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VEGETATIVE AND POMOLOGICAL CHANGES OF SOUR CHERRY AS AFFECTED BY SEWAGE SLUDGE APPLICATION

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Abstract

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This study was carried out for determining the effects of sewage sludge application on vegetative and pomological changes of sour cherry between the years of 2005 and 2007. Six application rates of sewage sludge (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)) were selected. The experiment was laid out in a randomized complete block design with three replications in 18 homogeneous and 1 year old saplings belonging to the cultivar of 'Kutahya/ *Prunus mahalep* L.'. Application of sewage sludge during plantation not only helped to improve vegetative parameters but also fruit chemical characteristics. The highest results of measured parameters were obtained from the application rate of 7.5 kg per tree. This dose improved vegetative growth of sour cherry more than 50%, as compared with the control. Results presented in this study showed that sewage sludge is an effective, low-cost organic input to develop sour cherry plantation. Further studies should be conducted to evaluate the effects of sewage sludge on other plants in different ecological conditions.

Key words: sour cherry, sewage sludge, vegetative growth, pomology, fruit chemical properties

Introduction

Supplementing the nutrient requirements of crops plays a key role in sustaining soil fertility and crop productivity (Soumare et al., 2003). Several mineral and organic inputs are used to ensure soil fertility and crop productivity. Mineral fertilization provides readily available nutrients for plant growth without making any improvement in soil physical properties. In addition to supplying essential nutrients for plant growth, organic amendments also improve soil physical properties and stimulate plant growth (Ferreras et al., 2006).

The use of wastes in agriculture, forestry and land reclamation is increasingly being identified as an important issue for soil fertility, conservation and residual disposal. Using wastes in agriculture not only helps to dispose these materials economically, but also reduces negative effects of them on environment. Sewage sludge is a concentrated suspension of solids, largely composed of organic matter and nutrient-laden organic solids. In addition to major plant nutrients in its content, sewage sludge also contains trace elements

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that are essential for plant growth (Anonymous, 1996).

Many studies have been conducted to determine the effects of sewage sludge application on crop and plant yield (Wong et al., 1996; Navas et al., 1998; Bozkurt and Yarilgac, 2003; Cheng et al., 2007) and soil properties (Aggelides and Londra, 2000; Holz et al., 2000; Tsadilas et al., 2005). But no attention has been given to the effects of sewage sludge application on vegetative parameters, pomology and fruit chemical properties of sour cherry. Therefore, studies should be conducted for determining the effects of sewage sludge application on vegetative parameters and pomological characteristics on woody plants.

Nowadays, there is an increasing demand on new plantation areas of sour cherry (*Purunus cerasus* L.) in different ecological conditions (Poland, Russian Federation and Turkey) because of its wide use in industry. Within purunus species, sour cherry is one of the most tolerant to disease and climatic stresses (Lezzoni et al., 1990). Therefore it is much more suitable for areas with low fertility and severe environmental conditions, with proper management strategies.

This study was carried out for determining the effects of sewage sludge application (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)) on vegetative parameters, pomological characteristics and fruit chemical properties of sour cherry.

Materials and Methods

Study site

This study was conducted between the years of 2005 and 2007 at Atatürk University, Faculty of Agriculture, Department of Horticulture Research and Application Orchard, in Erzurum (39° 55' N, 41° 61' E), Turkey. The experimental region has a semi-arid climate with long-term mean annual minimum and maximum temperatures, relative humidity and total precipitation; -8.7°C and 19.5°C, 64% and 447.0 mm, respectively. Soils in the experimental site are of alluvial and hydromorphic origin. Experimental region has slight slope angle (<2%) so no runoff was observed during the study.

Experimental layout

The experiment was laid out in a randomized complete block design with six sewage sludge application rates and three replications. One year old certificated (virus-free) sour cherry saplings were planted at 4 m x 5 m (20 m^2, per plant) spacing in the spring (April) of 2005. Plants were trained to central leader. Eighteen homogeneous and 1 year old saplings belonging to the cultivar of 'Kutahya/ *Prunus mahalep* L.' were selected for the experiment for homogenizing growth, new shoots at 75 cm above the grafted point were removed. Weeds were controlled around the base of the trees by repeated hoing. No pesticide was applied. Anaerobically stabilized sewage sludge, obtained from Ankara Municipality treatment plant, was applied to sour cherry trees in May 2005 in the rates of 0.0 (Control), 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight), no sewage sludge application was made after this date. Sewage sludge was applied to the root area of saplings (70 cm diameter, 20 cm depth). Initial soil properties and characteristics of sewage sludge were given in Table 1.

Data collection and statistical analysis

Plant height, trunk diameter, canopy width, shoot number, shoot length, and shoot thickness were measured for all sour cherry trees in the fall of 2005 and 2006, while leaf stalk length, leaf stalk thickness and fruit yield were measured in 2007. Leaf area was measured with a CI 202 portable digital area-meter in 2007 (Aslantas et al., 2007). Flower bud density was determined according to Bernard and Socias I Company (1997) in fall of 2006. Fruit stalk length, thickness, width, length, fruit thickness, weight, volume, density and pit weight were determined after harvest in 2007. Chemical analyses of fruits were done on same fruits on which pomological analysis were done. The pH of the fruits was measured in juices using a pH meter. Titrable acidity and total sugar were determined according to the methods given by Pirlak et al. (2003). Total soluble solids were determined using a digital refractometer, while ascorbic acid, malic acid, glucose and fructose were determined by an RQflex plus 10 Reflectometer. Fruit inner and outer

Table 1
Initial soil properties and characteristics of sewage sludge used in this study

Parameters (Unit) (Dry matter)	Soil		Sewage Sludge
Texture — Clay. %	11.4		-
Texture — Silt. %	19.40		-
Texture — Sand. %	69.20		-
Organic matter. %	0.55		34
Total N. %	NH_4	0.001	4.46
	NO_3	0.001	
Total P. %	1.22%		1.1%
CEC. me 100 g-1	22.87		62.43
Ca. me 100 g-1	17.18		37
Mg. me 100 g-1			15.83
Na. me 100 g-1	0.07		0.87
K. me 100 g-1	0.86		5.38
Fe (ppm)	0.85		1000
Zn (ppm)	0.43		873.53
Cu (ppm)	0.24		239.90
Mn (ppm)	1.52		903.99
Ni (ppm)	0.25		57
Pb (ppm)	0.25		152.5
Cd (ppm)	-		8.5
pH	7.34		6.82
Electrical Conductivity (mS cm^{-1})	0.29		6.54
Lime (%)	0.17		17.3
Salmonella (25 g)	-		Not found
Helmint egg (g)	-		Not found

colors were measured using a Minolta Colorimeter (Anonymous, 1979).

Analysis of variance was performed by SPSS Statistical Package (SPSS 13.0, SPSS Science, Chicago, IL) using GLM. Mean differences were considered significant if $P \leq 0.05$ (Duncan's Multiple Range Test).

Results

Initial soil properties and characteristics of sewage sludge are given in Table 1. Sewage sludge used in this study can be classified as "Class B" in USEPA and "Conventional" in EU Regulations (Epstein, 2003). It is clearly known that sewage sludge application not only increases macro and micro nutrients but also heavy metal content of soils. Therefore, application of sewage sludge should not increase heavy metal content of soil. In this study, amount of metals given into the soil by sewage sludge application were much lower than critical values (Table 2).

Effects of sewage sludge application on vegetative growth parameters are shown in Table 3. Sewage sludge application increased vegetative growth parameters in all of the application rates. These increases were also seen in the second year. However, studied parameters showed a parabolic curve. The highest

Table 2

Amount of metals added to soil by sewage sludge application, kg ha^{-1}

Application rate, kg per tree[a]	Zn	Cu	Ni	Pb	Cd
2.5	0.3	0.30	0.07	0.19	0.01
5.0	0.6	0.60	0.14	0.38	0.02
7.5	0.9	0.90	0.21	0.57	0.03
10.0	1.2	0.29	0.29	0.76	0.04
12.5	1.5	0.36	0.36	0.95	0.05
Critical soil concentration[b]	480	150	120	480	9.6
European regulations[b]	300	120	30	150	1.5
USEPA[b]	2800	1500	420	300	39

[a] Application rates were calculated considering 500 tree per ha (4 m x 5 m spacing).

[b] Obtained from Gascó and Lobo (2007).

Table 3

Effects of sewage sludge application on vegetative growth parameters

SS*	Plant height, cm		Trunk diameter, cm		Canopy width, cm	
	2005	2006	2005	2006	2005	2006
0.0	114.00b	149.00c	2.05c	2.73c	93.67b	114.67b
2.5	136.67ab	153.33bc	2.16bc	2.77c	104.67ab	122.33b
5.0	155.67a	187.67abc	2.26bc	2.78c	111.33ab	126.00b
7.5	176.33a	226.33a	3.13a	4.21a	135.00a	170.67a
10.0	163.67a	192.33ab	2.84ab	3.69ab	123.33ab	134.33ab
12.5	158.67a	186.00abc	2.46ab	3.07bc	118.00ab	134.00ab
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SS*	Shoot number		Shoot length, cm		Shoot thickness, *mm*	
	2005	2006	2005	2006	2005	2006
0.0	38.33	85.67b	24.65c	14.67c	3.53c	2.83b
2.5	38.67	86.67b	35.08bc	16.94c	4.20bc	3.87ab
5.0	51.67	115.33ab	31.10bc	20.22bc	3.90c	4.03ab
7.5	58.67	134.00a	49.05a	29.95a	5.30a	5.57a
10.0	44.67	88.33b	40.62ab	23.33b	4.80ab	4.47ab
12.5	47.67	100.00ab	38.33ab	15.68c	4.40bc	3.67b
P	ns	<0.05	<0.05	<0.05	<0.05	<0.05

* SS: Application rates of sewage sludge (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)).

ns: Not significant; Values followed by same letter are not statistically different.

Table 4
Effects of sewage sludge application on leaf properties, flower bud density and yield

SS*	Leaf area, cm^2	Leaf stalk length, mm	Leaf stalk thickness, mm	FBD, unit cm^{-1}	Yield§, g cm^{-2}
0.0	8.11b	20.93bc	1.25c	0.65	83.75
2.5	12.74a	18.58c	1.46ab	0.67	84.67
5.0	12.48a	18.80c	1.43ab	0.55	84.06
7.5	13.62a	23.18ab	1.56a	0.61	81.22
10.0	11.62a	20.10bc	1.59a	0.57	80.46
12.5	12.41a	25.34a	1.31bc	0.71	83.80
P	<0.05	<0.05	<0.05	ns	ns

* SS: Application rates of sewage sludge (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)).
FBD : Flower bud density, §: Cross sectional area
ns: Not significant; Values followed by same letter are not statistically different.

Table 5
Effects of sewage sludge application on pomological characteristics of sour cherry

SS*	Fruit width, mm	Fruit length, mm	Fruit thickness, mm	Fruit weight, g	Fruit volume, cm^3	Fruit density, g cm^{-3}	Pit weight, g	Fruit stalk length, mm	Fruit stalk thickness, mm
0.0	19.35c	17.63c	16.93c	4.13c	4.17c	0.99b	0.31b	57.32c	0.99bc
2.5	20.45b	19.28ab	18.00ab	4.66b	4.20c	1.11a	0.32b	62.33bc	0.90c
5.0	19.98bc	18.61abc	17.45bc	4.65b	4.07c	1.15a	0.31b	57.53c	0.98bc
7.5	21.34a	19.47a	18.70a	5.62a	6.17a	0.91b	0.41a	69.09a	1.06ab
10.0	19.66bc	18.08bc	16.91c	4.53bc	3.83c	1.18a	0.38a	63.35b	1.09a
12.5	20.11bc	18.73abc	16.73c	4.74b	4.83b	0.98b	0.33b	62.44bc	0.96c
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

* SS: Application rates of sewage sludge (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)).
ns: Not significant; Values followed by same letter are not statistically different.

results were obtained from the application rate of 7.5 kg per tree. Similar results were also seen in the rate of 10.0 kg per tree. Rates above these doses not only had negative effects on vegetative growth but also considered as not economic. As compared with the control, sewage sludge application increased plant height within the ratios of 20-54% and 3-52%, trunk diameter 5-53% and 2-54%, canopy width 12-44% and 7-49%, shoot number 1-53% and 1-56%, shoot length 26-99% and 7-104% and shoot thickness 11-50% and 30-97% in 2005 and 2006 years, respectively.

Effects of sewage sludge application on leaf properties, flower bud density and yield are given in Table 4. As in vegetative parameters, the highest results were obtained with the application rate of 7.5 kg per tree. Sewage sludge application increased leaf area within the ratios of 43-68% and leaf stalk thickness within 5-27%, as compared with the control. However, fluctuations were seen in leaf stalk length, flower bud density, and yield. Sewage sludge application increased pomological characteristics of fruit (Table 5). As in

Table 6
Effects of sewage sludge application on chemical properties of fruit

SS*	pH	Titrable acid, %	Ascorbic acid, mg 100 ml	Malic acid, %	Glucose, %	Fructose, %	Total sugar, %	Total soluble solids, %
0.0	3.80ab	0.90b	14.70f	3.34b	4.31e	8.20e	12.60f	16.60c
2.5	3.60cd	0.64e	24.20a	3.84a	4.71d	9.00c	13.80c	15.80d
5.0	3.70bc	0.77c	21.70c	3.28c	4.31e	8.60d	13.00d	15.50e
7.5	3.50d	0.71d	18.30e	3.28c	5.11c	9.50b	14.70b	15.20f
10.0	3.90a	0.71d	22.70b	2.98d	5.51b	7.10f	12.70e	16.90b
12.5	3.90a	0.96a	21.30d	3.34b	6.31a	10.50a	16.90a	17.80a
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

* SS: Application rates of sewage sludge (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)).
ns: Not significant; Values followed by same letter are not statistically different.

Table 7
Effects of sewage sludge application on *L*, *a* and *b* values

SS*	Outer			Inner		
	L	*a*	*b*	*L*	*a*	*b*
0.0	26.22	14.21b	3.19b	19,02	30.67	12,58
2.5	28.27	20.38a	5.84a	23.67	24.91	13.91
5.0	25.91	15.94b	4.13b	23.74	29.27	13,09
7.5	26.64	15.10b	3.85b	25.98	29.97	14.55
10.0	27.41	14.39b	3.94b	26.81	29.74	14.67
12.5	26.62	15.96b	3.56b	22.49	24.59	9,25
P	ns	<0.05	<0.05	ns	ns	ns

* SS: Application rates of sewage sludge (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 kg per tree (dry weight)).
ns: Not significant; Values followed by same letter are not statistically different.

vegetative and leaf parameters, the highest values were gained with the application rate of 7.5 kg per tree. Application of sewage sludge as 7.5 kg per tree, not only increased fruit weight (36%) but also pit weight (32%) which caused an increase in fruit dimensions. Effects of sewage sludge application on chemical properties of fruit were found statistically significant (Table 6). Effects of sewage sludge application on fruit color (L, a, and b) are shown in Table 7. Changes in chemical properties of fruit and fruit color were not affected directly by application dose.

Discussion

Application of sewage sludge to sandy loam textured soil not only stimulated vegetative growth but also generative. Main factors which influence vegetative and generative growth in horticulture can be classified as genotype, environmental conditions and proper annual managements. In same environmental conditions and genotype, vegetative and generative growth can only be maintained by proper inputs. Results presented in this study showed that sewage sludge

is an effective, low-cost organic input to develop sour cherry plantation.

Sewage sludge, due to its high organic matter and macro and micro nutrient content, improved all of the parameters measured. The highest results were obtained from the application rate of 7.5 kg per tree. This situation showed its effect for 3 years (2 years vegetative growth and 1 year pomology). However, application of 5.0 and 10.0 kg sewage sludge per tree showed similar effects as 7.5 kg per tree. Doses above these values had negative effects on vegetative parameters (Tables 3 and 4).

The higher dose will cause the higher heavy metal content of soil. Therefore, characteristics of sewage sludge should be taken into account when it's being applied. Flower bud occurring and blossom is the most important physiological event in fruit species. Whatsoever, flower bud density and yield was not found statistically significant; it should be evaluated with shoot number, shoot length and cross sectional area to calculate whole productivity. Increase in leaf area is important in the formation of flower bud due to sustaining assimilation matter. Thus, vegetative growth is an important issue for tree to develop its generative growth (Kaska and Paydas Kargi, 2007). Fruit dimension and weight are directly affected by soil moisture. While in humid regions fruit width exceeds 20 mm, it is approximately 10 mm in arid regions (Lezzoni et al., 1990). The study area is involved in semi arid region, it is expected that fruit width should be within 10-20 mm diameter, but sewage sludge application increased fruit weight and in some doses it exceeded 20 mm. This situation can be explained by increased water holding capacity of soil due to sewage sludge application. Ascorbic acid content of sour cherry is generally 10 mg 100 ml^{-1} (Westwood, 1993) and is affected by altitude. Due to altitude of study site (1853 m) and sewage sludge application, ascorbic acid content of fruits was much higher than this value. Most part of total soluble solids (TSS) is mainly sugar, and almost all of the total sugar is reduced sugar (Glucose + Fructose). As compared with control, sewage sludge increased total sugar, glucose and fructose content of fruit in all of the application rates, which is directly affected by vegetative growth, especially leaf area. Hence, difference between day and night temperatures caused assimilation matters converted into sugar.

Conclusion

The aim in horticulture is to increase quality and quantity of fruit with minimum input. Two main factors which influence vegetative growth are water and nitrogen. Organic materials provide nitrogen and increase water holding capacity of soil. Results obtained from this study have shown that sewage sludge is an effective way to improve vegetative and generative growth of sour cherry in coarse-textured soils. The most effective application rate was found as 7.5 kg per tree in this study. Application of sewage sludge during plantation helped to improve vegetative parameters as well as fruit chemical characteristics. However, this situation depends on ecological conditions and species.

In order to minimize negative effects of sewage sludge to soil, characteristics of sewage sludge should be taken into account according to the critical concentrations. Further studies should be conducted to evaluate the effects of sewage sludge on other plants at different ecological conditions.

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