

VARIATIONS IN NUTRIENTS AND DEVELOPMENT OF TOMATO PLANTS IN SOIL WITH OF URBAN SEWAGE SLUDGE

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Abstract

Accumulation of waste represents a huge problem for the urban development. One possibility of useful application of such waste is its application in agriculture. The effect of urban sewage sludge on the vegetative growth of tomatoes was checked on four types of soils from the Valencian region in Eastern Spain. Young plants were grown during four months in two experimental conditions, a control only with local irrigation water, and a treatment in which sewage sludge was added to each pot at the beginning of the experiment and watered with the same water type. Composition of soils, irrigation water and sewage sludge were analyzed and vegetative parameters, such as total length, length of stems and branches, and biomass of roots, stems, branches and leaves were measured. Plants achieved better vegetative development in the presence of sewage sludge in the four types of soils. The positive effect of the sludge is due to its high content in organic matter which clearly improves the qualities of Mediterranean soils, which are generally very poor.

Keywords: *water, macronutrients, micronutrients, vegetative growth, elemental composition*

Introduction

Lycopersicon esculentum mill. is one of the most important horticulture plants in Europe, with very high levels of production, commercialization and consume. Besides, this species is object of study in many research centers, due to its enormous importance. The present work refers to the effects of urban sewage sludge on the vegetative growth of the variety Marmande, due to its high degree of tolerance for saline stress and good flavor of its fruits. This variety is also suitable for cultivation in pots since plants are not too high. The addition of sewage sludge is justified by its effect in stabilizing the soil pH and by the need to provide organic matter to the soils, which in the Mediterranean region are generally very poor, but mostly by the need of finding an efficient use of the enormous amounts of urban waste.

The aim of this work is to check the vegetative development of tomato plants in the presence of urban sewage sludge on four different types of local soils. The morphological characteristics of the plants were correlated with the soils variables, the irrigation water used and the presence of urban sewage sludge.

Materials and methods

The soil and water correspond to areas of Benirrama, Marjal, Ramers and Salobre, localities situated in La Marina Alta, Valencian region, in Spain.

In the experimental design the four soil types were placed in pots of 15 kg and in each a tomato plant, *cv.* Marmande was cultivated (three replicas for each soil type and treatment). Tomato plants were transferred in young stage (15 cm high) and experiments were carried out during four months. Two treatments were applied to each soil type: a control watered with

local irrigation water, and a treatment with one kg of urban sludge added to each replica at the beginning of the experiment and watered with the same water type as the corresponding control. The sewage sludge used was the same for all soil types, but irrigation waters correspond to their geographic area.

The quality of irrigation water was evaluated. For each type of water the pH, the electrical conductivity (EC), the content in cations (Na, K and Ca), chloride, sulfate, nitrate, bicarbonate, fluorine and boron were determined. Cations were determined by atomic spectroscopy and the other components were quantified according to classic volumetric and colorimetric methods as described by Gomez *et al.* (1992). All parameters of irrigation waters are related to plant nutrition, salinization and alkalization of soil and water (Rhoades, 1990).

Following characteristics of urban sewage sludge were analyzed: electric conductivity (EC), pH, organic matter (OM) and elemental composition (N, P, K, Na, Ca, Mg, Cu, Fe, Zn, B, Cd, Cr, Hg, Ni, Pb, Al) by the same methods as above. For each type of soil following characteristics were analyzed: texture, pH, salinity, the percentages of total carbonates (Carb.) and active lime (Al), organic matter (OM) (Olsen and Sommers, 1982a), total nitrogen, phosphorus (Olsen and Sommers, 1982) and cations of saturated paste extract (Na, K, Ca and Mg) by atomic spectroscopy.

Following morphological characteristics of the plants were analyzed at the end of the treatment: leaf biomass and length and biomass of stems, branches and roots (Jones, 1991). Data were analysed using the programme SPSS for Windows, v.16.00.

Results and discussion

The results on the characterization of irrigation water are synthesized in Table 1. The pH is slightly basic in all types; the highest conductivity was registered in the Salobre which has a significantly different amount of sodium and chloride, being very saline. Remarkably different is the level of nitrates, varying from very low values from Benirrama (8 mg/l) to Ramers (184 mg/l). Significantly lower is the level of sulfates in the Benirrama. Regarding the fluorine, Salobre has the highest value which was also the most saline.

Table 1. Characteristics and composition of local irrigation water

Name	pH	EC dS/m	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cl ⁻ mg/L	SO ₄ ²⁻ mg/L	HCO ₃ ⁻ mg/L	F mg/L	NO ₃ ⁻ mg/L	B mg/L
Benirrama	7.56	1.04	198	8.3	30	30	290	58	133	0.31	8	0.13
Marjal	7.68	0.95	132	9.7	60	29	198	128	107	0.18	78	0.11
Ramers	7.49	1.01	95	3.7	108	20	143	218	92	0.30	184	0.40
Salobre	7.3	2.15	353	9.0	88	38	685	202	64	0.96	58	0.18

The values registered on the urban sewage sludge used in this experiment are shown in Table 2. All values registered are below the limits of toxicity allowed by the Spanish legislation.

Table 2. Characteristics and elemental composition of urban sewage sludge

pH	EC dS/m	OM %	N g/kg	P g/kg	K g/kg	Na g/kg	Ca g/kg	Mg g/kg	Fe g/kg	Mn mg/kg	Cu mg/kg	Zn mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Al mg/kg
5.5	6.35	52.6	36.2	25.1	1.8	6.1	50.3	5.9	3.9	68.1	539.8	834.9	1.0	115	189.1	7200

The results related to the chemical composition and electric conductivity of the different soil types are summarized in Table 3 for both control (1) and sewage sludge (treatment 2). Soils treated with sludge have significantly higher electric conductivity (EC) and percentage of organic matter (OM) than those in control. Only in Marjal soil, which is

exceptionally rich, there is no increment in OM. Interesting is the increment of phosphorous in all soils, but especially in Salobre, where it increased almost 10-fold in respect to the control. This is correlated with the high amount of P (25.1 g/kg) detected in the sludge. Table 3 shows the level of soil fertility at the beginning of the experiment. During the experiment the only new variable is that of irrigation water, which may affect the substrate-plant interaction.

Table 3. Chemical analysis of the soil in control (1) and treatment with sludge (2) at the beginning of the experiment (II)

Treatment	pH	EC dS/m	OM %	K g/kg	P mg/kg	N g/kg	Carb. %	Al %	Ca g/kg	Na g/kg	Mg g/kg
Benirrama 1	7.30	0.588	5.82	0.32	23.52	2.51	52	9.4	6.78	0.43	0.52
Benirrama 2	7.05	1.248	6.58	0.36	73.85	3.34	40	8.8	6.43	0.35	0.68
Marjal 1	7.27	0.802	14.85	0.34	14.68	6.34	43	14.2	7.58	0.34	0.93
Marjal 2	7.06	1.386	14.65	0.39	34.22	6.78	38	14.6	8.38	0.33	0.64
Ramers 1	7.27	0.598	2.00	0.49	272.70	2.32	15	0.9	5.20	0.30	0.36
Ramers 2	6.88	2.295	4.09	0.49	302.85	3.41	23	0.6	5.31	0.47	0.59
Salobre 1	7.01	0.613	1.66	0.37	14.22	1.72	25	1.0	5.67	0.43	0.54
Salobre 2	7.10	1.902	3.18	0.45	115.36	1.98	22	1.4	5.82	0.63	0.78

Once the crop growth cycle, we proceed to the extraction of plants from their substrate for subsequent chemical analysis of its various components (root, stem and branches and leaves). In addition, soils were analyzed to quantify the contributions of irrigation water and the removal of nutrients by plants. Table 4 shows the level of soil fertility at the end of the experiment. During the experiment the only new variable is that of irrigation water, which may affect the substrate-plant interaction.

Table 4. Chemical analysis of the soil in control (1) and treatment with sludge (2) at the end of the experiment (III)

Name	pH	EC dS/m	OM %	K g/kg	P mg/kg	N g/kg	Carb. %	Al %	Ca g/kg	Na g/kg	Mg g/kg
Benirrama 1	7,36	0,554	4,67	0,21	16,70	2,23	49	6,1	5,75	1,24	0,15
Benirrama 2	7,11	1,718	6,10	0,26	90,02	4,02	42	6,9	5,05	0,95	0,59
Marjal 1	7,31	0,644	11,69	0,20	10,89	5,58	40	10,9	6,65	1,10	0,90
Marjal 2	7,16	2,190	14,50	0,21	46,54	7,56	40	11,4	6,65	1,16	0,92
Ramers 1	7,62	0,433	2,40	0,35	195,30	1,89	21	0,6	5,17	0,59	0,34
Ramers 2	7,23	1,006	4,06	0,32	225,83	3,11	15	1,0	3,98	0,54	0,41
Salobre 1	7,49	0,942	2,18	0,30	21,53	1,25	14	0,5	5,26	1,43	0,52
Salobre 2	7,51	1,024	3,12	0,35	101,66	1,92	17	1,9	5,34	1,24	0,60

The results in Table 4 in comparison with the results in Table 3 show the effect on plants have led to water-soil interaction. Among the most significant results are:

That in relation to the electrical conductivity and organic matter, salinity and organic fertilization clear influence on these two parameters. The irrigation with more saline waters (1) cause a further increase in the EC, not even taking the effect of ions by the plant fails to stop (not Salobre). The soils with the sludge (2) reached significantly higher values than in soils (1). The near equality in EC Salobre 2 and 1, both saline irrigated with enough water, it may be, firstly, the presence of more favored microbial biomass by organic matter, and secondly, the greater retention capacity ion that it manifests (Navarro-Pedreño, J, 1992).

With regard to macronutrients, the nitrogen content whose main contribution is the organic matter, shows a behavior in general, parallel evolution in all soils 1, down from II to III. It is in the organic treatment which clearly reflects the positive effect of increased nitrogen content compared to soils without sludge. Regarding phosphorus, the evolution followed by

this macronutrient is parallel throughout the experiment, but more balanced, the evolution of nitrogen. Potassium is a distinctly minority element in these soils and waters, and even the sludge produced is relatively low in this nutrient.

The case of the Na ion is clearly significant influence of irrigation water. In all cases the sodium increases with time, with the largest increase in soil 1. In soils 2 sodium increased due to irrigation, is slightly stabilized by the buffering action of organic matter.

Calcium shows parallel developments in all cases and in all soils, coinciding minimum and maximum inflections in all samplings. The fact that its concentration is virtually uniform, perhaps due to the slight wobble in the content of active lime.

The evolution of magnesium compared to the values of the initial sampling, small maxima and minima coincidence with the minimum and maximum values of calcium (with the exception Salobre), perhaps due to antagonism attachment level, stay in the soil solution and plant absorption, which can be attributed to these nutrients.

The results of the concentration of macro and micronutrients of each of the parts of tomato plants at the end of its life cycle, are shown in Tables 5, 6 and 7.

Table 5. Chemical analysis of the leaves (mg/kg)

Name	N	P	Na	K	Ca	Mg	Fe	Cu	Mn	Zn
Benirrama 1	15,6	3,600	3,50	9,20	32,0	5,50	79,70	6,39	15,30	15,49
Benirrama 2	34,3	2,000	6,90	18,4	28,3	4,50	142,10	8,45	20,74	49,71
Marjal 1	32,0	1,950	6,60	16,2	23,2	5,50	90,80	1,24	11,67	14,92
Marjal 2	29,4	1,800	5,20	17,0	39,6	4,80	79,70	2,27	20,74	20,63
Ramers 1	36,9	3,600	4,40	25,4	12,3	3,10	152,50	13,59	11,67	36,60
Ramers 2	39,6	2,500	3,60	21,2	37,0	5,10	152,50	7,42	35,27	33,17
Salobre 1	19,7	1,400	5,90	12,8	42,1	6,00	183,70	4,33	28,00	19,49
Salobre 2	31,9	2,000	8,90	18,8	40,8	6,90	131,70	5,36	49,81	30,89

Table 6. Chemical analysis of the stem and branches (mg/kg)

Name	N	P	Na	K	Ca	Mg	Fe	Cu	Mn	Zn
Benirrama 1	6,70	1,900	4,10	25,5	11,9	3,20	48,50	4,33	0,76	76,52
Benirrama 2	21,3	2,300	6,40	28,0	23,2	6,00	90,10	6,39	6,21	68,54
Marjal 1	9,10	1,200	3,70	24,0	15,7	4,20	38,10	2,27	2,58	50,86
Marjal 2	23,5	2,200	4,40	21,6	25,7	5,10	48,50	1,24	4,39	49,14
Ramers 1	13,3	1,700	2,30	27,7	11,9	2,20	38,10	5,36	4,39	35,46
Ramers 2	22,3	2,500	3,10	28,1	18,2	3,70	48,50	2,27	6,21	56,56
Salobre 1	10,1	0,680	5,70	17,3	10,6	3,60	58,90	3,30	2,58	37,74
Salobre 2	16,7	1,250	8,70	18,6	22,0	5,90	58,90	2,27	8,03	53,71

Table 7. Chemical analysis of the root (mg/kg)

Name	N	P	Na	K	Ca	Mg	Fe	Cu	Mn	Zn
Benirrama 1	17,7	1,500	4,50	16,2	18,2	2,70	960,00	11,54	11,67	42,30
Benirrama 2	24,7	1,500	6,00	12,2	16,8	3,90	277,08	10,50	8,03	19,49
Marjal 1	18,3	1,200	4,30	11,8	27,0	4,00	1005,00	8,45	17,11	49,71
Marjal 2	18,3	2,100	5,90	7,70	47,1	5,00	2564,80	23,90	35,20	56,00
Ramers 1	14,5	0,640	1,90	2,80	13,1	1,00	1420,90	13,60	26,19	17,21
Ramers 2	17,7	2,500	6,30	11,6	27,0	5,00	2460,80	35,23	33,46	66,82
Salobre 1	12,2	0,750	6,50	10,9	15,7	3,10	1420,90	15,66	26,19	23,48
Salobre 2	19,7	1,500	7,10	9,00	18,2	3,70	1940,80	13,60	31,64	34,32

They revealed that the plants with a high nitrogen content reduced fruiting, delay ripening and produce excessive vegetation. In our study this fact manifests itself clearly in soils plants with the number 2, Benirrama, marshes, Ramers and less significance in the soil Salobre. In this case the positive influence of sewage sludge on soil and the plant is significant.

When a relative deficiency of nitrogen the leaves are usually pale yellow-green color due to the low chlorophyll synthesis. This is particularly evident in plants on soils Benirrama 1, Salobre 1 and Ramers 1. In general throughout the experiment are different behaviors in the block Salobre-Benirrama and Marjal-Ramers block, except as mentioned on the nitrogen. The different behavior of the two plants in soil blocks in the first is due to their higher organic matter content and the second the effect of salinity on mineralization of organic matter.

The phosphorus concentration is more restricted in plants on soils with sludge, where it is stabilized and even decreased. This stabilization is more pronounced in soils plants with the highest proportion of organic matter. The explanation may be the most powerful chelator and buffer dissolution of soil as a result of increased soil organic matter.

The highest concentrations of sodium in the leaves, appear on the soles on the floor with mud, even in those with higher initial organic matter content (Marjal and Benirrama), there is a significant stabilizing effect that is absent in land plants Salobre. In the case of plants grown in soil Ramers, the result can be explained possibly as due to a combination of low sodium saline irrigation water and the dampening effect of organic matter in the sewage sludge. The sodium content in the stem and branches and roots in all soils follows the same sequence, ie higher in plants grown in soil with sludge and lowest in bare soil.

The results obtained show that the potassium content decreases along the evolutionary cycle, unlike sodium developments discussed above. Its concentration increases from the root to the stem and branches and leaves. The evolution of the potassium in the stem and branches and roots, also appears to show some antagonism with sodium. As a confirmation of previous results and comments on macronutrients have the values for the overall development of plants in length and mass. The data obtained on plant development are shown in tables 8 and 9

Table 8. Physical parameters of tomato plants in control (1) and treatment with sludge (2)

Name	Plant Height (cm)	Biomass stem (g)	Branches length (m)	Branches Biomass (g)	Leaves Biomass (g)	Roots Biomass(g)	Total biomass(g)
Benirrama 1	105	41.33	6.18	60.58	38.26	8.55	148.99
Benirrama 2	88	42.22	10.32	148.63	105.25	10.72	306.82
Marjal 1	92	57.97	11.83	186.36	111.54	23.05	378.92
Marjal 2	150	95.5	18.31	252.83	279.47	40.74	668.54
Ramers 1	79	68.29	6.10	139.60	22.13	10.00	240.02
Ramers 2	91	51.65	12.25	183.88	147.03	27.36	409.92
Salobre 1	111	58.34	8.25	101.07	69.51	13.80	242.72
Salobre 2	98	52.58	11.25	143.04	131.60	9.76	346.98

When comparing the two treatments it is clear that plants improved their vegetative growth when sludge was added. Plants from Treatment 2 (with sludge) are more vigorous: total biomass and height, as well as branches and leaves biomass significantly increased. This finding indicates the sewage sludge treatment is effective on all type of soils. Regarding the different types of soils, the most developed plant material was obtained from Marjal, followed by plants grown in soils Ramers, Salobre and Benirrama.

Tab. 9 Dry weight of tomato plants in control (1) and treatment with sludge (2)

Name	Stem + branches biomass (g)	Leaves biomass (g)	Root biomass (g)	Total biomass (g)
Benirrama 1	19.38	6.58	2.11	28.07
Benirrama 2	31.84	21.08	2.06	54.98
Marjal 1	44.39	19.56	4.74	68.69
Marjal 2	58.64	47.97	7.49	114.10
Ramers 1	42.70	5.54	2.75	50.99
Ramers 2	41.08	29.21	5.44	75.73
Salobre 1	31.10	11.05	2.82	44.97
Salobre 2	32.89	20.65	2.43	55.97

The analysis of the total dry weight also indicates that the application of sludge is effective, the values in treatment 2 being generally higher than in controls in all soil types.

Conclusions

Once the analysis leaves, branches and stem and root of each plant can manifest as more significant the following considerations:

- In the steady increase in foliar concentrations of sodium in all samples in the expected order, greater in the plants on the amendment for soil (soil 2) and lowest in plants grown in soil 1. This same pattern occurs in the stems and branches and roots. On the other hand, presents a different evolution of magnesium content and decreasing the concentration in plants grown from the soil 1 to 2 of soil. As for the micronutrient copper, this generally exhibits a continuing sharp decline in plants on soils with sludge.
- On the stem and branches, as well as the evolution of sodium previously mentioned, we found a significant increase in calcium in the soil plants 2, with respect to other plants in which calcium increases from the soil 1, except those grown in soil in Benirrama produced the opposite result.
- In the root is worth noting, in addition to the sequence obtained for sodium, the lowest concentration of the element potassium in plants on soils 2 with the exception of Ramers soil where the concentration of soil 1 is less the soil 2.
- Concerning micronutrients, notwithstanding the evolution of each soil where there are significantly higher concentrations of iron in all samples. The concentrations are focused in the roots. There are significant differences in the concentrations of other micronutrients in different parts of the plant, without reaching the levels of iron. Here evolution does not follow a defined sequence, as it is higher in the plants in soils 2 except the Salobre plant, which is larger the plant 1.

We can conclude that the vegetative development of plants clearly improved in the in the treatment with sewage sludge due to nutrient supply and improving the soil physical properties. For this reason we consider that the use of this type of waste as fertilizer in tomato cultivation is a good strategy.

References

- García-Serna, J.R. (1992). Salinidad del agua de riego y fertilizantes nitrogenados de liberación lenta. Desarrollo de nuevas compuestas. Tesis doctoral. Universidad de Alicante, Alicante (Spain).
- Gómez, I., J. Navarro-Pedreño and J. Mataix (1992). Aguas de riego: análisis e interpretación, Servicio de Publicaciones de la Universidad de Alicante-CAM, Alicante (Spain).
- Gregori, I.; Llinares, J.V.; Sendra, F. (2011). Ensayos en invernadero de lodos de EDAR en Luvisol crómico, VI Congreso Ibérico de Agroingeniería, Évora (Portugal).
- Martínez-Cortijo, F. J.; Sendra, F.; Marco, J. (2011). Several effects on the composition of grounds irrigated with wastewater. The Fifth International Scientific Conference Rural Development 2011, 309-313. Kaunas (Lithuania).
- Sendra, F.; Llinares, J.V.; Boscaiu, M. (2010). Use of Urban Sewage Sludge as Soil Amendment and its Influence on the Development of Tomato Plant. Bulletin UASVM Horticulture, 67 (2)/2010, 309-313, Cluj-Napoca (Romania).
- Sendra, F.; Martínez-Cortijo, F.J. (2010). Influencia de la adición de lodo procedente de una EDAR en algunos suelos de regadío. Congreso Internacional sobre suelos y materia orgánica a partir de residuos. Sesión VIII-B, 11 p, Valladolid (Spain).