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EFFECT OF SOIL AMENDMENT WITH SEWAGE SLUDGE ON WHEAT GROWTH AND PRODUCTIVITY

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ABSTRACT

Wheat as a cereal crop might display the top among all strategic crops, in Egypt the annual production is always behind the need and the gap between production and consumption remain great. The main target of the present investigation has been to study the effect of sewage sludge as organic fertilizer on wheat as a major cereal crop in Egypt. Composted and air-dried sewage sludge was obtained from the Municipal Wastewater Treatment Station at Al-Sheikh-Zowaied and applied at three rates for comparison, these rates were: 10%, 20% and 30%. For experimentation, the recommended cultivar Sakha-93 of *Triticum aestivum* L. was obtained and field experiments were conducted within the University Agriculture Farm at Al-Arish where the soil is typically sandy loam with little silt and clay. From each treatment, three plant samples were collected during the vegetative and reproductive phases and finally at the grain stage for comparing growth, productivity and yield-quality. The results indicated that fresh & dry weight of plant parts increased greatly by increasing the amount of sewage sludge. The effect was more prominent at the flowering stage. All concentrations of sludge amendment showed prominent increase in fresh & dry weight. Sludge amendment increased greatly total lipids, total protein and heavy metals absorption; however, the amount of increase was much higher compared to control natural soil. Growth and yield of wheat were greatly increased by sewage sludge amendment. The best yield (1.69 Ton/ Feddan) was reported at the sludge concentration of 20%.

Key Words: Wheat, Sewage Sludge, Organic Fertilizer, Composted, Total Protein and Heavy Metals, Growth, Productivity & Yield-Quality.

INTRODUCTION

1. Importance of wheat as a crop:

Wheat (particularly *Triticum aestivum* L.) is the first important and strategic cereal crop for the majority of world's populations. It is the most important staple food of about two billion people (36% of the world population).

Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally.

It exceeds in acreage and productivity every other grain crop including rice, maize, etc. and is cultivated over a wide range of climatic conditions **(Breiman & Graur, 1995).** It is planted annually in about 7.2 million ha^{-1} with an average annual yield of 1596 $kgha^{-1}$ and **(Rangaraj *et al.,* 2007).**

2. Challenges and problems related to wheat productivity worldwide:

Challenges and problems are variable and numerous nevertheless, their types and intensity vary greatly from country to another but the major challenge could be the cultivar selection or preparation. For obtaining an appropriate cultivar of outstanding high productivity-potential and better disease-resistance, breading or genetic engineering has to be used as a matter of choice. Other challenges are very often starting in the field, continuing through harvesting, and extending during storage.

3. Sewage sludge as a fertilizer usage and importance:

Chemical fertilizers are usually used but most commonly leading to an increase of crop cost. To reduce such expenditure and to manage soil quality application of manure and sludge (as organic fertilizers) became an alternative source of plant nutrients.

The use of organic wastes on farms for agricultural purposes has been identified as a standard of good agricultural practices. These wastes constitute considerable resources of fertilizer components and organic matter, which is connected with their biological origin **(Kalembasa*et al.,* 2004; Mosquera-Losada*et al.,* 2010)**.

Organic amendments to the soil are variable, may be in the form of chicken litter, oil cakes, rice husks, organic mulches, sludge or in the form of compost, farm-yard-manure, stable-manure, and green-manure.

Sewage sludge can:

1-modify soil physical, chemical and biological properties (**Alcantara *et al.,* 2009; Angın & Yağanoğlu, 2009).**

2-improve crop-yield by reducing the cost effect for nitrogen and phosphorus **(Petersen *et al.,* 2003).**

3-increase plant growth rate, crop-yield and biomass **(Samaras *et al.,* 2008; Togay *et al.,* 2008; Angın & Yaganoğlu, 2011).**

4- afford macronutrients like: N, P, K, Ca and Mg, and micronutrients like: B, Cu, Fe, Ni and Zn (**Yan *et al.,* 2009; Du *et al.,* 2012; Gu *et al.,* 2013).**

MATERIALS AND METHODS:

The main intention of the present investigation have been to compare between the effect of different sewage sludge concentrations (as an organic fertilizer) and control natural soil on the productivity of wheat as a major cereal crop in Egypt.

1. Field design and experimentation:

For field experiments, the recommended winter variety of wheat (*Triticum aestivum* L.), Sakha-93 was obtained from the Agricultural Research Center, Ministry of Agriculture, Giza. After being washed several times with tap water, wheat grains were surface sterilized by immersing in 1.5 % sodium hypochlorite for three minutes followed by soaking in 70% ethanol for two minutes **(Royse & Ries, 1978)** then rinsed with sterile water. For field cultivation, wheat grain amounts at the rate of 70 Kg/Fed were used.

Field experimentation has been conducted during early winter (November of the season 2012 and repeated in the next season November of 2013) in a plot within

The Agriculture Farm, Faculty of Agricultural & Environmental Sciences at Al-Arish. The experimental plot was subdivided further into subplots (2 × 2 m) where plants were grown in rows of 10 cm apart. In addition to natural soils control (C), three different concentrations of soil amended with sludge (S) at 10%, 20% and 30%.

This experiment was conducted under the natural conditions prevailing at the University Farm where the temperature showed a minimum of $14^{o}C$ and a maximum of $17^{o}C$ and the day-length was 14 h and the night-time was 10 h and the relative humidity of 60 % and the light-intensity was 310 $\mu Em^{-2} S^{-1}$. Form each

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treatment, three groups of plant samples were collected randomly at different time intervals during the experiment of each season. The first two groups of samples at two different stages during the vegetative growth.

One group of samples at the tillering stage i.e after 55 days from sowing and another at the flowering stage i.e after 75 days from sowing.

After drying at 70^{o}C for 7 days, dry fresh samples were ground into fine powder and tested for: **a-** heavy metals, **b-** total lipids and **c-** total protein.

The third group of samples (was represented by grains after maturity of kernels and yellowing of internodes i.e. after 150 days from sowing) was taken after harvesting to determine the following parameters: **a-** grain yield (Kg/fad), **b-** weight of 100 seeds, **c-** concentration of heavy metals, **d-**total lipids, **e-** total protein.

2. Sludge characteristics

Composted sludge was collected in polyethylene bags from the Municipal Wastewater Treatment Station at Al-Sheikh Zowaied, North-Sinai.

The obtained amount was air-dried and crushed and sieved through 2 mm sieve and kept in clean bags till use.

3. Chemical properties:

For the chemical characterization of sludge, 20 g samples were taken and subjected to chemical analysis of heavy metals content using the **Standard Methods for the Examination of Water and Wastewater, 20th Edition (1999)**. Heavy metals concentrations were

determined after digestion in concentrated H_2SO_4 and 33% H_2O_2 at 440°C (Digesdahl digestion apparatus of Hach).

The concentrations of metal ions were measured by atomic absorption spectroscopy, using a Perkin Elmer Model 2380 Spectrophotometer Table (1).

Statistical analysis of the data obtained during this study was carried using statistical analysis of variance (ANOVA) according to **Snedecor & Cochran (1980)** and the least significant difference (LSD) was calculated to determine the statistically significant treatment at 5% level of significance for the error degree of freedom **(Little & Hills, 1978).**

RESULTS

1. Effect of sludge amendment on fresh and dry weight of wheat plants

Three concentrations of sludge (S) namely 10%, 20%, and 30% were studied in natural soil. Comparison was made at two different growth phases, at tillering (after 55 days) and flowering (after 75 days) and the results are given in Table (2).

The data clearly indicate that changes in the fresh and dry weight of shoots, roots and total plants follow almost a similar trend where weights clearly increased upon increasing the amount of sludge. By comparison, weights of all elements (shoots, roots and total plants) showed greater values at the flowering stage than at the tillering stage.

The results **of Table (2),** show also that by Comparison with control natural soil, sludge amendment significantly increased fresh & dry weight of all elements. Comparing the effect of different sludge concentrations (S) at tillering and flowering stages and control natural soil, indicated that sludge amendment gave better values of growth parameters than control soil.

Amending sludge at the concentration of 30 % to showed the most significant increase.

Table (1): Heavy metal content of sludge.

Parameter	mg/l
Aluminum **(Al)**	5.095
Boron **(B)**	1.356
Cadmium **(Cd)**	0.459
Cobalt **(Co)**	0.023
Chromium **(Cr)**	1.432
Copper **(Cu)**	48.630
Iron **(Fe)**	459.000
Manganese **(Mn)**	10.520
Molybdenum **(Mo)**	2.853
Nickel **(Ni)**	2.371
Lead **(Pb)**	36.465
Strontium **(Sr)**	6.225
Vanadium **(V)**	7.315
Zinc **(Zn)**	265.800

Table (2): Effect of different sludge concentrations on the fresh and dry weight of wheat plants at tillering and flowering stages.

Growth Stage	Treatment	Fresh weight (gm)			Dry weight (gm)		
		Shoot	Root	Total plant	Shoot	Root	Total plant
Tillering (after 55 days)	C	0.98±0.13	0.06±0.00	1.05±0.13	0.19±0.04	0.02±0.02	0.21±0.04
	S 10 %	1.29±0.02	0.15±0.03	1.43±0.04	0.20±0.01	0.02±0.02	0.22±0.08
	S 20 %	1.31±0.02	0.19±0.01	1.50±0.02	0.20±0.04	0.03±0.04	0.23±0.07
	S 30 %	1.47±0.24	0.22±0.03	1.69±0.21	0.25±0.04	0.05±0.02	0.30±0.06
	LSD (5 %)	**0.51**	**0.06**	**0.50**	**0.20**	**0.07**	**0.21**
Flowering (after 75 days)	C	7.14±0.13	1.94±0.07	9.06±0.14	2.31±0.58	1.35±0.31	3.66±0.87
	S 10 %	6.70±0.79	2.81±0.09	9.51±0.87	2.34±0.15	1.50±0.03	3.84±0.14
	S 20 %	7.57±0.54	3.04±0.07	10.61±0.61	3.97±0.37	1.62±0.08	5.59±0.45
	S 30 %	7.93±0.06	3.59±0.04	11.52±0.09	4.49±0.31	1.64±0.03	6.13±0.28
	LSD (5 %)	1.33	0.32	1.41	1.13	0.42	1.38

Abbreviations: C; Control natural soil, **S;** Non- Mycorrhized soil treated with sludge, Values in the table are means ± standard, **LSD;** least significant difference at P=0.05.

For example, the data of fresh shoots at the flowering stage, in sludge concentration of 30% showed an average weight of 11.52 gm while 9.08 gm in control soil.

2. Effect of sludge amendment on total protein:

Changes in total protein due to changes in the rate of sludge amendment (S) and are shown in Table (3), where the data clearly indicated that total protein, in plant tissues, follow the same trend by always being significantly high in sludge-amended soils by comparison with control.

At the flowering stage, the sludge amendment at concentration of 30 % showed the highest amount of total protein (9.73%). The same pattern of protein change in plant tissues upon changing sludge concentration (S) was also revealed by grains at the maturity stage.

3. Effect of sludge amendment on heavy metals uptake:

The effect of sludge (S) amendment (at different concentrations) and soil mycorrhization (M) separately and combined on the uptake of some heavy metals (Fe, Cu, Pb, Zn and Mn) was studied at the flowering and grain maturity stages and the related data are given in Table (4).

The absorption of the five heavy metals under test, do not follow the same pattern. The data clearly indicated that upon increasing sludge alone (S), plants absorbed greater amounts of Fe, Cu and Pb than mycorrhized soils, while Zn & Mn showed the opposite trend by showing more absorption in mycorrhized than sludge-amended soils.

The combined treatment of mycorrhization and sludge amendment showed more a significant increase in Zn & Mn than Fe, Cu and Pb at the flowering and grain maturity stages.

4. Effect of sludge amendment on growth and productivity:

The data of all parameters adopted for comparison (No. of flowers/spike, No. of seeds/spike, weight of 100 grain and yield) showed almost the same trend where the addition of more sludge (S) improved all studied characters compared to control natural soil.

As for quality (expressed as No. of seeds/spike), sludge was able to increase the number of seeds/spike from 40 (in control treatment) to 49.7 at sludge concentration of 10% (S), to 54 at sludge concentration of 20% and 54.3 at sludge concentration of 30% (S).

The data of Table (5) clearly indicated that the addition of sludge improved seed quality (expressed as weight of 100 seeds) from 5.7 gm (in the control treatment) to 6.00 gm at sludge (S) concentration of 10%, to 6.30 gm at sludge concentration of 20% (S) to 6.03 at sludge concentration of 30%.

The same trend of improvement was also revealed by total yield (Ton/ Feddan) which showed regular increase in sludge-amended soils (S). The data showed that the best yield (1.69 Ton/ Feddan) was reported at the sludge concentration of 20%.

DISCUSSION

1. Sewage sludge as a fertilizer:

Both of sewage sludge, as an organic fertilizer, and soil endomycorrhiza, as a biofertilizer, became very important elements in sustainable agriculture. Because of the low cost of the first element and the ability to increase the latter element in soil both have been adopted in many countries.

Table (3): Effect of different sludge concentrations on total protein at flowering and grain maturity stages.

Growth Stage	Treatment	Total Protein (%)
Flowering (after 75 days)	C	7.867±0.120
	S 10 %	8.433±0.233
	S 20 %	9.133±0.067
	S 30 %	9.733±0.186
	LSD (5 %)	**0.559**
Grain maturity (after 150 days)	C	9.713±0.195
	S 10 %	9.736±0.070
	S 20 %	9.860±0.070
	S 30 %	10.531±0.286
	LSD (5 %)	0.622

Abbreviations: C; Control natural soil, **S;** Non- Mycorrhized soil treated with sludge, Values in the table are means ± standard, **LSD;** least significant difference at P=0.05.

Table (4): Effect of different sludge concentrations on heavy metals uptake at flowering and grain maturity stages.

Growth Stage	Treatment	Zn (mg/gm)	Mn (mg/gm)	Fe (mg/gm)	Cu (mg/gm)	Pb (mg/gm)
Flowering (after 75 days)	C	0.0217±0.0012	0.0137±0.0015	0.4147±0.0097	0.0087±0.0007	0.0237±0.0009
	S 10 %	0.0320±0.0021	0.0190±0.0006	0.8983±0.0544	0.0243±0.0007	0.0553±0.0072
	S 20 %	0.0367±0.0019	0.0343±0.0029	1.1460±0.0462	0.0363±0.0071	0.0677±0.0003
	S 30 %	0.0553±0.0050	0.0570±0.0120	1.6887±0.1926	0.0423±0.0030	0.0887±0.0044
	LSD (5%)	0.1682	0.1682	0.2343	0.0090	0.0113
Grain maturity (after 150 days)	C	0.0184±0.0021	0.0061±0.0006	0.4589±0.0093	0.0046±0.0002	0.0109±0.0001
	S 10 %	0.0194±0.0014	0.0062±0.0014	0.7041±0.0462	0.0066±0.0001	0.0707±0.0035
	S 20 %	0.0216±0.0004	0.0120±0.0001	0.7461±0.0106	0.0109±0.0001	0.1146±0.0061
	S 30 %	0.0221±0.0007	0.0145±0.0014	0.9668±0.0015	0.0110±0.0011	0.1419±0.0002
	LSD (5 %)	0.0047	0.0042	0.0561	0.0014	0.0075

Abbreviations: C; Control natural soil, **S;** Non- Mycorrhized soil treated with sludge, Values in the table are means ± standard, **LSD;** least significant difference at P=0.05.

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Table (5): Effect of different sludge concentrations on growth and productivity of wheat plant.

Treatment	Growth & Productivity				
	No. of flowers/spike	No. of grain/spike	Wt. of 100 seeds (gm)	Total Plant Yield (gm)	Total Yield (Ton/Feddan)
C	86.00±2.00	40.00±2.89	5.75±0.08	2.30±0.19	1.16±0.12
S 10 %	96.00±3.46	49.67±0.88	5.97±0.09	2.97±0.08	1.48±0.04
S 20 %	109.67±2.19	54.00±3.06	6.28±0.06	3.39±0.19	1.69±0.09
S 30 %	110.00±8.72	54.33±2.96	6.03±0.14	3.28±0.24	1.64±0.12
LSD (5 %)	13.25	8.97	0.35	0.74	0.36

Abbreviations: C; Control natural soil, **S;** Non- Mycorrhized soil treated with sludge, Values in the table are means ± standard, **LSD;** least significant difference at P=0.05.

Sewage sludge contains useful compounds of potential environmental value The organic matter content in sewage sludge can improve soil physical, chemical, and biological properties reflected in better cultivation and aquiferous capacity of soil **(FAO, 1992 and Csattho, 1994)**. Furthermore, sludge applications have resulted in some other improvements of soil characters revealed by: elevated levels of P **Silva *et al.* (2002),** development the humic fraction of organic matter **Melo*et al.* (1994),** and increasing the cation exchange capacity **(Oliveira *et al.,* 2002).**

Regarding the chemical analysis of sludge used in the present study, the results indicated clearly that the load of heavy metals especially Cd, Cu, Fe, and Pb came within the permissible limits by comparison with the critical levels (mg/kg) reported in many countries like Japan **(Nishimune, 1993),** USA **(US EPA, 1999),** Denmark **(Carrington 2001),** Europe Union **(European Commission, 2001)**, Estonia **(Kahru*et al.,* 2002),** Pakistan **(Usman *et al.,* 2005),** Botswana **(Veronica *et al.,* 2006),** Germany **(Dubey *et al.,* 2006),** China **(Liu *et al.,* 2007),** Syria **(Al-Zoubi *et al.,* 2008),** Tunisia **(Cherif*et al.,* 2009).**

2. Effect of sludge amendment on wheat growth and productivity:

A. Fresh and dry weight:

The data revealed that sludge amendment significantly increased fresh and dry weight compared with control. The increase in biomass (fresh & dry weight) upon amending sewage sludge was also noticed by several investigators in different countries like **Sharif *et al.* (2009)** in Pakistan; **Bozkurt & Yarılgaç (2003)** in Turkey; **Mohammad & Athamneh, (2004)** in Jordan; **Lakhdar*et al.* (2010)** in Tunisia; **Kotb (1999); Mazen*et al.* (2010); Galal (2012)** in Egypt.

The concentration of 20%, which have been reported as a most suitable rate for wheat fertilization, in our study, was also noticed for wheat in Turkey by **Özyazici (2013)** during his study on the yield and yield-components of wheat in a crop-rotation program and in India by **Bose & Bhattacharyya (2012)**.

B. Heavy metals uptake:

Data of the present study clearly showed that the five heavy metals under test did not follow the same pattern of uptake, while Fe, Cu and Pb followed a specific pattern Zn and Mn followed another pattern.

Plants absorbed greater amounts of Fe, Cu and Pb upon increasing sludge concentration in both mycorrhized and sludge-amended soils.

However, by comparison, the absorption rate in sludge-amended soils is much greater than that in mycorrhized soil, indicating AM fungi can help alleviate metal toxicity to plants by reducing metals translocation from root to shoot **(Hinsley *et al.,* 1982; Jarausch-Wehrheim *et al.,* 1999; Mc-Grath *et al.,* 2000).**

In Egypt, a survey of literature up to the present time on studies related to the effect of sewage sludge applications on the uptake of heavy metals in wheat or other crops referred toward a clear selectivity of absorption among plant tissues.

The study on wheat by **Galal (2012)** is by far the most relevant one. He found that sludge application combined with biofertilizer such as AM, *Azospirillum* and *Rhizobium* greatly improve the yield.

While, in other crops **Badawy & El-Motaium (2000)** noticed that the concentrations of Cu, Zn, Cd, and Pb in tomato leaves and fruits were increased upon the increase in sewage sludge.

Very similarly observations were also reported by **Rabie (2005)** during his study on red-kidney and by **Mazen*et al.* (2010)** during their study on wheat grown in a desert reclaimed soil. In both studies, the accumulation of heavy metals was much more in roots than shoots.

C. Total yield and yield quality:

The effect of sludge amendment and soil mycorrhization, separately or in combination, was studied and also various concentrations of sludge were tested.

The data, clearly showed a prominent positive effect of both treatments (separately or combined) on both total yield and yield quality.

Our observation on the improvement of total yield and yield quality as a result of sludge amendment were also noticed by many investigators worldwide like **Chatha *et al.* (2002); Jamil *et al.* (2004); Akrivos *et al.* (2006); Tamrabet *et al.* (2009); Aslam *et al.* (2011); Özyazıcı (2013)** who noticed a significant effect on yield and yield quality upon the amendment of sludge.

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الملخص العربي

تأثير التسميد بحمأة الصرف الصحي المعالجة علي نمو وإنتاجية القمح

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يعتبر نبات القمح من أهم محاصيل الحبوب الإستراتيجية في مصر والعديد من بلدان العالم إلا أن الإنتاج السنوي في مصر دائماً لا يكفي الاستهلاك المحلي ودائماً ما تكون هناك فجوة كبيرة بين معدل الإنتاج ومعدل الاستهلاك مما يستلزم الاستيراد بكميات كبيرة من الخارج.

ولقد تغيرت أساليب التسميد كثيراً في القرن الماضي. وبعد التطبيق للعديد منها تبين أن بعضها قليل الفاعلية أو غير مجدي من الناحية الإقتصادية أو ذو آثار ضارة علي الإنسان والبيئة. وجري البحث العلمي في إتجاهات مختلفة بهدف الوصول إلي طرائق آمنه وفعالة وقليلة التكلفة وكان من ثمار ذلك استخدام المخصبات الحيوية والذي يطبق حالياً بأساليب مختلفة، ومن هنا جاءت فكرة هذه الدراسة وهي زيادة إنتاجية نبات القمح من خلال تقييم فعالية استخدام حمأة الصرف الصحي (كمخصب عضوي).

وقد تم استخدام حمأة الصرف الصحي المجففة (composted) في الهواء كسماد وتم الحصول عليها من محطة معالجة مياة الصرف الصحي في مدينة الشيخ زويد وتم تطبيقها بعد إجراء التحليل الكيميائي والميكروبي لها. وقد أستعملت الحمأة في ثلاثة تركيزات للمقارنة هي: ١٠٪، ٢٠٪ و٣٠٪ لتحديد أحسنهم ملائمةً للإستعمال.

ولتقييم تأثير كلا من حمإة الصرف الصحي والميكوريزا علي النمو والإنتاجية في القمح تم استخدام سلالة القمح سخا ٩٣ وهو من الأصناف جيدة الإنتاج والملائمة لمناخ منطقة الدراسة طبقا لتوصيات وزارة الزراعة. تم تجهيز منطقة تجارب في مزرعة الجامعة بالعريش وتم تقسيم المعاملات إلي الآتي:

أولاً: معاملة قياسية: التربة طبيعية بدون اضافات.

ثانياً: تربة طبيعية مضاف اليها الحمأة بتركيزات مختلفة هي: ١٠٪، ٢٠٪ و ٣٠٪.

تم زراعة محصول القمح وتم جمع العينات الممثلة للمعاملات السابقة علي ثلاثة مراحل وهي: مرحلة التفريع (tillering)؛ مرحلة الازهار (flowering) وأخيراً مرحلة نضج الحبوب (grain maturity) لمقارنة النمو والإنتاجية وجودة المحصول.

وقد أظهرت النتائج ما يلي:

١- زيادة النمو الخضري في النباتات المعاملة بالحمأة زيادة معنوية؛ وقد انعكس ذلك علي طول النبات في الجذر والساق وكذلك الوزن الطازج والجاف للنبات وكان ذلك عن طريق زيادة كمية الحمأة وكان التأثير أكثر وضوحاً في مرحلة الإزهار.

٢- ساهمت الحمأة في تحسين إنتاجية محصول القمح وجودته؛ بينما أظهرت النتائج أن الأفضل عند تركيز حمأة ٢٠٪ حيث بلغت أعلي انتاجية وهي ١,٦٩ طن/ فدان.

٣- أظهرت النتائج أن وجود العناصر الثقيلة في الحمأة كان له تأثير سلبي علي التربة حيث أن تراكم هذه العناصر يجعل التربة علي المدي الطويل غير صالحة للزراعة.

التوصيات:

١- لتحسين الإنتاجية في التربة الصحراوية من الممكن تطبيق استراتيجية زيادة التربة بالحمأة لما تحتوية من عناصر مفيدة لخصوبة التربة.

٢- لا يوجد ما يمنع من استخدام حمأة الصرف الصحي المعالجة بشكل جيد في تسميد التربة وخاصة الرملية حيث الأثر الإيجابي في تحسيين خواص التربة من حيث القدرة علي الإحتفاظ بالماء وزيادة محتواها من العناصر المعدنية.

٣- لتجنب الآثار الضارة لاستخدام حمأة الصرف الصحي في التسميد ومن اهمها زيادة محتوي التربة من العناصر الثقيلة بسبب استعمال التركيزات العالية يجب ان يكون التسميد متقطع (كل سنتين) وليس بالضرورة كل عام.

الكلمات الإسترشادية: القمح، حمأة الصرف الصحي، التسميد العضوى، الإنتاجية، كمية المحصول.

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