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Effects of Sewage Sludge used as Fertilizer on Heavy Metal Contents of Bird's-Foot Trefoil (*Lotus corniculatus L.*) and Soil

V. SARUHAN[1,*], I. GUL[1], A. KUSVURAN[2] and F. AYDIN[3]

[1]Dicle University, Faculty of Agriculture, Field Crops Department, 21280 Diyarbakir, Turkey
[2]Cankiri Karatekin University, Kizilirmak Vocational High School, 18100 Kizilirmak, Cankiri, Turkey
[3]Dicle University, Faculty of Science Chemistry Department, 21280 Diyarbakir, Turkey

*Corresponding author: Fax: +90 412 248815; Tel: +90 412 2488509 / 8538; E-mail: veysel_saruhan@hotmail.com

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This study was carried out to determine the effects of the sludge which was provided from a wastewater refinement facility of Municipality of Diyarbakir on bird's-foot trefoil plant production and its soil properties. For this purpose, the increasing level of sewage sludge has been applied to the soil samples which are taken from the plant rotation field of Dicle University campus area in Turkey and this sludge was left. At the end of study, the chemical properties of the soil have been determined and the results have been compared statistically. In this study three times reiterated randomized blocks design type has been established in the pod to determine the effects of the sludge to the plants and also the mineral content (Hg, Cr, Zn and Ni) of bird's-foot trefoil plant. The sludge that was applied to the soil with increasing amounts, raised the heavy metal content of bird's-foot trefoil plant, but this raising did not line-out for allowable limit.

Key Words: Bird's foot trefoil, Heavy metal, ICP-OES, Sewage sludge, Soil.

INTRODUCTION

In recent years, the use of urban and industrial wastes for the productivity of soil has been increasing steadily. Since sewage sludge is rich in nutritional elements, using it in agricultural fields might be a good way of reusing these elements and protecting the natural resources. Using the sewage sludge as fertilizer is regarded as an important approach not only in respect of recycling nutritional elements but also disposing of sewage sludge as well[1]. Moreover, these wastes can be used in the recovery of unproductive fields. In addition to the nutritional elements in the sewage sludge, using the urban sewage sludge in the soil can bring important benefits to municipalities in their annual operational costs. Using the sewage sludge in the soil ameliorates physical and chemical features of soil and increase the vegetable productivity of soil[2].

It has been reported that certain trace elements such as Zn and Cu can be frequently missing in soils that have been long cultivated[3] and that using the sewage sludge might assists eliminating the deficiency of these metals[4].

However, using the sewage sludge in the soil poses toxic effects since heavy metals such as manganese, zinc, copper, chrome, cobalt, nickel, lead, selenium, mercury and cadmium are found in the sludge in high concentrations. Coexistence of such elements in high concentrations creates toxic effects on plants and some of them accumulate in the food chain and pose a danger against humans and animals. For that reason, in order not to cause environmental hazard, the specifications of the sewage sludge and heavy metal levels in plants and soil after application should be determined experimentally according to plant type, climate and soil conditions[2].

The elements that have the potential to cause toxic effect as a result of accumulation in time are defined as potentially toxic elements (PTE). The potentially toxic elements limit values that are permitted in the USA and EU countries and in the Regulation for the use of Urban and Municipal Sewage Sludge on Soil (RUUMSSS) in Turkey for the use of sewage sludge in soil are given in Table-1[5]. It has been reported that sewage sludge is richer than farm manure in respect of nitrogen, phosphorus and zinc amounts[6].

In a study where the effect of heavy metals in the soil and pastures in the long term is studied with application of urban sewage sludge in the pastures, the researchers applied the sludge for three years in 25, 50 and 75 m^3 ha^{-1} $year^{-1}$. In conclusion, they reported the annual heavy metal intake in pastures to be 0.04 for Cu, 0.09 for Zn and 0.02 mg kg^{-1} for Pb[7]. In similar studies, it was determined that heavy metal content increases with the increase in waste sludge amount added to soils[8,9].

In a similar study in the province of Diyarbakir, researchers reported that fresh and dried grass productivity increases in parallel to the increase of doses in plants with waste sludge application in varying doses applied to bird's-foot trefoil plant[10].

TABLE-1
HEAVY METAL LIMIT VALUES PERMITTED FOR SEWAGE SLUDGE TO BE USED IN THE SOIL (mg kg^{-1}, DRIED SUBSTANCE)

Country	Cd	Cr	Cu	Hg	Ni	Pb	Zn
USA (EPA)*	85	3000	4300	57	420	840	7500
EU**	40		1750	25	400	1200	4000
Turkey***	10	1000	1000	10	300	750	2500
Turkey****	15	1500	1200	10	300	1500	3000

*Limited use. Cannot exceed a certain loading ratio annually (USA/EPA503, 1999); ** Maximum values recommended in member states (86/278/EEC, 2009); *** Maximum heavy metal content permitted in sewage sludge that can be used in the soil, pH 6.0-8.5 (RUUMSSS, 2010);**** Ten years in the soil.

In other study which was conducted by the cooperation of New York State University and Amherest Municipality, the changes in Zn, Cu, Ni, Pb and Cd concentration of soil and plant were examined with the aim of determining whether the sewage sludge in agricultural soil would be used as a commercial fertilizer and whether it would cause heavy metal accumulation or not. According to the results of this study, it was concluded that there was a slight increase in Cu content of soil and Zn content of the plant with the addition of sewage sludge and this application was beneficial[11]. In pot trials with wheat plant, it was determined that sewage sludge that was applied in increasing ratios increased plant's dry weight and also nitrogen, phosphorus and potassium intake[12].

Forages have important role in ruminant nutrition in terms of providing energy, protein and minerals. Bird's foot trefoil (*Lotus corniculatus* L.) is one of the self-generating plants in native pasture in Turkey[13]. The nutritive value of bird's foot trefoil was comparable with other legumes[14].

The purpose of present study is to research the effect of sewage sludge that is obtained from Waste Water Sewage Facilities of General Directorate of Water and Sewerage Administration of Diyarbakir Metropolitan Municipality in the contents of some of the heavy metal elements (Hg, Cr, Zn and Ni) in bird's-foot trefoil plant and in the soil and it has also been aimed to constitute a resource for similar studies in determining the appropriate dose for the application of waste sludge in the soil as a fertilizer.

EXPERIMENTAL

In this study, the sewage sludge that is obtained from Waste Water Sewage Facilities of General Directorate of Water and Sewerage Administration of Diyarbakir Metropolitan Municipality was used as fertilizer and bird's-foot trefoil (*Lotus corniculatus* L.) was used as plant material.

At the end of experiment, the effect of waste sludge in heavy metal levels of Hg, Cr, Zn and Ni in soil and bird's-foot trefoil plant in increasing doses was analyzed. The analysis values of Hg, Cr, Zn and Ni in sewage sludge permitted according to Regulation for the use of Urban and Municipal Sewage Sludge on Soil (RUUMSSS) and the values of these metals in our sewage sludge are given in Table-2[5].

TABLE-2
COMPARISON OF HEAVY METAL ANALYSES RESULTS OF SEWAGE SLUDGE OBTAINED FROM WASTE WATER SEWAGE FACILITIES OF GENERAL DIRECTORATE OF WATER AND SEWERAGE ADMINISTRATION OF DIYARBAKIR METROPOLITAN MUNICIPALITY AND MAXIMUM HEAVY METAL VALUES PERMITTED IN THE SEWAGE SLUDGE TO BE USED IN THE SOIL (mg kg^{-1})

	Cr	Ni	Zn	Hg
Hamburg Stadtentwasserung	69	77	753	1.1
RUUMSSS	1000	300	2500	10

Other chemical and physical features of our sewage sludge are given in Table-3[15]. Furthermore, radioactivity analysis of this sewage sludge was conducted by Turkish Atomic Energy Authority and it was reported that the radioactivity values were found to be within natural radiation levels and there was no problem in using them.

TABLE-3
CERTAIN PHYSICAL AND CHEMICAL FEATURES PERTAINING TO SEWAGE SLUDGE USED AS FERTILIZER

Parameters	Test Results	Unit	Method
Colour	Dark brown		DIN EN ISO 7887
Odor	Mould odor		DIN 38 403-B1/2
Density	Solid		Sensonical
Total solidity	39.5	%	DIN 38 414-S2
Volatile solidity	50.8	%	DIN 38 414-S3
Total phosphorus	5710	mg kg^{-1} TS	DIN EN ISO 11885
Total nitrogen	1600	mg kg^{-1} TS	DIN 19684-4

HSE: Hamburger Stadtentwaesserung Testing Laboratory

Trial soil was obtained from Research Field of the Faculty of Agriculture of Dicle University and it was loose soil with medium alkali (pH 7.9), low organic substance (1.44 %), medium level P (14.9 mg L^{-1}) and high level of K (350 mg L^{-1})[16,17].

The study was designed as 3 repetitions according to randomized split plots design. 24 pots were divided into 8 groups according to doses of sewage sludge and trial groups were formed as follows: (1) Control group (only soil); (2) N group (20 kg ha^{-1} N fertilizer was added to the soil); (3) S1 group (30 tons ha^{-1} sewage sludge was added to the soil); (4) S2 group (60 tons ha^{-1} sewage sludge was added to the soil); (5) S3 group (90 tons ha^{-1} sewage sludge was added to the soil); (6) N+S1 group (20 kg ha^{-1} N fertilizer + 30 tons ha^{-1} sewage sludge were added to the soil); (7) N+S2 group (20 kg ha^{-1} N fertilizer + 60 tons ha^{-1} sewage sludge were added to the soil); (8) N+S3 group (20 kg ha^{-1} N fertilizer + 90 tons ha^{-1} sewage sludge were added to the soil).

After having been dried in air, sewage sludge was weighed separately for each pot and mixed in the pot soil. Each pot was watered regularly with intervals of 7-10 days throughout the growing period. The plants were mowed in the period when 10 % of flowering occurred.

The harvested plant samples were washed with pure water and dried at 70 ºC until reaching a stable weight and their dry weights were recorded. MWS-2 model microwave solubilization system was used in the preparation of samples for analysis. The samples of Cr, Zn and Ni that were obtained as a result of solution in microwave were analyzed in ICP-OES (inductively coupled plasma optical emission spectrometry) due to their high sensitivity[18-20] while Hg was analyzed in hydride system-ICP OES (hydride generation combined with inductively coupled plasma optical emission spectrometry, HG-ICP-OES). The wavelengths with the most appropriate quantification limit and the greatest sensitivity were chosen in analyses where the matrix effects were not found. These wavelengths are 267, 716 nm (Cr); 206, 200 nm (Zn); 231, 604 nm (Ni); 253, 632 nm (Hg)[20]. The optimum instrumental conditions are given in the Table-4.

TABLE-4
WORKING PARAMETERS OF ICP-OES

View	Axial view
Optical System	Echelle
Power/W	1450
Plasma gas flow/L min^{-1}	15
Auxiliary gas flow/L min^{-1}	0.2
Detector	Liquid state detector
Sample flow rate/mL min^{-1}	1.5
Nebulizer nebulizing chamber	Cyclonic
Nebulizer	Concentric glass (meinhard) type A
Cr	267,716 nm
Zn	206,200 nm
Ni	231,604 nm
Hg	253,632 nm

Statistical analysis was carried out by using the SPSS program. Statistically the different results were performed Duncan test. A value of $P < 0.05$ was considered statistically significant. Variables were reported as mean ± SD (SD: standard deviation).

Chemical procedure: All of the chemicals used in the tests (HNO_3, HCl and H_2O_2) have analytical purity and supplied from Merck Company. Solutions were prepared using bidistillated water (Milli-Q™). Zn, Cr and Ni concentrations in ground plant samples (ground surface organ) and in soil were measured with ICP-OES Spectrophotometry (Optima™ 2100 DV) since precise measurement can be done at minor and major concentration level. Mercury analyses were measured with HG-ICP-OES spectrophotometry. Digestion processes of plant and soil samples were done in microwave oven (Bergh of Speedwave MWS-3).

RESULTS AND DISCUSSION

In this study, it was aimed to determine the effect of waste sludge that is applied as fertilizer in different doses in the growth of bird's-foot trefoil and in the level of heavy metal content and to detect the possible accumulation of heavy metal in soils. Since sewage sludge contains organic substance in the ratio of 50-70 % and plant nutrients in important concentrations in dry material, it has been regarded as an important source of extraordinary soil organic substance and organic fertilizer recently. It has been reported that plant nutritional value of sewage sludge is similar to stable manure and organic compost[21,22] and that contains all of the necessary elements for the development of plants[23].

Although sewage sludge contains many nutrients that are necessary for the growth of plants, the value of fertilizer varies according to the source of waste, features of the purified water and sludge sewage processes used. In some areas, heavy metals were found in high concentrations in plant tissues of products grown in the soil fertilized by sewage sludge[24-26].

The results of the analysis that was conducted with the aim of determining how heavy metal levels are affected on the growth of bird's-foot trefoil plant when sewage sludge is used as a fertilizer are given in Tables 5 and 6.

TABLE-5
EFFECT OF APPLICATIONS ON Cr, Zn, Ni AND Hg CONTENTS OF BIRD'S-FOOT TREFOIL PLANT (mg kg^{-1})

	Hg	Cr	Zn	Ni
Control	N.D	0.18 ± 0.11	5.04 ± 0.6	1.5 ± 0.4
N	N.D	0.13 ± 0.04	5.12 ± 0.4	1.2 ± 0.9
S1	N.D	0.21 ± 0.08	15.3 ± 1.3	9.6 ± 1.0
S2	N.D	0.35 ± 0.12	20.9 ± 2.5	14.7 ± 1.3
S3	N.D	0.46 ± 0.20	34.8 ± 3.1	19.6 ± 1.4
N+S1	N.D	0.22 ± 0.06	12.3 ± 2.1	9.5 ± 1.2
N+S2	N.D	0.35 ± 0.15	18.7 ± 1.2	14.4 ± 1.8
N+S3	N.D	0.47 ± 0.27	31.3 ± 2.4	18.9 ± 1.4
P	**NS**	p<0.01	p<0.05	p<0.05

Values are the average of three repetitions; ND: Not determined.

TABLE-6
EFFECT OF APPLICATIONS ON Cr, Zn, Ni AND Hg CONTENTS OF SOIL (mg kg^{-1})

	Hg	Cr	Zn	Ni
Control	N.D	0.36 ± 0.08	10.9 ± 1.7	25.6 ± 4.2
N	N.D	0.25 ± 0.11	12.8 ± 3.9	29.2 ± 7.5
S1	N.D	0.67 ± 0.13	25.6 ± 5.0	45.6 ± 3.5
S2	N.D	0.88 ± 0.25	32.7 ± 4.3	71.8 ± 2.9
S3	0.08 ± 0.02	1.15 ± 0.49	45.6 ± 3.4	98.4 ± 4.1
N+S1	N.D	0.42 ± 0.21	22.8 ± 3.2	32.3 ± 2.1
N+S2	N.D	0.65 ± 0.35	29.3 ± 2.8	58.7 ± 3.2
N+S3	0.06 ± 0.01	1.07 ± 0.27	43.7 ± 4.4	71.2 ± 9.4
P	p<0.001	p<0.05	p<0.05	p<0.01

Values are the average of three repetitions; ND: Not determine

Mercury is a highly toxic element as known and creates inhibitor effect. The value of Hg element that is permitted in sewage sludge for Turkey is 10 mg kg^{-1}. The value of Hg in our sewage sludge is 1.1 mg kg^{-1}. The value of Hg recorded in the soil after application was found to be 0.08 mg kg^{-1} in S3 as the highest and below 10 mg kg^{-1} as the lowest value in others. In bird's-foot trefoil, on the other hand, it was determined that Hg values were below 10 mg kg^{-1} in all applications. According to the researches, plants tend to intake heavy metals according to their increasing concentrations and the features of the soil play an important role. Mercury is in the last place in the solubility order of heavy metals[27]. It has been reported that sewage sludge application in studies with wheat remains below RUUMSSS in plant and soil in respect of Hg amount[5].

Chrome forwards sugar in the blood to cells and is a very important element for fat and protein synthesis. Chrome (III) is necessary for the body whereas chrome (VI) is carcinogenic. The value in sewage sludge that is permitted in Turkey for chrome is 1000 mg kg^{-1}. Chrome content of waste sludge used in the study is 69 mg kg^{-1}. As it can be seen, the value in the waste sludge is quite low for this toxic metal. In the analysis of the soil as a result of the experimental study, the highest level for chrome was found to be 1.15 mg kg^{-1} while the lowest value was 0.42 in N+S1. In the analysis on bird's-foot trefoil, the highest value was 0.47 mg kg^{-1} in N+S3 and the lowest was 0.21 mg kg^{-1} in S1. There was no statistically significant variation in P, K, Ca, Ni, Cr and Cd concentrations in plants with sewage sludge application conducted by other researchers[2,28].

Although zinc is an element which is used in galvanizing, its intoxication is deadly. The limit value in Turkey for sewage sludge in respect of zinc is 2500 mg kg^{-1}. The content of zinc in sewage sludge in present study was 753 mg kg^{-1}. The highest zinc value in the soil as a result of the experimental study was 45.6 mg kg^{-1} in S3 while the lowest value was 22.8 mg kg^{-1} in N+S1. The analysis values in bird's-foot trefoil were as follows; the highest value was 34.8 mg kg^{-1} in S3 while the lowest value was 12.3 mg kg^{-1} in N+S1. It was determined that the contents of N, P, Ca, Mg, Fe, Mn, Zn, Cu and Co increase in respect of nutritional element and heavy metal content with the use of sewage sludge[24,26,28]. Moreover, in studies related to the growth of plants such as spinach and lettuce, it was determined that cesspool sludge has no harmful effect on growth however the amount of Zn increased[29-31]. This conclusion is in harmony with present study.

Although nickel is being used very commonly in the production of alloys, extended exposure to nickel compounds and minerals is highly toxic. The limit value in Turkey for nickel is 300 mg kg^{-1}. The value in present sewage sludge was 77 mg kg^{-1}. The highest value after the application in soil was 98.4 mg kg^{-1} in S3. The lowest value, on the other hand, was 32.3 mg kg^{-1} in N+S1. In the analysis on bird's-foot trefoil, the highest value was 19.6 mg kg^{-1} in S3 and the lowest was 9.5 mg kg^{-1} in N+S1. In contrast to the results of present study, another study concluded that application of vegetable originated organic fertilizer to pots where sewage sludge is applied reduced heavy metal intake such as Zn, Ni and Cd[32]. Bozkurt *et al.*[28] reported that the application did not have a great impact on Co and Ni contents in soil for the plant of corn.

It was suggested that the limit values were not exceeded in respect of zinc, chrome, nickel and mercury contents when compared to maximum heavy metal limit values permitted in sewage sludge that can be used in soil according to Regulation for the use of Urban and Municipal Sewage Sludge on Soil (RUUMSSS) published in the official newspaper dated 03.08.2010. This is also very positive in respect of environment pollution. Furthermore, the increase in the probability of existence of heavy metals in bird's-foot trefoil with the increase in their amount is evident from the fact that the highest values are generally found in S3. Thus, as a result of the experiment, it was determined that sewage sludge increased the micro and macro element contents of bird's-foot trefoil.

From these results, it can be proposed that using sewage sludge as fertilizer is reliable with suitable doses. When the ratio in the plant is taken into account, extra attention should be paid to the fact that the contents of materials coming out of sewage facilities to be used in this process should be below the highest heavy metal limit values permitted by regulations. It has been reported that agricultural values (macro and microelement content) and heavy metal content are the parameters that should be taken into account if this type of organic wastes are to be used[33].

Conclusion

According to the results of this study, since the concentrations of toxic materials such as Hg, Ni, Cr and Zn in wastes are not very high; heavy metals do not accumulate in the soil and in plants grown in these fields. For this reason, discharging the wastes into agricultural fields or discharging them after sewage processes do not pose a serious threat in respect of environment and human health. The increase in metal content of the plant together with the increase in the amount of sewage sludge was observed with the increase of values in S3 at maximum level (90 tons ha^{-1}).

Being a substitute material in cultivation of bird's-foot trefoil, sewage sludge can be used as an alternative fertilizer since it is an alternative source that is rich in nutritional elements with cheap and high organic content. Pure sewage sludge should be used in plantation areas in bio-solid state after being processed when toxic metal concentrations exceed the limit values in respect of both human health and the growth of bird's-foot trefoil and other plants. Using these bio-solids in the production of bird's-foot trefoil will not pose a threat in respect of human health. It is a prerequisite to provide healthy working conditions (hygienic) by taking necessary precautions during these works. In that event, eliminating the heavy metals in sewage sludge extractive shall make these materials usable.

It has been determined by this study that this is not possible for the time being. Consequently, the sewage sludge that is obtained from sewerage sewage facility of Diyarbakir Metropolitan Municipality is not toxic and contains Hg, Ni, Cr and Zn in levels that can be comfortably used in the production of bird's-foot trefoil and other fodder plants. Nonetheless, since sewage sludge can be applied to soil for many years, it shouldn't be forgotten that the soil should be analyzed with certain intervals with the aim of preventing the accumulation of metals.

REFERENCES

1. B. Topcuoglu, M.K. Onal and N. Ari, *Akdeniz Univ. J. Agric.*, **16**, 87 (2003) (in Turkish with English abstracts).
2. M.A. Bozkurt and T. Yarilga, *Turk. J. Agric. For.*, **27**, 285 (2003).
3. D.C. Martens and D.T. Westermann, in eds.: J.J. Mortvedt, F.R. Cox. L.M. Shuman and R.M. Welch, Fertilizer Applications for Correcting Micronutrient Deficiencies in Micronutrients in Agriculture, Soil Science Society of American Book Series, No. 4, Madison, Wisconsin, American Society of Agronomy (1991).
4. T.J. Logan and L. Chaney, in eds.: A.L. Page, T.L. Gleason, J.E. Smith, I.K. Iskender and C.E. Sommers, Utilization of Municipal Wastewater and Sludge on Land: Metals, pp. 235-326, Riverside (1983).
5. Anonymous, Regulation for the Use of Urban and Municipal Sewage Sludge on Soil, Legislation Ministry of Environment and Forest (2010). http://www2.cevreorman.gov.tr/yasa/yonetmelik.asp.
6. M. Kucukhemek, K. Gur, R. Uyanoz and U. Cetin, Effect of Sewage Sludge and Farm Manure on Turfgrass Productivity and Colour Feature. I. National Symposium of Sewage Sludge. 23-25 March 2005, Izmir, Turkey, pp. 375-384 (2005) (in Turkish with English abstract).
7. E.G. O'riordan, V.A. Dodd and G.A. Fleming, *Irish J. Agric. Food Res.*, **33**, 61 (1994).
8. J.G.A. Fiskell, D.G. Neary and N.B. Comerford, *Forest Ecol. Manag.*, **37**, 27 (1990).
9. J.M. Zenhas, B.F. Saltao, M.I. Martins, A.J. Victoria, M.R. Gusmao and M.H. Domingues, Effect of Application of Sewage Sludge and Pulp-Mill Sludge from Wastewater Treatment on Plants Nutrition and Soil Fertility, Plant Nutrition for The Next Millenium Nutrients, Yield, Quality and The Environment (Abstract), Cario, Egypt, pp. 144-145 (2000).

10. V. Saruhan, I. Gul and I. Aydin, *Scient. Res. Essays*, **5**, 2567 (2010).
11. B.R. Reed, P.E. Carriere and M.R. Matsumoto, *Biocycle*, **32**, 58 (1991).
12. G.M. El-Dawwey, *Assuit J. Agric. Sci.*, **24**, 171 (1993).
13. M. Kaplan, A.I. Atalay and S. Medjekal, *Livestock Res. Rural Develop.*, **21**, 99 (2009).
14. G.C. Waghorn and I.D. Shelton, *Proc. New Zealand Soc. Anim. Produc.*, **52**, 89 (1992).
15. HSE, Hamburger Stadtentwaesserung Testing Laboratory, Hamburg (2004).
16. Anonymous, Analysis of Soil Results. Water and Soil Department, Ankara, Turkey (1997).
17. M. Basbag, I. Gul and V. Saruhan, *New Zealand J. Agric. Res.*, **47**, 225 (2004).
18. I. Aydin, *Microchem. J.*, **90**, 82 (2008).
19. I. Aydin, S. Imamoglu, F. Aydin, A. Saydut and C. Hamamci, *Microchem. J.*, **91**, 63 (2009).
20. I. Aydin, U. Yuksel, R. Guzel, B. Ziyadanogullari and F. Aydin, *Atom. Spectrosc.*, **31**, 67 (2010).
21. M.A. Tabatabai and W.T. Frankerberger, Chemical Composition of Sewage Sludges in Iowa, Agriculture and Home Economics Experimental Station, Iowa State University of Science and Technology Research Bulletin, p. 586 (1979).
22. L.E. Sommers, *J. Environ. Qual.*, **6**, 225 (1997).
23. D.R. Linden, C.E. Clap and R.H. Dowdy, Hydrologic Management: Nutrients. in Proceedings of the Workshop on Utilization of Municipal Wastewater and Sludge on Land, Riverside, University of California, pp. 79-103 (1983).
24. B.B. Asik and A.V. Katkat, *Uludag. Univ. J. Agric*., **18**, 59 (2004).
25. A. Filibeli, Wastewater Sludge Processing, D.E. Univ., Faculty of Engineering Press Units, Izmir, Turkey, pp. 1-222 (2005) (in Turkish).
26. M. Kucukhemek, K. Gur and R. Uyanoz, *Selcuk Univ. J. Agric. Fac.*, **22**, 94 (2008).
27. H. Kaptan and I. Kizilgöz, Environmental Pollution. Harran University Agricultural Faculty Course Notes, 9 (1998) (in Turkish).
28. M.A. Bozkurt, I. Erdal, K.M. Cimrin, S. Karaca and M. Saglam, *Ankara Univ. J. Agric. Sci.*, **6**, 35 (2000).
29. P. Truby and A. Raba, *Angew. Bot.*, **65**, 253 (1991).
30. S.G. Misra, M. Dinesh and D. Mani, *Curr. Agric.*, **18**, 49 (1994).
31. R. Demir and F. Aydin, *J. Ecol. Environ.*, **36**, 15 (2000).
32. B. Sommers, Causes, Development and Diagnosis of Symptoms Resulting from Mineral Element Deficiency and Excess, Nutritional Disorders of Plants, Ed.: W., 13 Ergrnann, Leipzig (1984).
33. M. Soumare, A. Demeyer, F.M.G. Tack and M.G. Verloo, *Bioresour. Technol.*, **81**, 97 (2002).