UTILIZATION OF SOME GRAMINEA SPECIES IN PHYTO-DEWATERING OF SEWAGE SLUDGE AND PHYTOSEQUESRATION OF CARBON DIOXIDE

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ABSTRACT

Sewage sludge contains 97 - 99% water. Because of such high-water content, sewage sludge should be thickened or dewatered for ease of handling and utilization in many purposes. In this work, plants were used to dewater or thicken sludge. Also, cultivating plants help mitigating the impacts of greenhouse gases by sequestering carbon dioxide. In this work, five (200 L) pilot-scale sludge drying ponds were constructed and operated to dewater sewage sludge. They were cultivated by four types of gramineae family, namely: Niseila (*Paspalidium geminatum*), Common reed (*Phragmites australis*), Sammar (*Cyperus alopecuroides*), and Pardee (*Cyperus papyrus*) either individually or in combinations.

It was found that relative growth rate (RGR) can be used as a growth indicator. The results showed that the highest RGR was found on day 12, 90 - 95% dewatering efficiency at day 30 in case of Niseila (*Paspalidium geminatum*). It was clear from the results obtained that the studied plants have ability to grow in sewage sludge matrix and to speed up the process of sludge dewatering.

Keyword: Sewage sludge, Niseila, Common reed, Sammar, Pardee, Sequestration, dewatering.

INTRODUCTION

Sewage sludge could be recycled as fertilizer and soil improvement material because it contains large percent of organic substances as well as some elements like potassium, nitrogen and phosphorus, which are the main nutrients of plants and soil fertility.

The use of sewage sludge (SS) as fertilizer is a common agricultural practice aimed at supplying valuable nutrients (e.g., nitrogen-N and phosphorus-P) and organic matter (OM) to agricultural soil, which, on the other hand, allows the reutilization of a by-product of wastewater treatment plants. The application of SS to agricultural soil has shown to enhance its physicochemical and biological properties (and, hence, soil quality), while providing plants with essential nutrients. (Latare *et al.*, 2014 and Lloret *et al.*, 2016)

Sewage sludge represents the final output of wastewater treatment plants (WWTP). It has an organic nature containing 1-3% total solids (Uggetti *et al.*, 2009). The cost of sludge management accounted for 20-60% of total sludge treatment cost (Cleverson *et al.*, 2007). It is worthy to mention that the water content of such sludge varies from 97-99%. Sludge Drying Beds Treatment (SDBT) is the final stage in wastewater treatment plants (WWTP). This stage is affected by many factors among them climate conditions such as humidity and ambient temperature (Uggetti *et al.*, 2009). There are many methods for sludge dewatering or thickening. Dissolved air flotation and centrifugal thickening (Wang *et al.*, 2008), but they have the drawback of large footprint with low thickening ability. Also, forward osmosis assisted microfiltration was used for deep thickening (Xiawen *et al.*, 2021), screw centrifuge decanter (Ginisty *et al.*,2021), modified hydrocyclone (Senfter *et al.*, 2021), were tested to achieve dewatering.

Gramineae Family (grass family) is the 4th spermatophyte family having 11000 species and 800 genra worldwide (Khan *et al.*, 2019). Phragmites australis (Peruzzi *et al.*, 2009), Typha (Li *et al.*, 2014) were used for sludge treatment.

Using of constructed wetlands in the treatment of wastewater is reviewed by (Purdi *et al.*, 2021). The growth of Echinchloa Pyramidalis and Cyprus Papyrus was investigated (Kengne *et al.*, 2008) and grasses were studied for their potential in phytoremediation (Rabêlo *et al.*, 2021). Planted drying beds proved that they are low energy demand, low operating and maintaining costs and they are resource recycling efficient as they flourish plants with nutrients (Gueye *et al.*, 2016). Such flourishing supports the mitigation of greenhouse gas impacts through the consumption of carbon dioxide.

In Egypt, a 2-3 months period is needed to achieve drying of sludge in summer season and more than this is required to get dryness in winter.

The aim of this work is to test the potential of four species of gramineae family, namely Niseila (*Paspalidium geminatum*), Common Reed (*Phragmites australis*), Sammar (*Cyperus alopecuroides*), and Pardee

(*Cyperus papyrus*) either individually or in combinations to affect dewatering of sewage sludge. Also, to get benefit from sludge nutrients to support the growth of such plants and work as carbon dioxide sequestering plants to mitigate greenhouse effects.

MATERIALS AND METHODS

All experiments were conducted on liquid sewage sludge collected from Arab abo-saed wastewater treatment plant (WWTP), in Helwan city; Cairo Governorate. The treatment plant receives wastewater from municipal as well as industrial activities.

Experimental setup:

All experiments were carried out in an open field environment with air temperatures ranging from 21 ^{o}C to 42 ^{o}C with an average value of 30 ^{o}C. This range of air and temperature is known to support plant growth. The selected plants were cultivated in ponds made of buildings and the shell was made for it and isolated from the inside to prevent water leakage from them the capacity of each tank was 250 liters (H) 100x (W) 50 × (L) 50, filled with only 200 L.

Materials:

Plants used in the experiments:

Four different plant species from graminaea family were tested in the current study. They include Niseila (*Paspalidium geminatum*), Common reed

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(*Phragmites australis*), Sammar (*Cyperus alopecuroides*), and Pardee (*Cyperus papyrus*).

Sludge: The WWTP has a primary sedimentation stage followed by secondary treatment. The secondary treatment consists of an activated sludge process. The primary sedimentation and the secondary sedimentation stage produce sludge that are collected and mixed together before being dewatered at conventional drying beds. The sludge that was used in the experiments was collected from the mixed sludges before entering the drying beds. The collected sludge was transferred to the location of the experiments at kafr EL Dewar – Abdo pasha farm in El–Beherah Governorate.

Methods:

Experimental design: The five ponds were (200 L) as follows:

- -The first pond was cultivated by Niseila (Paspalidium geminatum) only.
- The second pond was cultivated by Niseila (Paspalidium geminatum) with Common reed (Phragmites australis).
- The third pond was cultivated by Niseila (Paspalidium geminatum) with Pardee (Cyperus papyrus).
- The fourth pond was cultivated by Niseila (Paspalidium geminatum) with Sammar (Cyperus alopecuroides).
- The fifth pond Niseila (Paspalidium geminatum), Common reed (Phragmites australis), Sammar (Cyperus alopecuroides) and Pardee (Cyperus papyrus) were cultivated together in one pond.

Physicochemical analysis of sludge: The collected sludge and all different groups analyzed at the start and the end of the experiments. The sludge samples were analyzed at zero time and after seven weeks. Total Dissolved Solids (TDS) were determined according to APHA (1998).

Analysis of plant growth and relative growth rate (RGR): Plant masses (on a fresh mass basis) in all ponds were measured dailyto investigate the growth of the different plant species at a specific time, M_t/M_o was calculated and used for evaluation. Where M_t is the plant fresh mass at time t, M_o is the initial fresh mass (at t_o = time 0).

The growth of plants was evaluated by comparing the average values of the relative growth rate (RGR) for each RGR can be calculated using Equation according to Mitchell (1974).

$$RGR = \frac{lnM_t - lnM_o}{\Delta t}$$

Where, M_t is the plant fresh mass at time t,
M_o is the initial fresh mass (at t_o = time 0),
and Δt is the duration of time and equals to $(t - t_o)$

Efficiency of sludge dewatering: To evaluate the dewatering process of the sewage sludge, the difference in water height (Δh) is measured in cm in every pond every three consecutive days. The volume (V) of evaporated /evapotranspirated water is calculated as follows, V= Δ h * pond area (Given that water density is =1, the volume equal mass (M)

$$\text{Dewatering Efficiency, \%} = \frac{M\ w\ Evap}{M\ s\ initial} * 100$$

Where,

M_W Evapis the total mass after time t, from the start of the experiment,

M_S Initial is the initial mass of sludge at the start of the experiment.

RESULTS AND DISCUSSION

Physicochemical analysis of sludge: The general properties of sewage sludge at zero time and after seven weeks are tabulated in Table (1). The average pH at zero time and after seven weeks of the sewage sludge used in this study was 8.0. These results found an alkaline pH of sewage sludge as a consequence of the decrease of acidic surface groups (Song and Guo, 2012).

The average value of EC (a measure of salinity) in sewage sludge was 100 µS/cm at zero time. While average values at seven weeks were 4000 µS/m. This may be related to the enriched inorganic ash contents (DeLuca *et al.,* 2015).

The temperature of sewage sludge at zero time was 30°C, whereas, after seven weeks, it was 38°C. Furthermore, the temperature of pond sewage sludge at zero time was 25°C, as well as, after seven weeks, it was 31, and 30°C, respectively.

The weight of one liter sewage sludge was 1010 g, while the height in the pond at zero time was 40 cm. After seven weeks, it was 1030g and the height was7.0 cm. Total dry solids in sewage sludge at zero time were 145 mg/L, and after seven weeks, it was 260 mg/L. This may be due to the highest moisture in sewage at zero time and the lowest moisture after seven weeks.

Table (1): Analysis of sewage sludge at zero time and after seven weeks

Analysis	Sludge	
	at zero time	after Seven weeks
pH	8.0	8.0
EC (µs/cm)	100	4000
Temperature °C	30	38
Temperature of pond °C	25	31
Weight of sludge (g/l)	1010	1030
Height sludge in pond (cm)	40	7.0

Growth behavior of the studied plants upon cultivation in sewage sludge:

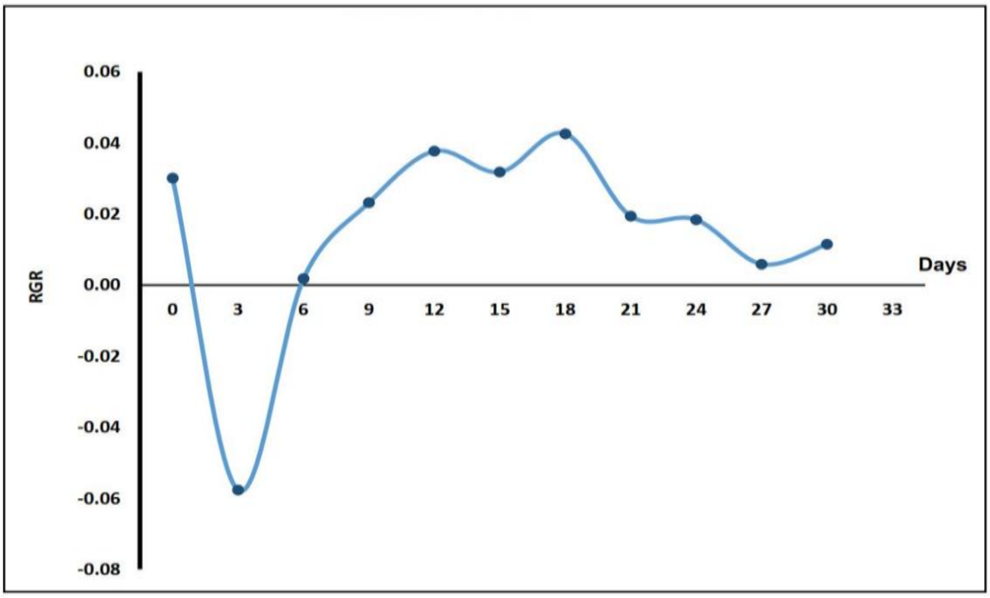

Figure (1): Relative growth rate for Niseila in sewage

The first pond contains Niseila separately in sewage sludge and the results are displayed in the above Figure (1). The results from Niseila plants in pond sewage sludge observed that the negative relative growth rate of -0.0577 at day 3, Figure (2), and started to increase gradually until day 6. In such case, this decrease can be resulted from a chock took place to plants which depress the growth of plant. Also, this may be considered a period of adaptation and acclimatization in which the plant adapt itself to such stress sewage sludge matrix. Also, it can be noticed that the growth over the period from day 6thtoday 18th is flourished to reach 0.04. Drying time achieved was 30 days. Another issue can be deduced from the figure that the relative growth rate RGR can be used as growth index for plants cultivated in such sewage sludge matrix.

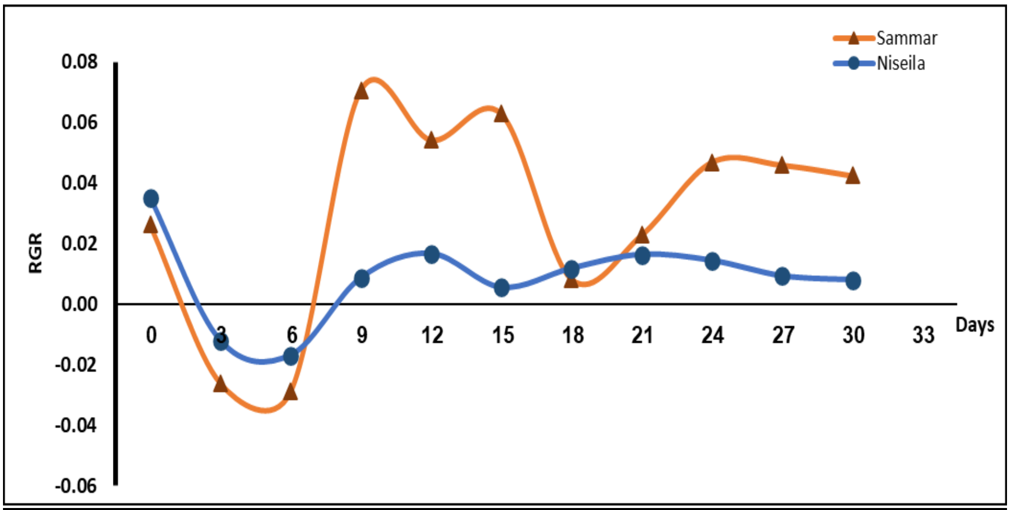

Figure (2): Relative growth rate for Niseila with Sammar in sewage sludge

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In figure 2, Niseila was cultivated with Sammar. Results showed that Niseila followed the same trend as when cultivated separately. Also, Niseila showed a better relative growth rate compared to Sammar as it achieved 0.078 and 0.06 at days 9 and 18 respectively. Also, it can be noticed that has a dominant growth all over the period of experiment, as Sammar recorded a value of RGR ranged below 0.02. Drying time achieved was 30 days.

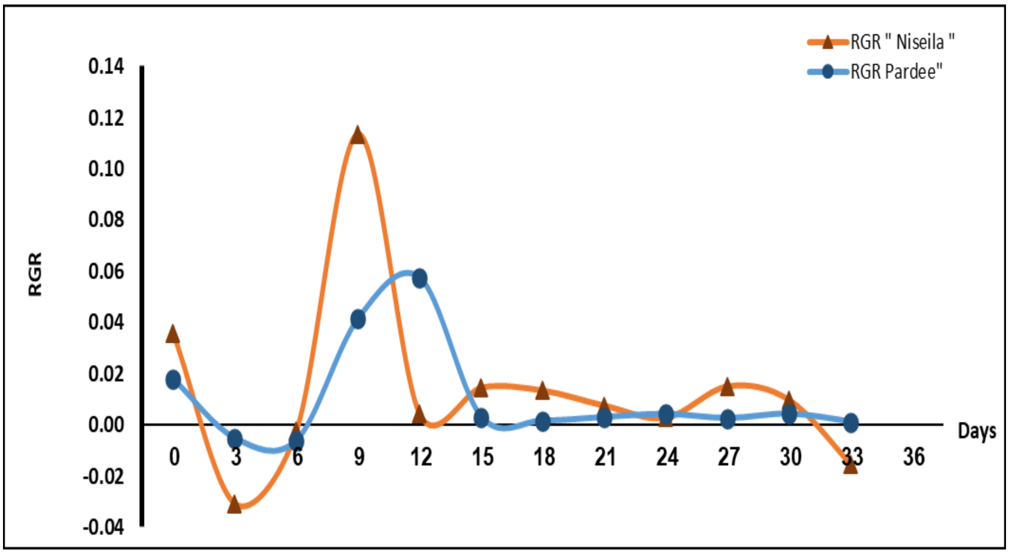

Figure (3): Relative growth rate for Niseilia, and Pardee in sewage sludge

In figure (3), Niseila was cultivated with pardee. Results showed that Niseila followed the same trend as when cultivated separately. Also, Niseila showed a better relative growth rate compared to Pardee as it achieved 0.12 at day 9. Also, it can be noticed that has a dominant growth all over the period of experiment, as Pardee recorded a value of RGR 0.002. Also, it can be deduced that a growth competition between Pardee and Niseila. Also, it can be shown that Pardee is less tolerant to sewage sludge matrix. Drying time achieved was 30 days.

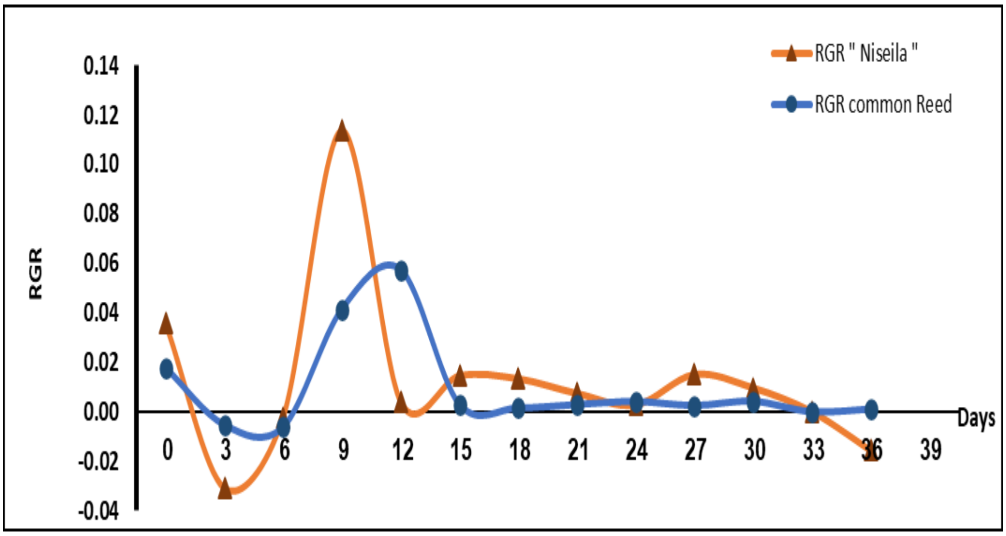

Figure (4): Relative growth rate for Niseila, and Common Reed in sewage sludge

In figure (4), Niseila was cultivated with common reed. Results showed that Niseila followed the same trend as when cultivated separately. Also, Niseila showed a better relative growth rate compared to Common reed as it achieved 0.12 at day 9. Also, it can be noticed that has a dominant growth all over the period of experiment, as common reed recorded a value of RGR 0.001. Also, it can be deduced that a growth competition between Common

Reed and Niseila and showed that common reed is less tolerant to sewage sludge matrix. Drying time achieved was 30 days.

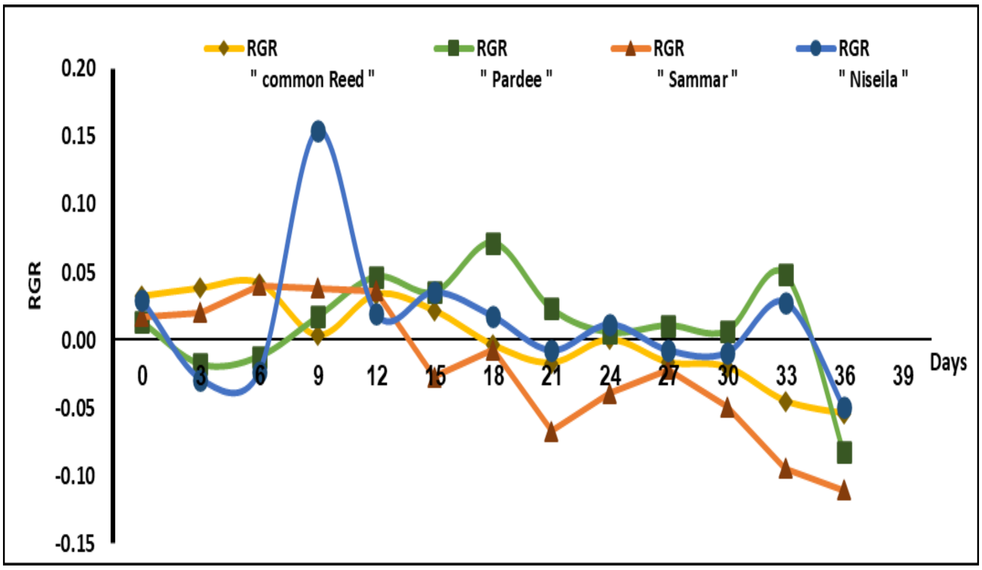

Figure (5): Relative growth rate for Niseila, Common red, Pardee, and Sammar

In figure (5), Niseila was cultivated with Pardee, Sammar, and Common reed. Results showed that Niseila followed the same trend as when cultivated separately. Also, Niseila showed a better relative growth rate compared to the rest of other plant as it achieved 0.15 at day 9. Also, it can be noticed that it has a dominant growth all over the other plant, as common reed and Pardee recorded negative RGR. Also, it can be deduced that a growth competition between the other plants and Niseila and showed that they are less tolerant to sewage sludge matrix. Drying time achieved was 30 days.

Efficiency of dewatering: The main objective of this experiment is to measure the potential of the studied plants for sludge dewatering of during the experiment.

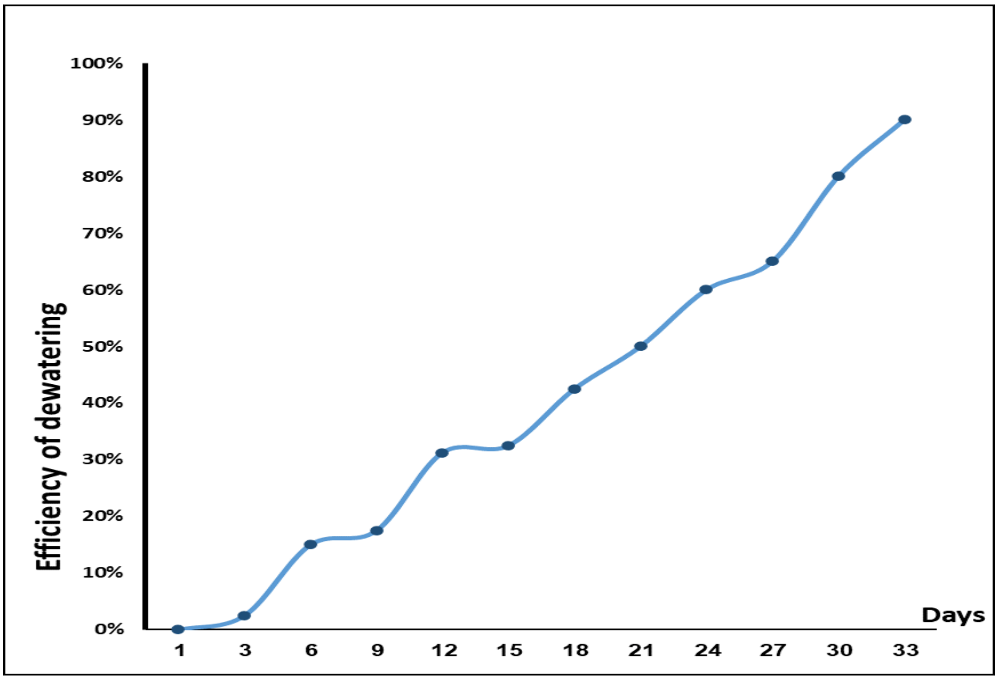

Figure (6): Efficiency of for Niseila in sewage sludge dewatering

In figure (6), upon the use of Niseila, it can be observed that dewatering process took place stepwise. Three dewatering stages can be differentiated from the graph. This is true when referring to the first 6 days required for adaptation and acclimatization, then two growth stages until day 15, after that gradual increase was noticed. The period required for dewatering was 33 days.

The results showed that the efficiency of dewatering after 3-6 days from the start of cultivation was 12.0%. At the end of experiment the efficiency of dewatering was 90.0%. Also, it can be deduced that complete dewatering was achieved at 33 days. Results were in agreement with those reported by El Gendy *et al.*, 2017.

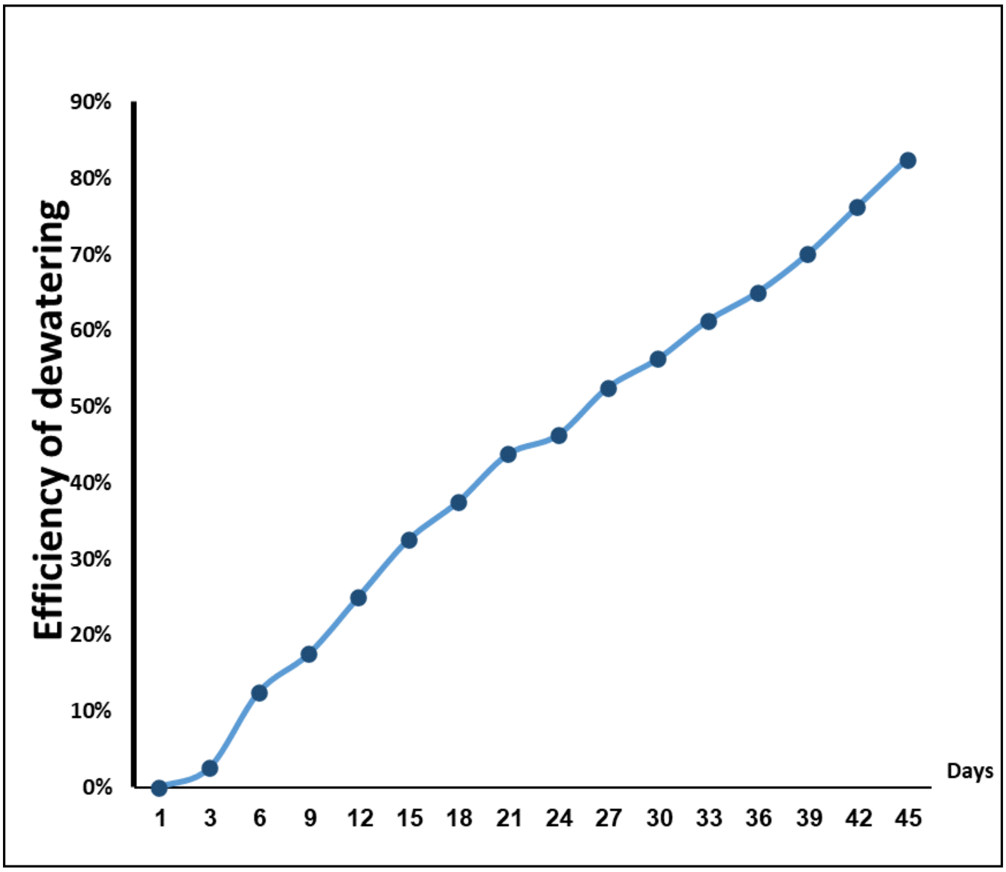

Figure (7): Efficiency of for Pardee in sewage sludge dewatering

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In figure (7), upon the use of Pardee, it could be noticed that only the acclimatization stage can be differentiated at the first three days. After that a gradual increase in dewatering efficiency. 88 % Dewatering efficiency was achieved after 45 days. This was attributed to the negative relative growth rate mentioned before and the late growth period noticed.

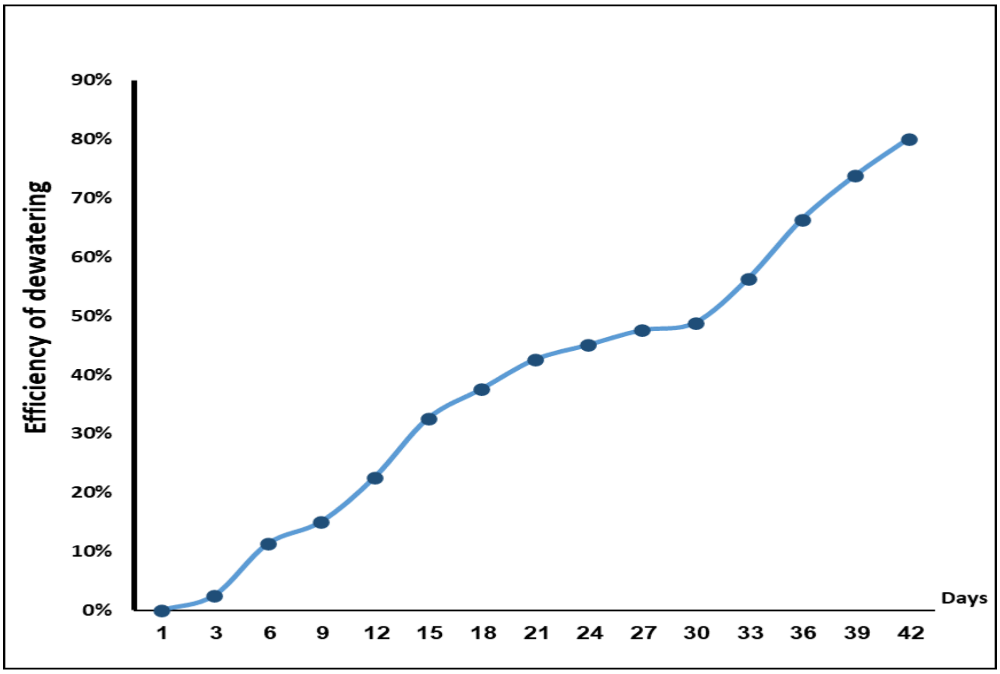

Figure (8): Efficiency of dewatering for Common Reed in sewage

In figure (8), in case of using common reed, also, only the acclimatization stage that can noticed, while over the period from day 18 to day 30 there is an increased dewatering efficiency and finally a gradual increase stage. 80% dewatering efficiency was recorded at the day 42th.

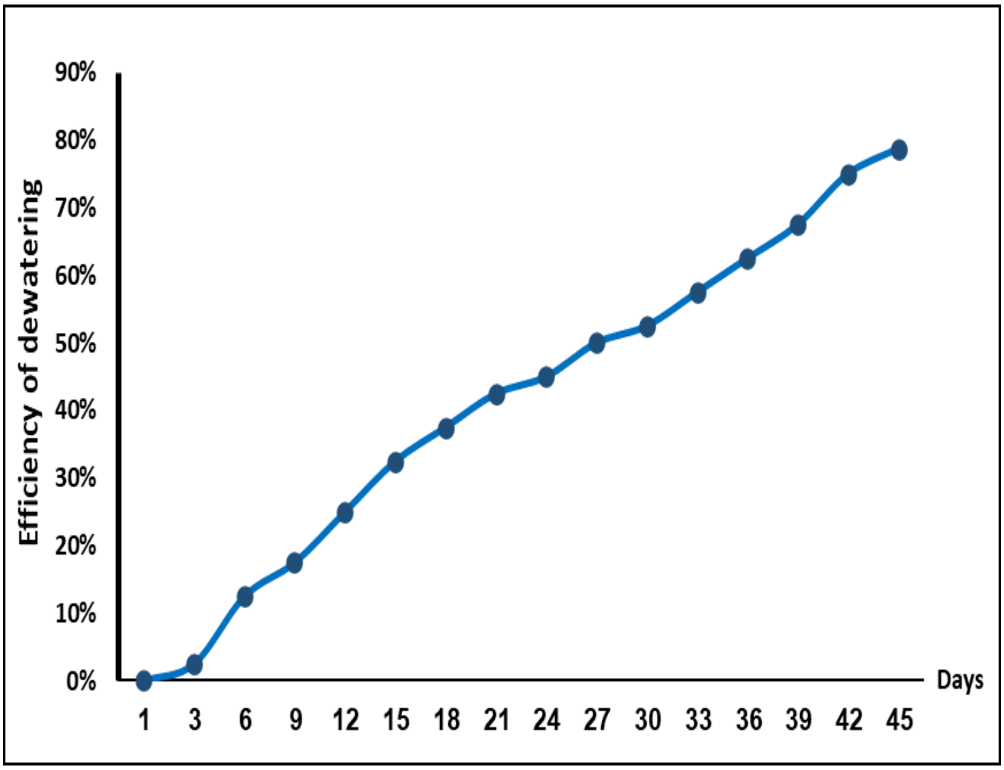

Figure (9): Efficiency of dewatering for Sammar in sewage sludge

In figure 9, in case of Sammar, a smooth increase in dewatering efficiency and the only step that can be distinguished is the acclimatization stage, first three days. Dewatering efficiency reached 78% at day 45.

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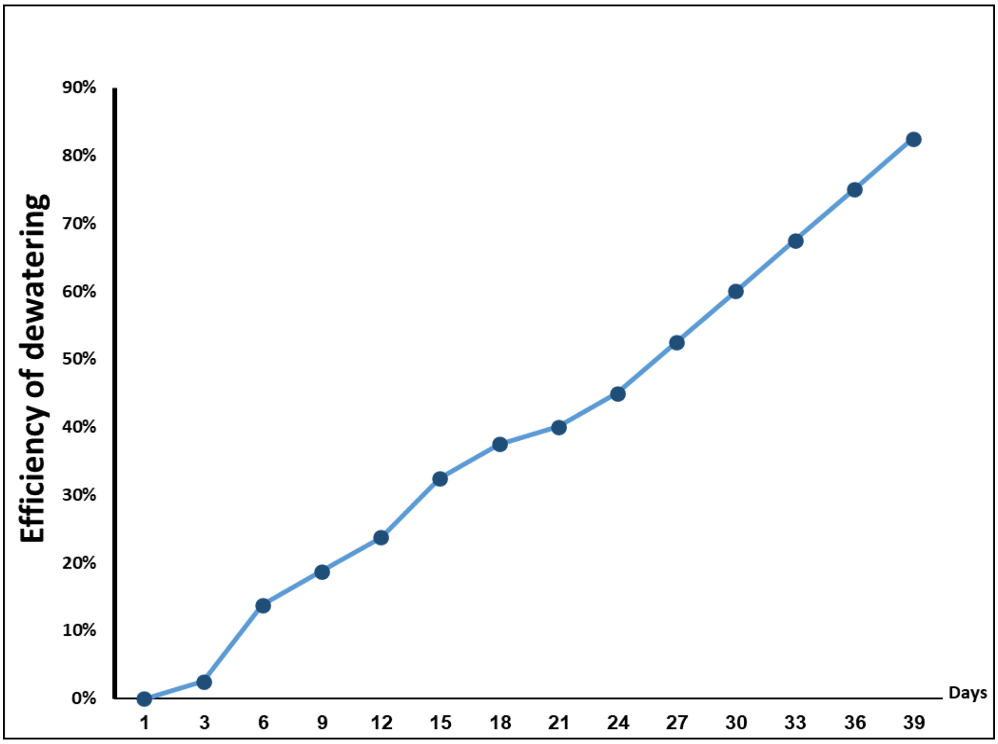

Figure (10): Efficiency of dewatering for all plants (Niseila, Common Reed, Padree and Sammar)

In figure (10), all of the studied plants were cultivated in one pond. The efficiency trend followed the sequence done when they were cultivated separately and the stepping disappeared along the dewatering period. This can be attributed to summation of dewatering behavior. Also, dewatering time 39 days is more than using Niseila only 33 days but it less than the using the other plants Padree, common reed and Sammar as they recorded 45, 42 and 45 days respectively.

Floating aquatic plant systems, employing water Pardee, Common reed, Sammar, and Niseila, can be excellent candidates for the sludge dewatering process based on their high capability for water consumption. While previous works (George *et al.*, 2003) utilized aquatic plants to treat wastewater, there is a noticeable dearth of such research focusing on sludge dewatering. It should be pointed out that sludge composition may affect the performance of the four selected plants due to the difference between sludge and wastewater.

CONCLUSION

The sewage treatment produces sludge, of which solids represent approximately 1-2%. To benefit from this sludge, it must be dried in drying beds and it takes a long time. Therefore, this work examined the potential of Niseila (*Paspalidium geminatum*), Common Reed (*Phragmite saustralis*), Sammar (*Cyperus alopecuroides*), and (*Cyperus papyrus*) plants to dry the sludge. It was proven that the above-mentioned plants adapt itself to grow in the sewage sludge matrix with different relative growth rates and they could do dewatering in 33-45 days. Niseila (*paspalidium geminatum*) showed good dewatering properties and achieved the highest relative growth rate among the tested plants. Also, in case of Niseila (*Paspalidium geminatum*) dewatering took place within 33 days only.

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استخدام بعض الانواع النجيلية في نزح المياه من حمأة مياه الصرف الصحي وتنقية ثاني اكسيد الكربون بالنباتات

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المستخلص

أجريت التجارب الميدانية لدراسة نمو اربعة أنواع مختلفة من النباتات المائية في حمأة الصرف الصحي. وشملت هذه النباتات: النسيلة، البوص، السمار والبردى. وقد أجريت جميع التجارب في ٥ احواض زراعية سعة الحوض (٢٠٠ لتر). تم جمع النباتات من حافة ترعة قرية البسلاقون، كفر الدوار. وتم جمع حمأة الصرف الصحي السائلة من محطة عرب أبو ساعد لمعالجة مياه الصرف الصحي في مدينة حلوان بمحافظة القاهرة. تنتج محطة المعالجة الحمأة من الترسيب الأولى والحمأة النشطة التي يتم التخلص منها والناتجة من المعالجة الهوائية الثنائية. تم إجراء التجارب في هذا البحث على تلك الحمأة المختلطة وقبل وصولها إلى أحواض التجفيف. وقد تم زراعة النباتات المختارة اما بشكل فردى او مجتمعة مع نبات او نباتات أخرى. وكان الهدف من هذا البحث هو دراسة نمو أنواع النباتات المذكورة سابقا في حمأة الصرف الصحي السائلة وكذا قدرة تلك النباتات على تجفيف حماة الصرف الصحى. وقد وجد انه يمكن استخدام معدل النمو النسبي (Relative Growth Rate-RGR) كمؤشر للنمو.

لقد اظهرت النتائج انه تم الحصول علي اعلي نسبة (RGR) في اليوم الثاني عشر لنبات النسيلة ، وكفاءة نزح للمياه ٩٠–٩٥% في اليوم ال ٣٠ . واتضح من النتائج المتحصل عليها ايضا ان النباتات محل الدراسة لديها القدرة علي النمو في مصفوفة حمأة الصرف الصحي والاسراع فى عملية نزح او تجفيف الحمأة.

الكلمات الدالة: حمأة الصرف الصحي، تجفيف، النسيلة، البوص، السمار، البردي، حبس الكربون، نزح.