The Effect of Sludge and Water from a Sewage Treatment Plant on the Growth of Cotton Plants (*Gossypium hirsutum*)

A. Tsakou[1], *N.S. Christodoulakis*[1], *F. Kokkinos*[2], *I. Petri*[2]
[1] University of Athens, Department of Biology, 157 84 Athens, Greece.
[2] Hellenic Cotton Board, 150 Syngrou Avenue, 176 71 Athens, Greece.

ABSTRACT

The effect of water and sludge from a Sewage Treatment Plant (STP) in Keratea, Greece, on the growth of G. hirsutum was studied in a pot experiment. Cotton plants were grouped according to the substrate in which they were cultivated: soil, soil + fertilizer, soil + sludge in two different rates (10:1 and 2:1). Half of the plants in each group were irrigated with tap water and half with STP water. Application of sewage sludge as soil amendment and irrigation with STP water (after chlorination), strongly promoted growth and fiber production of cotton plants. Fiber and seed quality were also high. STP products prime plant growth resulting into earlier fructification . These observations indicate that STP products could be in favour of the agriculturist through faster plant development and greater productivity.

Introduction

In order to protect the environment and comply with the European Community's regulations (Anon, 1991) Greece has started designing and constructing Sewage Treatment Plants for the majority of towns. The increasing production of sludge and wastewater posed the question of an alternative solution for their utilization instead of their land-filling or disposal into the sea respectively.

Wastewater could be used for the irrigation of cultivated crops, especially in a country with limited water sources like Greece. Sludge on the other hand, known for its rich potential in nutrients (such as P or N) (de Haan, 1980), micronutrients and organic matter could be used as fertilizer or a soil amendment (Goda *et al.,* 1986). Under alkaline conditions most heavy metals become less soluble, thus less available to the plants due to their precipitation. Many soils in Greece are alkaline with pH values above 7. This fact in combination with the limited or none industrial activities of Greece, which results in sewage sludge with low concentration of heavy metals, make the use of sewage sludge in agriculture permitable (Rawajfih *et al.,* 1990).

Gossypium species are ideal as experimental plants since they can grow in alkaline soils and their main product (fibers) that is used world wide, consists of pure cellulose and does not accumulate heavy metals.

The objective of this study was to investigate the impact of sewage sludge and wastewater on the growth and productivity of cotton plants.

Materials and methods

Seeds of *Gossypium hirsutum* were imbibed and seedlings were moved to black-coloured polystyrene pots with upper diameter of 25 cm. These pots were filled with 10 Kg of growing substrate as shown below. Pots were divided into groups of 10 pots. Every group had different treatment during the experiment. The soils low in nutrients from the installation area were used as a basis for the growing substrate. Ground plain soil or a mixture of this soil with fertilizer or sludge (dewatered and digested) was used to fill pots in all eight groups.

During the growing period phenological observations were recorded once a week. At the end of the experiment, dry weight of the above-ground matter, roots, fibers and seeds were measured. The surface of the 8th leaf of the cotton plants was also measured (with a leaf area meter). Leaves were counted from the ground to the apex. In the end the fiber and seed quality were measured in the Hellenic Cotton Board. The fibers were examined in a High Volume Instrument (HVI) following the ASTM D4605-86 method, whereas the cotton seeds were examined for their concentration in oil and protein in a Soxhlet and a Kjeltec-System I instrument respectively.

Results and discussion

From the data we present it appears that soil amendment with sewage treatment plant's by-products promotes plant growth (Fig. 2 and 3) significantly more than when fertilizers are added. In combination to their irrigation with Sewage Treatment Plant (STP) water the yields of stem and root increase even more.

Soil:sludge ratio of 10:1 in addition to STP water gave the greater yields. Similar results were obtained for the leaf surface (Fig. 4). On the other hand the flowering and fructification periods were primed because of the application of sludge and irrigation with STP water (Fig. 1). In the case of sludge the period of flowering started 4 weeks earlier. This is a great advantage for

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countries with the same latitude as Greece, where the cultivation period is relatively short.

The dry weight of mature fibers among the different groups of plants varied significantly (Table 3). Application of sewage sludge promoted fiber production up to a 248.63% (ratio 2:1) or 139.64% (ratio 10:1) compared to that obtained when adding fertilizers to the soil. Higher production was also observed in the group of plain soil when irrigating with Sewage Treatment Plant (STP) water instead of tap water. In all other groups the combination of sewage sludge/STP water or fertilization/STP water provided lower fiber production than the respective combinations with tap water.

The results of HVI fiber quality tests are summarized in Table 4. This shows that the quality of fibers from the different groups of treatment is within the standards for the Greek cotton. Quality characters were more or less the same as in the reference group (group 2, soil + fertilizer). Similar results were obtained for cottonseed quality. The % concentrations of oil and protein in cottonseeds in the various groups of plants vary (Table 5) but at normal levels (Table 6).

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Summary of Treatments: Groups of 10 pots: The properties of the soil are shown in Table 1.

	group 1	plain soil		[S]
	group 2	soil + fertiliser		[S + F]
1) tap water	group 3	soil and sludge	10:1 v/v	[S : SS (10:1)]
	group 4	soil and sludge	2:1 v/v	[S : SS (2:1)]
	group 5	plain soil		[S]
2) water from the STP after chlorination	group 6	soil + fertiliser		[S + F]
	group 7	soil and sludge 10:1v/v		[S : SS (10:1)]
	group 8	soil and sludge 2:1 v/v		[S : SS (2:1)]

Figure 1. Phenological observations of the flowering, fructification and open capsule appearance period.

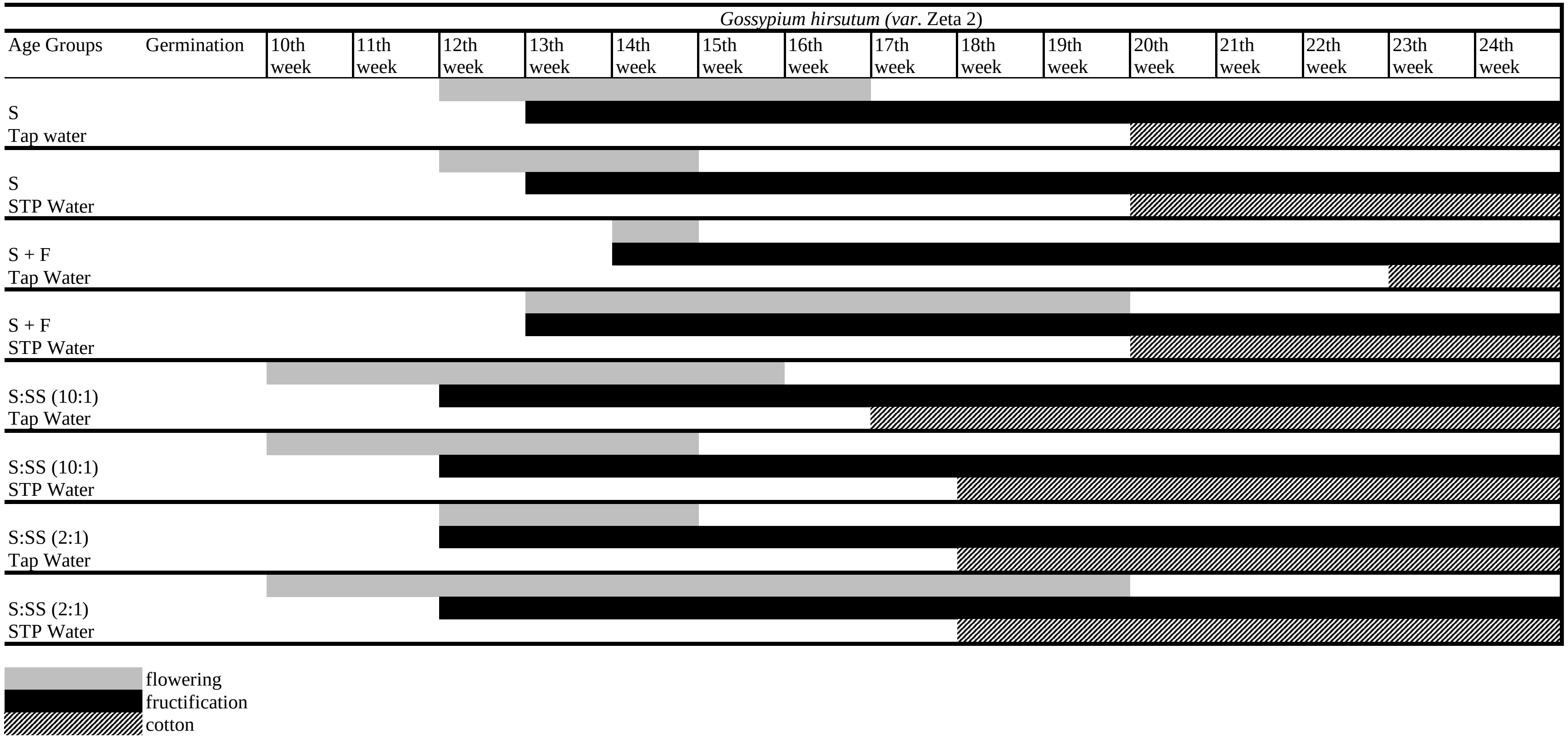

Table 1. Properties of Keratea soil used in the experiment.

Property	Measurement	Property	Measurement
Organic matter %	0.76	Mg (ppm)	460
EC (mS/cm)	4.559	Ca (ppm)	5.640
pH	8.43	Na (ppm)	4.810
Total P (ppm)	12	Fe (ppm)	4.70
Total K (ppm)	31	Cu (ppm)	0.30
Clay %	18.90	Zn (ppm)	0.20
Silt %	31.40	Mn (ppm)	1.50
Sand %	49.70		

Table 2. Some relevant characteristics of domestic sewage sludge from Keratea's secondary sewage treatment plant.

Property	Measurement	Property	Measurement
Organic matter (%)	53.08	Cd (ppm)	9.930
EC (mS/cm)	50.51	Zn (ppm)	2307.283
pH	5.80	Ni (ppm)	322.227
K (%)	0.869	Cu (ppm)	260.392
Fe (%)	3.337	Hg (ppm)	1.994
Mn (ppm)	769.071	Pb (ppm)	817.700

Table 3. Production of fibers in the various groups of plants.

Group of plants	Dry weight of mature fibres	% increase of fibre production over group 2	Group of pots	Dry weight of mature fibres	% increase of fibre production over group 2
1	7.65	-71.34	5	15.74	-41.03
2	26.69		6	20.54	-23.04
3	63.96	139.640	7	44.12	65.31
4	93.05	248.63	8	40.30	50.99

Table 4. Quality characters of fibres.

Group of Pots	1[1]	2	3	4	5	6	7	8
Micronaire	-	3.9	4.2	3.7	4.2	2.9	4.6	4.8
Fibre Strength (g/tex)	-	21.4	22.6	23.0	19.7	25.8	22.6	22.5
Fibre Length (mm)	-	29.4	30.3	29.7	28.6	30.1	27.2	31.2
% Uniformity of length	-	51.4	54.6	51.1	52.7	53.8	57.2	56.9
% of short fibres	-	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5
% Fibre Elongation	-	5.2	5.4	5.6	5.6	6.6	5.9	5.2
Cotton Colour Grade [2]	-	31-1	31-2	31-1	31-1	21-2	31-2	31-1
Reflectance	-	79.4	79.9	79.5	80.4	83.0	77.1	79.7
Yellowness	-	7.6	6.9	7.5	7.6	7.0	7.6	7.7

[1] : not enough (for this analysis) fibres were obtained from this group of plants
[2] (based on Universal Standards for Grades of American Upland Cotton)

Table 6. Average of % oil and protein (in dry matter) of cotton seed of the *G. hirsutum (var. Zeta 2)*, from cultivations in Greece during the last years.

Group of plants	Dry weight of mature fibres	% increase of fibre production over group 2	Group of pots	Dry weight of mature fibres	% increase of fibre production over group 2
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Table 5. % cottonseed concentration in oil and protein (in dry matter) of the *G. hirsutum* (var. Zeta 2) used in the experiment.

Pot groups	% oil (in dry matter)	% protein (in dry matter)
1	-	15.67
2	20.86	22.32
3	21.49	20.12
4	18.24	23.79
5	17.91	19.69
6	20.60	21.24
7	21.39	19.92
8	18.67	22.27

Figure 2. *Gossypium hirsutum* (var. Zeta 2) above ground dry weight (gr).

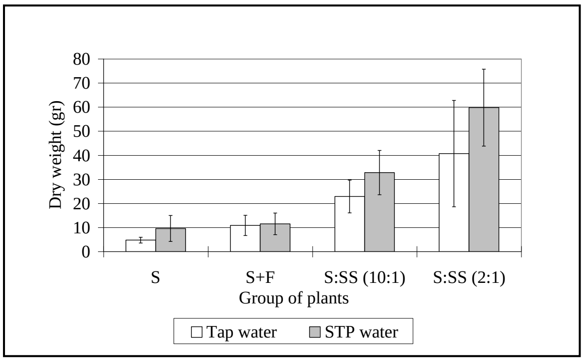

Figure 3. *Gossypium hirsutum* (var. Zeta 2), dry root weight (gr).

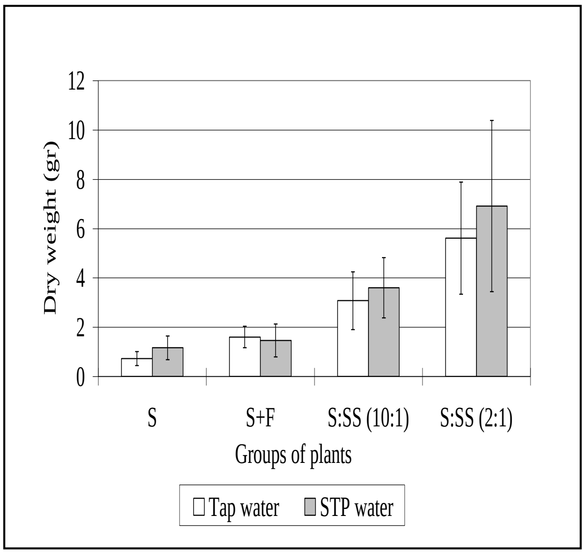

Figure 4. *Gossypium hirsutum* (var. Zeta 2); Average leaf surface of 8th leaf (mm x mm).