2

[3]. Daud MK, Quiling H, Lei M, Ali B, Zhu SJ. (2015). Ultrastructural, metabolic and proteomic changes in leaves of upland cotton in response to cadmium stress. Chemosphere 120: 309-320. DOI: http://dx.doi.org/10.1016/j.chemosphere.2014.07.060

[4]. Cevheri C, Polat T. (2009). Past, Analysis of the socio-economic profile of fodder crops producer farmers' in Sanlıurfa. HR. U.Z.F. Journal. 13(1): 63-76

[5]. Delibacak S, Kayıkcıoglu HH, Okur IB, Yagmur B, Ongun AR. (2007). Effects of Urban Sewage Sludge Application on Yield and Some Soil Properties in Peanut and Barley Vetch Mixture Production. Higher Education Institutions Supported Project.

[6]. Cerqueira B, Vega FA, Serra C, Silva LF, Andrade M. (2011). Time of flight secondary ion mass spectrometry and high-resolution transmission electron microscopy/energy dispersive spectroscopy: a preliminary study of the distribution of Cu2+ and Cu2+/Pb2+ on a Bt horizon surfaces. J Hazard Mater. 422–431.

[7]. Cerqueira B, Vega FA, Silva LF, Andrade L. (2012). Effects of vegetation on chemical and mineralogical characteristics of soils developed on a decantation bank from a copper mine. Sci Total Environ. 421-422: 220–229

[8]. Arenas-Lago D, Vega FA, Silva LFO, Andrade ML. (2013). Soil interaction and fractionation of added cadmium in some Galician soils. Micro chem J. 110: 681–690.

[9]. Uzun P, Bilgili U. (2011). Possibilities of Using Sewage Sludge in Agriculture. Journal of Agricultural Faculty of Uludag University. 25(2): 135-146
[10]. Akyarli A, Sahin H. (2005). Use of Sludge in the Disposal of Sewage Sludge. I. National Sewage Sludge Symposium. MCH 2005 23-25 March 2005, Izmir.
[11]. Sommer LE. (1977). Chemical Composition of Sewage Sludges and Analysis of Their Potential as Fertilizers. J. Environ. Quality. 6: 225-239.
[12]. Pedreno NJ, Gomez I, Moral R, Mataix J. (1996). Improving the agricultural value of a semi-arid soil by addition of sewage sludge and almond residue, Agriculture Ecosystems and Environment. 58: 115-119.
[13]. Berthet B, Amiard JC, Triquet CA, Maillet Metayer C, Bahec JL, Letard M and Pelletier J. (1989). Fate of metals linked with sewage sludge or municipal refuses used as improvements in market gardening. Wat. Sci. Tech. 21(12): 1917-1920.
[14]. Menelik G, Reneau RB, Martens Jr DC, Simpson TW. (1991). Yield and elemental composition of wheat grain as influenced by source and rate of nitrogen. Journal of Plant Nutrition, 14 (2): 205-217
[15]. Smith SR. (1994). Effect of soil pH on availability to crops of metals in sewage sludge-created soils. I. Nickel, copper and zinc uptake and toxicity to ryegrass. Environ Pollut. 85(3): 321–327. DOI:10.1016/0269-7491(94)90054-X
[16]. Logan TJ, Lindsay BJ, Goins LE, Ryan JA. (1997). Field assessment of sludge rate response. J. Environ. Qual. 26(2): 534-550
[17]. Jackson ML. (1967). Soil Chemical Analysis. Prentice-Hall of India Private Limited Newdelhi.
[18]. Schlichting E, Blume HP. (1966). Bodenkundliches Praktikum. Verlag Paul Paney, Hamburg Und Berlin
[19]. Bouyoucos G.J. (1962). Hydrometer method improved for making particle size analysis of soil. Agronomy Journal. 54(5): 464– 465.
[20]. Bremner JM. (1965). 'Total Nitrogen', in C. A. Black (Ed.). Methods of Soil Analysis. Part 2, American Society of Agronomy Inc., Madison, Wisconsin, USA. 1149-1178.
[21]. Olsen SR, Sommers LE. (1982). Do Plants Have a Choice of Traits to Be Modulated. Evidence from an Invasive Plant Mikania micrantha Kunth in Different Urban Environments.
[22]. Pratt PF. (1965). Potassium. In: C A Black (Ed), Methods of Soil Analysis Part II: Chemical and Microbiological Properties, Madison, Wisconsin: ASA, pp. 1023-1031
[23]. Lindsay WL, Norvell WA. (1978). Development of a DTPA Soil Test For Zn, Fe, Mn and Cu. Soil Amer. J. 42 (3): 421-428
[24]. Ozyazici, M.A. (2013). Effects of sewage sludge on the yield of plants in the rotation system of wheat-white head cabbage-tomato. Eurasian Journal of Soil Science, 2(1):35 - 44
[25]. Tan, M. Serin, Y. (1996). A Study on the Determination Of Optimum Mixture Rates and Cutting Stages for Different Vetch + Cereal Mixtures. Ataturk University Faculty of Agriculture der. 27(4): 475-489.
[26]. Steel, R.G.D. Torrie, J.H. (1980). Principles and Procedures of Statistics. McGraw Hill Book Co., Inc., New York
[27]. Singh, R.P. Agrawal, M. (2007). Effects of sewage sludge amendment on heavy metal accumulation and consequent responses of Beta vulgaris plants. Chemosfer. 67(11):2105-2312
[28]. Hernández, T. Moreno, J.I. and Costa, F. (1991). Influence of sewage sludge application on crop yields and heavy metal availability. Soil Science and Plant Nutrition. 37(2): 201-210
[29]. Al Zoubi, M.M. Arslan, A. Abdelgawad, G. Pejon, N. Tabbaa, M and Jouzdan, O. (2008). The effect of sewage sludge on productivity of a crop rotation of wheat, maize and vetch) and heavy metals accumulation in soil and plant in aleppo governorat. American-Eurasian Journal of Agriculture & Environ. Sience, 3(4): 618-625
[30]. Moreno, J.L., Garcia, C., Hernandez, T., Ayuso, M., 1997. Application of composted sewage sludges contaminated with heavy metals to an agricultural soil: effect on lettuce growth. Soil Sci. Plant Nutr. 4, 565– 573

[31]. Selmer-Olsen, S. (1986). Basis for metal limits relevant to sludge utilization. Editor: Davis, R.D. Haeni, H. CRC Press. 25-110
[32]. Singh, S., Sinha, S., 2004. Scanning electron microscopic studies and growth response of the plant of Helianthus annus L. grown on tannery sludge amended soil. Environ. Int. 30, 389–395
[33]. Singh, S., Sinha, S., 2005. Accumulation of metals and its effects in Brassica Juncea (L.) Czern. (cv. Rohini) grown on various amendments of tannery waste. Ecotoxicol. Environ. Safety 62, 118–127