Fruit Growing Research, Vol. XXXVIII, 2022 DOI 10.33045/fgr.v38.2022.19
https://publications.icdp.ro/index.php

UTILIZAREA COMPOSTULUI OBȚINUT DIN NĂMOLURILE ORĂȘENESTI, CA FERTILIZANT ÎNTR-O LIVADA DE PIERSICI

THE USE OF COMPOST OBTAINED FROM SEWAGE SLUDGE, AS FERTILIZER IN A PEACH ORCHARD

Titirică Irina, Dima Milica, Diaconu Aurelia, Paraschiv Alina-Nicoleta, Netcu Florentina, Nanu Stefan
Research-Development Station for Plant Cultivation on Sandy Soil Dăbuleni, Romania

Abstract

The study was carried out in a peach orchard, `Cardinal` variety, on a sandy soil, within the Dăbuleni Research - Development Station for Plant Cultivation on Sandy Soil. The experimental plot was fertilized with different doses of compost, obtained from sludge resulting from the processing of domestic wastewater. Following fertilization, the soil analyzes showed an increase in nitrogen, phosphorus and potassium content, with higher values for fertilized variants with doses of 60 and 80 t/ha compost, compared to the control variant. Also, in the leaves the macroelements registered the highest values in the variant fertilized with 60t / ha sludge compost (3.53% nitrogen, 0.32% phosphorus, 1.69% potassium). The soil heavy metals content recorded higher values on the variants fertilized with sludge compost, but the recorded values did not exceed the maximum allowed limits by the layer. The rate of the photosynthesis, the perspiration, the stomatal conductance and the chlorophyll content index, as well as the biochemical properties of the fruits, respectively total dry matter, soluble dry matter, amount of carbohydrates and vitamin C, recorded significantly higher values on the variants fertilized with sewage sludge compost.

Cuvinte cheie: calitate fructe, conținut în metale grele, procese fiziologice.
Key words: fruit quality, heavy metals content, the plant physiological process.

1. Introduction

Efforts are being made throughout the world in terms of sanitation and wastewater treatment with the aim of saving water and protecting the environment. These efforts lead to the production of increasing quantities of secondary residues called "sludge" (Marzougui, 2022). Globally, sewage sludge production is around 200 million tons per year (Vaithyanathan, 2021 cited by Marzougui, 2022). Europe, North America, and East Asia are the main sewage sludge producers in the world (Spinosa, 2011). In many countries, sewage sludge used as fertilizer for horticultural plants is a widely debated topic, with opinions both for and against its use. In terms of resources, sewage sludge contains nutrients such as phosphorus (P), nitrogen (N), potassium (K) and carbon (C), which are critical elements for plant growth (Herring and Fantel, 1993 cited by Ecane, 2021; Cordell et al., 2009; Rosemarin et al., 2009; Hudcova et al., 2019; Powers et al., 2019; Withers, 2019). However, from a risk point of view, sewage sludge also contains unwanted substances such as heavy metals (Cd, Cu, Hg, Ni, Pb, Zn), non-degradable microplastics2, pathogens, antibiotics and other antimicrobial substances, emerging groups of chemicals such as per- and polyfluorinated hydrocarbons or PFAS3 and substances of concern that can harm human health and the environment if not handled properly or safely (Ecane, 2021). Even valuable nutrients such as P pollute aquatic and terrestrial ecosystems when applied in excess or indiscriminately to agricultural land through chemical fertilizers, sewage sludge and animal manure (Kleinman et al., 2015; Barreau et al., 2018 cited by Ecane, 2021). In Romania, the use of urban sludge as a fertilizer in fruit growing is an older concern, and yet a current topic. Until now, research has been carried out in fruit growing on the use of compost from sewage sludge by Iancu, Sumedrea et al., 2008, and Nicola et al., 2001, on apple species. The present work aims to highlight the effect of compost fertilization obtained from sludge resulting from the processing of domestic wastewater, in a peach plantation, on a sandy soil in the Southwest of Romania.

2. Material and methods

2.1. Study area

The study was carried out in a peach experimental plot of the Research and Development Station for Plants Culture on Sands, Dăbuleni. The orchard was established in 2014 year, with Cardinal cultivar. The location of experimental plot was 43 80 60 N and 24 95 97 East on a sandy soil poorly in nitrogen

(0.02 %), phosphorus (24 ppm), and potassium (38 ppm). The organic carbon content (0.07%) is very low and is characteristic of sandy soils, and the soil reaction is neutral (pH 6.36).

To evaluate the effect of urban sludge compost as fertilizer, in 2020 year in the first decade of April, a single factor experiment was designed (five experimental variants with four replicates) the experimental factors with the following graduations: V1=0 tons/hectare; V2=20 tons/hectare; V3=40 tons/hectare; V4 = 60 tons/hectare; V5=80 tons/hectare (t/ha) of urban sludge compost obtained at the Mioveni wastewater treatment plant applied as fertilizer, the doses were mixing to the 30 cm soil depth. The compost was applied as fertilizer in the peach orchard in compliance with the Environmental Acquis ([*** 29, 30, 31]).

2.2. Soil sampling and laboratory analysis

In the study period 2020-2021, for evaluating the soil chemical characteristics the following determinations were made: total nitrogen by Kjeldahl method (KJELDAHL); the extractable phosphorus (P-AL) by Egner - Riem Domingo method, by which phosphates are extracted from the soil sample with a solution of acetate - ammonium lactate at pH - 5.75, and the extracted phosphate anion is determined calorimetrically as - molybdenum blue; the changeable potassium (K-AL) by Egner-Riem Domingo method which the hydrogen and ammonium ions of the extraction solution replace by exchange the potassium ions in exchangeable form from the soil sample which are thus passed into the solution (EGNER & al.). The potassium dosing in the solution thus obtained is done by flame emission photometry; the organic carbon by the method of wet oxidation and titrimetric dosing (Gogoasa modification); the soil pH by the potentiometric method; the determination of the content of heavy metals in the soil, before the application of the compost and after the application was performed at the National Research and Development Institute for Soil Science, Agrochemistry and Environment Bucharest. The geoaccumulation index of heavy metal in soil (Igeo) was calculated after formula: Igeo = log2 (Cn /1.5xBn) (MULER et al.) where Cn is the measured concentration of the element in sewage sludge (mg/kg) and Bn is the geochemical background value in soil. The constant value 1.5 is introduced for better analysis of the natural variability of the content of the chosen substance in the environment. Also, the bioavailability indices of heavy metals were determined according to the formula BI = mg metal in leaf X 100/mg metal in soil (after Moreno 1997, cited by Nicola, 2022).

2.3. Vegetable material sampling and laboratory analysis

After the administration of the compost, during the month of July, period of intense growth of the shoots, leaf samples were collected to determine the nitrogen, phosphorus and potassium content of the plants. The chemical content in the leaves during the period of intense growth of shoots was evaluated by the following methods: the total nitrogen by the Kjeldahl method; the total phosphorus by the colorimetric method; the total potassium by method of dosing by flame emission photometry.

Physiological processes in the plant were carried out in the month of July, with the LCpro SD device at a temperature of 36 ^{0} C, atmospheric pressure (hPa) of 1101 mm Hg and solar radiation active in photosynthesis of 1730 (µmol/m2/s). The determinations were made on 3 leaves/repetitive/variant.

2.4. Statistical analyses

The obtained results were statistically analyzed using the analysis of variance (ANOVA). Means were compared using Duncan's multiple range test. The different letters from figures are significantly different according to Duncan test (P≤0.05). The bars in the figure represent the standard deviation at 5.

3. Results and discussions

The chemical composition of the soil in the study period

The data in figure 1 show that in the first year (2020) of applying the compost, the nitrogen reserve in the soil is higher compared to the years following the application of compost as a fertilizer for all fertilization variants, except for the non-fertilized. Analyzes of soil organic carbon content (Fig. 1) showed the highest values for all the fertilization variants studied in 2022 (the third year from the application of compost as a fertilizer). In the first year after fertilization, the 2020 year, the pH values were located between 6.3 and 6.6, later three years after the application of the urban sludge compost, respectively in the year 2022, the pH decreased progressively for all fertilization variants, subtracting to 4.3 on the version fertilized with 80t/ha compost (Fig.2). Regarding the phosphorus reserves, shown in figure 2, the recorded values show that in the third year after the application of the compost, i.e. 2022, the differences compared to the first year ranged from 2% to 19%. The soil phosphorus content recorded the highest values in the third year after the application of compost, in the second year on the fertilized version with 80 t/ha the values were 22 ppm higher compared to the first year, to the unfertilized version the recorded values decreased progressively annually (Fig. 2.).

The geoaccumulation index of heavy metal in soil (Igeo)

Table.1, reflects the degree of pollution of sandy soils after the application of urban sludge compost as fertilizer in the peach plantation. The recorded data show that for some chemical elements (cadmium, aluminum, arsenic) the application of this compost as a fertilizer must be done with caution at a longer interval of years, because the period of the present study of only 3 years, the frequency of application of this compost as fertilized in the plantations peach has not yet been established, studies needing to be continued to be able to establish exactly the frequency of the possibility of application as a fertilizer without producing an increase in pollution indices. Till now the Igeo index, show a composition that does not exceed the maximum limits allowed according to the actually legislation.

The bioavailability indices (BI)

The BI index for the heavy metals in the variants fertilized with compost are lower than in the unfertilized control, except for Cd at the variant fertilized by 40 t /ha. The bioavailability indices lower than to the unfertilized variant show those heavy metals are retained locked in the soil. Higher bioavailability indices than in the unfertilized control indicate that the heavy metals are absorbed into the plants. At the 40 t/ha compost fertilization option, the Igeo index suggests moderate soil pollution with Cd (Table 3.). We practically in our experimental plot, have reserves of Cd in soil and plant material contaminated with this metal. The soil pollution index following the application of compost as fertilizer shows high pollution in the case of cadmium on the 20t/ha fertilized variant and moderate on the other fertilization variants. Moderate soil pollution is also recorded in the case of lead and zinc on the variants fertilized with compost obtained from urban sludge.

The influence of the application of composts obtained from sludge after processing of domestic wastewater as fertilizer in the orchard, on the vegetative growth, the physiological processes and the biochemical content of leaves and fruits

The vegetative growth was evaluated by monitories of the average length of the annual shoots. The recorded data show that the highest values (72.33 cm) was obtained on the variant fertilized with the highest dose of compost, respectively 80 t/ha (Table 2).

In figure 4, is represented the supply status of the plants, respectively the content of the leaves in nitrogen, phosphorus and potassium. The data show that in the case of phosphorus and potassium, the highest values were recorded in the first year after the application of the compost as fertilizer in the plantation, in the case of nitrogen, the highest values were recorded in the first year after compost application for the variant fertilized with 20 and 40 t/ha.

The physiological processes represented in table 2, show that the rate of photosynthesis oscillated between 3.50 µmol CO2/m2/s in peach trees that were not applied to composts obtained from sludge resulting from the processing of urban sludge and 7.49 µmol CO2/m2/s in the variant fertilized with 80 tons of compost/ha. From a statistical point of view, the values recorded on the variants fertilized with compost were differentiating in five statistical classes. The both the hot climatic conditions and the increase in the dose of compost applied to the peach grown on the sandy soils at SCDCPN Dăbuleni, led to the intensification of transpiration through the stomata, from 1.85 mmol H2O/m2/s in the not fertilized variant, up to the value of 2.36 mmol H2O/m2/s for the 60 tons of compost/ha fertilized variant. Compared to the control, all analyzed variants sweated much more intensely, the recorded differences ranging from 37.91% to 43.76 (Table 2). Also, the stomatal conductance values were positively influenced by the application of compost, the best results being recorded in the variants fertilized with compost in doses of 60 and 80 tons/hectare (Table 2). The chlorophyll index recorded in the variant fertilized with 80 t/ha compost was significantly different from the other variants with differences ranging between 47.5% and 26.22%, differences ensured from a statistical point of view.

The average weight and biochemical content of fruits. The fertilization with compost obtained from the urban sludge, positively influenced the values of the quality fruits indicators, the data illustrated in table 2 show an increase of the following fruit indicators: the soluble dry matter, titratable acidity and glucides by 1 to 1.4 units compared to the non-fertilized variant. The analysis of the fruit vitamin C content showed that on the fertilized variants the values registered were higher by 34 to 100% compared to the non-fertilized variant. Also, the average weight of the fruits shows a progressive increase of them with the increase of the doses of compost in both years of fruiting after the compost application, so in the variant fertilized with 80 t/ha compost the fruits had an increase in weight of up to 27.1% compared to the nonfertilized variant (Table 3).

4. Conclusions

The fertilization with compost obtained from the urban sludge has positively influenced the values of the vegetative growth, the plant physiological processes and the biochemical content of leaves and fruits versus unfertilized variant.

In the study period the soil pollution index, show a composition that does not exceed the maximum limits allowed according to the actually legislation but in the experimental plot, was registered reserves of cadmium and zinc in soil and plant material, so, studies needing to be continued in future to be able to establish exactly the frequency of the possibility of application as a fertilizer without producing an increase in pollution indices.

Acknowledgements

This work was supported by the Romanian Ministry of Agriculture and Rural Development, project ADER 7.3.10/2019.

References

1. Barreau S., Magnier J. and Alcouffe C., 2018. Agricultural Phosphorus Regulation in Europe – Experience-Sharing for 4 European Countries. International Office for Water (IOWater). (accessed June, 2022).
2. Cordell D., Drangert J.O. and White S., 2009. The story of phosphorus: global food security and food for thought. Glob. Environ. Chang. 19: 292–305. DOI: 10.1016/j.gloenvcha.2008.10.009.
3. Ecane N., Barquet K., Rosemarin A., 2021. Resources and Risks: Perceptions on the Application of Sewage Sludge on Agricultural Land in Sweden, a Case Study. Front. Sustain. Food Syst., 19 April 2021. Sec. Waste Management in Agroecosystems. https://DOI.org/10.3389/fsufs.2021.647780.
4. Egner H., Riehm H., Domingo W.R., 1960. Untersuchungen über die chemische bodenanalyse als grundlage für die beurteilung des nährstoffzustandes der böden. II. Chemische extractionsmethoden zur phosporund kaliumbestimmung. Annals Royal Agricultural College, Sweden, 26: 199-215.
5. Kjeldahl J., 1983. New method for the determination of nitrogen. Chemestry News., 48(1240): 101-102.
6. Herring J. and Fantel R., 1993. Phosphate Rock Demand into the Next Century: Impact on World Food Supply. Natural Resources Research. Vol. 2 (Kluwer Academic Publishers), 226–246. DOI: 10.1007/BF02257917.
7. Hudcova H., Vymazal J. and Rozkosny M., 2019. Present restrictions of sewage sludge application in agriculture with the European Union. Soil Water Res. 14: 104–120. DOI: 10.17221/36/2018-SWR
8. Kleinman P., Sharpley A., Withers P., Bergström L., Johnson L. and Doody D., 2015. Implementing agricultural phosphorus science and management to combat eutrophication. Ambio 44 (Suppl. 2): S297–S310. DOI: 10.1007/s13280-015-0631-2.
9. Marzougui N., Ounali N. Sabbahi S., Fezzani T., Abidi F., Sihem J., Melki S., Berndtsson R., Queslati W., 2022. Howcan Sewage Sludge use in sustainable Tunisian agriculture be increased? Sustainability. https://doi.org/10.3390/su142113722.https://w.w.w.mdpi.com/journal/sustainability.
10. Moreno J.l., Garcia C., Hernandez T., Ayuso M., 1997. Application of composted sewage sludges contamined with Heavy Metals to an agricultural soil effect on lettuce growth. Soil Sci. plant Nutr., 43(3): 565-573.
11. Muller G., 1969. Index of geoacumulation in sediments of the Rhine River. GeoJournal, 4: 108-118.
12. Nicola C., Paraschiv M., 2021. Use of urban sluge compost as fertilizant on apple orchards. Fruit Growing Research, vol. XXXVII: 103-114. DOI:10.33045/fgr.v37.2021.15.
13. Powers S., Chowdhury R., MacDonald G., Metson G., Beusen A., Bouwman A., et al., 2019. Global opportunities to increase agricultural independence through phosphorus recycling. Earth's Future 7: 370–383. DOI: 10.1029/2018EF001097
14. Rauta C., Chiriac A., 1980. Metodologia de analiză a plantei pentru evaluarea stării de nutriție minerale. Ed. Academiei Române de Științe Agricole și Silvice.
15. Rosemarin A., de Bruijne G. and Caldwell I., 2009. Peak phosphorus: the next inconvenient truth. Broker 15: 6–9. Available online at: https://www.thebrokeronline.eu/peak-phosphorus/ (accessed July 2022).
16. Spinosa L., 2011. Wastewater Sludge: Aglobal Oweriew of the current status and future prospects, 2nd ed., Iwa Publishing London UK, pp 7-59.
17. Sumedrea D., Iancu M., Chitu E., 2008. Influence of urban sludge used as fertilizer on Idared apple behavior, Fruit Growing Research, vol. XXIV: 178-186.
18. Vaithyanathan V.K., Cabana H., 2021. Intregrated biotechnology management of biosolids: Sustainable ways to produce value-Added products. Front Water 3: 729679.
19. Withers P., 2019. Closing the phosphorus cycle. Nat. Sustaina, 2: 1001–1002. DOI: 10.1038/s41893-019-0428-6.
20. ***, 1999. Council Directive 1999/31/EC of 26 April 199 on the landfill of waste.
21. ***, 2006. Commission Regulation (EC) No.1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuff (Text with EEA relevance).
22. ***, 2008. Commission Regulation (EC) No.834/2007 on organic production and labeling of organic products with regard to organic production, labeling and control.

DOI 10.33045/fgr.v38.2022.19

Tables and Figures

Table 1. The content of sandy soils in heavy metals and the degree of pollution after the application of compost from urban sludge as fertilizer in peach plantations

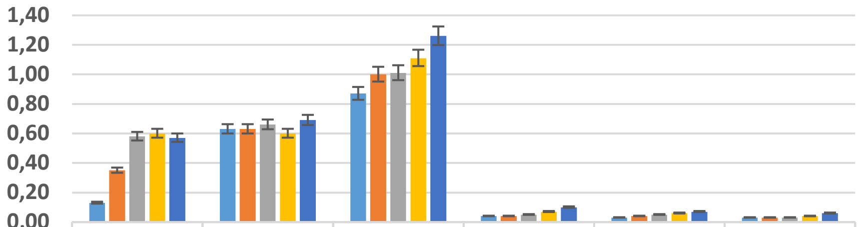
Doze of compost applied (t/ha)	The analyzed metal	*Havy metal content of fertilized soil (mg/kg)	*Heavy metal content of plant material (mg/kg of d.m)	Conţinutul de metale grele din compost (mg/kg of d.m)	Index Igeo	Degree of heavy metal pollution in the soil
V_1=0	Cd	0.053	0.041			
	Cu	60.58	449			
	Co	2.37	0.21			
	Mn	173	150			
	Ni	7.68	4.71			
	Pb	4.03	0.10			
	Zn	17.8	26.3			
V_2=20	Cd	0.081	0.051	1.04	3.91	High pollution
	Cu	80.9	500	72.36	0	No pollution
	Co	3.01	0.21	8.04	0	No pollution
	Mn	306	144	446.14	0	No pollution
	Ni	11.6	4.80	29.53	0	No pollution
	Pb	4.97	0.16	32.21	1.26	Moderate pollution
	Zn	31.8	26.9	557.00	1.39	Moderate pollution
V_3=40	Cd	0.011	0.060		1.01	Moderate pollution
	Cu	21.3	521		0	No pollution
	Co	1.55	0.26		0	No pollution
	Mn	274	149		0	No pollution
	Ni	8.95	4.81		0	No pollution
	Pb	4.43	0.23		1.59	Moderate pollution
	Zn	20.7	27.4		1.27	Moderate pollution
V_4=60	Cd	0.201	0.068		1.09	Moderate pollution
	Cu	43.9	533		0	No pollution
	Co	15.1	0.41		0	No pollution
	Mn	414	160		0	No pollution
	Ni	17.6	3.61		0.25	No pollution
	Pb	6.63	0.15		1.18	Moderate pollution
	Zn	39.3	28.0		0.97	Lightly polluted
V_5=80	Cd	0.091	0.067		1.32	Moderate pollution
	Cu	32.5	631		0	No pollution
	Co	1.48	0.46		0	No pollution
	Mn	3.11	180		0	No pollution
	Ni	20.7	3.62		0	No pollution
	Pb	4.24	0.20		1.73	Moderate pollution
	Zn	26.3	31.3		1.86	Moderate pollution

Table 2. The influence of the composts obtained from urban sludge as fertilizer in peach orchard on the vegetative growth and physiological processes

Doze of compost applied (t/ha)	The photosynthesis (μmolCO_2/m^2/s)	The plant transpiration (mmol H_2O/m^2/s)	The stomatal conductance (mol/m^2/s)	The chlorophyll index	The shoots length (cm)
V1=0	3.50e	1.85d	0.10b	20.13e	51.50 e
V2= 20	5.57d	3.29a	0.12b	23.53d	60.00 c
V3= 40	5.68c	2.40c	0.12b	29.37b	58.83 d
V4= 60	6.07b	2.36c	0.14ab	23.90c	66.33 b
V5 =80	7.49a	2.98b	0.21a	29.70a	72.33 a

Table 3. The influence of the composts obtained from urban sludge as fertilizer in peach orchard on the fruits quality

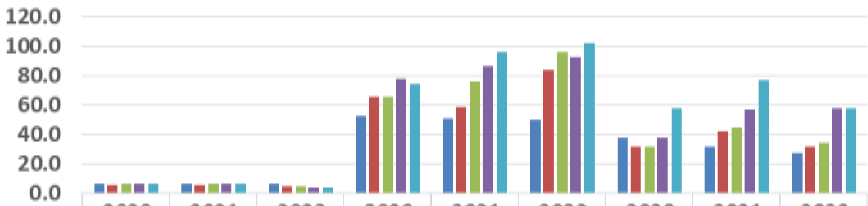
Doze of compost applied (t/ha)	The weight (g)	The water content (%)	The dried metter (%)	The soluble solid (%)	The titrable acidity (g acid malic la 100g s.p)	The glucides (%)	The vitaminC (mg/100g)
V1=0	188 e	84.82a	15.18d	15.0e	1.30d	12.90e	2.64e
V2= 20	194 d	84.55b	15.45c	16.0c	1.19e	13.76c	3.52d
V3= 40	203 c	84.13c	15.87b	15.2d	1.48c	13.10d	7.92b
V4= 60	235 b	81.70d	18.30a	16.8a	1.87a	14.45a	8.80a
V5 =80	239 a	81.70d	18.30a	16.4b	1.59b	14.11b	5.28c



	Organic carbon (%) 2020	Organic carbon (%) 2021	Organic carbon (%) 2022	Total nitrogen (%) 2020	Total nitrogen (%) 2021	Total nitrogen (%) 2022
0t/ha	0,13	0,63	0,87	0,04	0,03	0,03
20t/ha	0,35	0,63	1,00	0,04	0,04	0,03
40t/ha	0,58	0,66	1,01	0,05	0,05	0,03
60t/ha	0,60	0,60	1,11	0,07	0,06	0,04
80t/ha	0,57	0,69	1,26	0,10	0,07	0,06

0t/ha 20t/ha 40t/ha 60t/ha 80t/ha

Fig. 1. The soil content in total nitrogen and organic carbon in the study period



	Ph 2020	Ph 2021	Ph 2022	Extractable phosphorus (ppm) 2020	Extractable phosphorus (ppm) 2021	Extractable phosphorus (ppm) 2022	Extractable potassium (ppm) 2020	Extractable potassium (ppm) 2021	Extractable potassium (ppm) 2022
0t/ha	6.6	6.7	6.8	53.0	51.0	50.1	38.0	32.0	27.7
20t/ha	6.3	6.0	5.6	66.0	59.0	84.1	32.0	42.0	32.0
40t/ha	6.5	6.6	5.0	66.0	76.0	96.0	32.0	45.0	34.1
60t/ha	6.5	6.6	4.3	78.0	86.0	92.4	38.0	57.0	57.6
80t/ha	6.5	6.6	4.3	74.0	96.0	102.2	57.6	77.0	57.6

0t/ha 20t/ha 40t/ha 60t/ha 80t/ha

Fig. 2. The phosphorus, potassium and soil pH content in the study period

DOI 10.33045/fgr.v38.2022.19

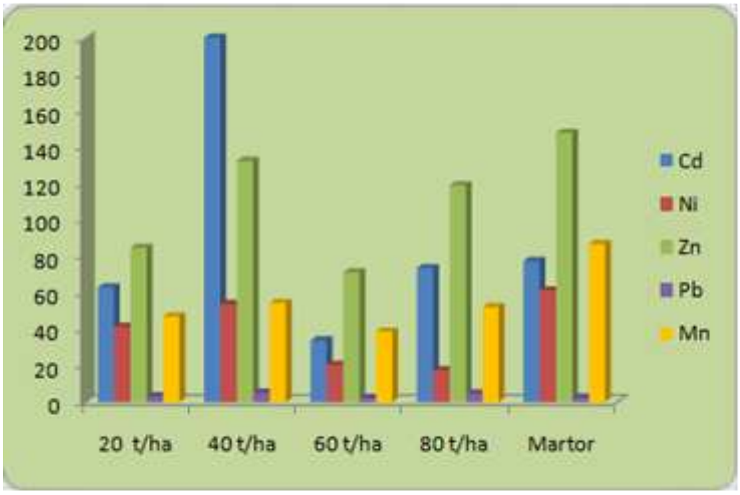
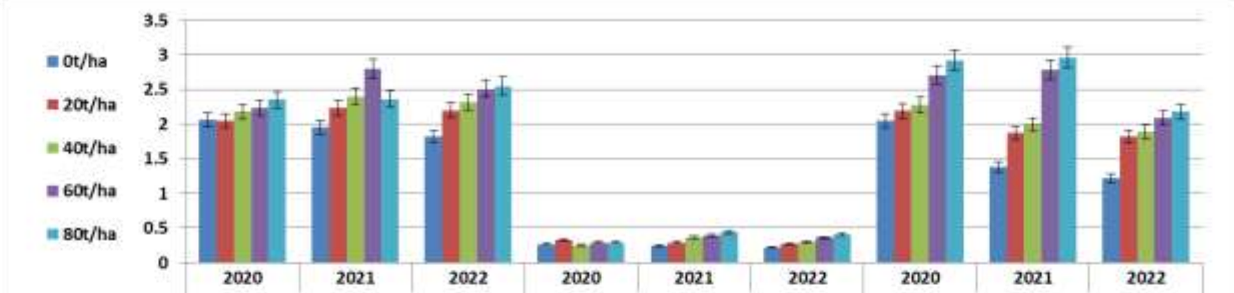


Fig. 3. The heavy metals bioavailability indices (BI)



	Total nitrogen(%)			Total phosphorus (%)			Total potassium (%)		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
0t/ha	2.06	1.96	1.82	0.26	0.24	0.22	2.05	1.38	1.22
20t/ha	2.05	2.23	2.20	0.33	0.29	0.27	2.19	1.87	1.82
40t/ha	2.18	2.40	2.32	0.25	0.37	0.30	2.28	1.99	1.89
60t/ha	2.23	2.80	2.51	0.29	0.39	0.36	2.71	2.79	2.09
80t/ha	2.35	2.36	2.55	0.29	0.44	0.4	2.92	2.96	2.18

Fig. 4. The leaf NPK content