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# EFFECTS OF WASTEWATER SLUDGE ON GROWTH OF PERENNIAL RYEGRASS (*Lolium perenne* L.)

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**ABSTRACT**

**The objectives of this study were to evaluate the effects of sun dried wastewater sludge (SDS) and peat amendments on perennial ryegrass (*Lolium perenne* L.) growth, as well as to identify the optimum rates of amendments and impact of irrigation frequencies for turfgrass production. The experiments were conducted over a 40-day period under greenhouse conditions in Bursa, Turkey in 2008 and 2009. The experimental design was a randomized split-split plot design with three replications. Irrigation frequencies served as main plots, amendments were subplots, and cover mixture rates were sub-subplots. Wastewater sludge samples were obtained from the Food Company, where the domestic and industrial wastewater was treated together. Results showed that the content of plant nutrient matter of SDS was high and its heavy metal contents were found below the critical levels according to the soil pollution control instructions. Based on these observations, we recommend amending soils with 50-75% SDS for optimum *Lolium perenne* L. growth. SDS amendment at these levels can greatly improve the soil nutrient supply without significantly affecting its heavy metal and soluble salt contents.**

**Keywords: E. coli, heavy metal, *Lolium perenne* L., Turfgrass, wastewater sludge**

## INTRODUCTION

Excessive irrigation of turf not only increases costs associated with water consumption, but can also result in high rates of nutrient leaching beyond the root-zone and therefore contribute to ground water pollution. In addition, turf managers in many regions are faced with reduced availability of water resources to expanding urban populations. Thus, the capacity to cope with restrictions to both volume and frequency of irrigation, whilst maintaining a surface of suitable quality, is an important management objective for turf areas in many regions of the world. Careful management of water in turf culture should enable the conservation of water and minimise nutrient leaching with relatively small losses in quality of turf (Gibeault et al., 1985). Irrigation is necessary to provide its desired function and aesthetics, and different irrigation levels can lead to different evapotranspiration (ET) and different quality of turfgrass (Bastug and Buyuktas, 2003). Evapotranspiration is the main water consuming form of turfgrass and an important index for turfgrass irrigation (Beard, 1973).

The use of peat as a major constituent of potting media in the nursery industry is challenged by economic and environmental pressures. High-quality peat is becoming less available and high transportation costs have become a major component for containerized media. Additionally, in recent years there has been increasing environmental and ecological concerns over the use of peat because its harvest is destroying endangered wetland ecosystems worldwide (Barkham, 1993; Buckland, 1993; Robertson, 1993). Sewage sludge is one of the final products of the treatment of sewage at wastewater treatment plants. Composted sewage sludge contain substantial amounts of nutrients that may improve plant growth and reduce the need for fertilizer, and thus may be economical partial substitutes for conventional media components such as peat (Brady and Weil, 1999; Zhang et al., 2004). Wastewater sludge may be evaluated as a slow release fertilizer especially due to the high organic nitrogen content (Kocaer et al., 2003).

One concern on application of composted sewage sludge is its relatively high heavy metal contents, which can potentially cause soil pollution and toxic effect on plant growth. Heavy metals may limit the use of composted sewage sludge as a soil amendment (Cheng et al., 2007). However, application of untreated sludge introduces large amounts of bacteria to leachates and soil (Kocaer et al., 2004). Composted sewage sludge are expected to have elevated soluble salt contents because relatively high concentrations of soluble salts are typically present in composted sewage sludge, and the potential hazard associated with high soil salinity is an important consideration for composted sewage sludge utilization (Sanchez-Monedero et al., 1997; Eklind et al., 2001; Perez-Murcia et al., 2006).

Because of the presence of both beneficial such as nutrients and organic matter, and non-beneficial elements such as heavy metals and soluble salts components in composted sewage sludge, it is necessary to systematically study the impacts of composted sewage sludge amendment with different irrigation condition on turfgrass growth.

The objectives of this study were to (i) compare turfgrass growth in response to increasing amendment of SDS and peat, (ii) evaluate the impact of irrigation frequencies on growth of perennial ryegrass, and (iii) identify the optimum levels of cover materials for turfgrass production.

## MATERIALS AND METHODS

The experiments were conducted in spring season over a 40-day period under greenhouse conditions at the Uludag University Agricultural Faculty in Bursa, Turkey. The growth of perennial ryegrass (*Lolium perenne* L. cv. Esquire) was compared in ten different cover mixture rates of two amendments [sun dried wastewater sludge (SDS) and peat (P)] with soil (S) in three irrigation frequencies (daily, 4 days and 7 days interval). Plastic pots of 20 cm in width and 50 cm in length were filled with 9.0 kg of soil. Cover mixtures were 0% SDS+100% S, 25% SDS+75% S, 50% SDS+50% S, 75% SDS+25% S, 100% SDS+0% S, and 0% P+100% S, 25% P+75% S, 50% P+50% S, 75% P+25% S, 100% P+0% S.

Wastewater sludge samples were collected from the Penguen Food Company, Bursa where the domestic and industrial wastewaters of the canning plant were treated together by an activated sludge system. Raw sludge sample was sun-dried for several days on concrete ground during hot summer days in order to achieve microbial stabilization. Sun-dried sludge was placed on ground in order to spread uniformly on the surface of the plots. Major chemical and biological properties of the base soil and the SDS used in this study are summarized in Table 1 and 2.

**Tablo 1.** General characteristics of soil and sun dried sludge sample

| Parameters (on DM basis) | Soil | Sludge |
|---|---|---|
| pH (1:2.5, soil:water and 1:10, sludge:water) | 8.3 | 6.3 |
| EC (1:2.5, soil:water and 1:10, sludge:water) (μS) | 134 | 1910 |
| Total-N (mg.kg$^{-1}$) | 1088 | 25800 |
| Ammonium-N (mg kg$^{-1}$) | 31.6 | 622 |
| Nitrate-N (mg kg$^{-1}$) | 18.1 | 27.6 |
| Total-P (mg kg$^{-1}$) | 703 | 7318 |
| Available-P (mg kg$^{-1}$) | 18.4 | 628 |
| Organic C (%) | 1.2 | 22.3 |
| C/N (%) | 10.9 | 8.6 |
| Soluble B, (mg kg$^{-1}$) | 1.2 | 15.2 |
| $Na^+$ (free+exchangeable) mg.kg$^{-1}$ | 52.3 | 2095 |
| $K^+$ (free+exchangeable) mg.kg$^{-1}$ | 112 | 1812 |

In these studies, treatments were arranged in a randomized split-split plot design with three replications. Irrigation frequencies were arranged in main plots, amendments were allocated to the subplots, and cover mixture rates constituted sub-subplots. Seeds of perennial ryegrass with a germination rate of 88.2% were planted at a seeding rate of 40 g/m$^2$ in the plastic pots. Seeds were established on March 28 in 2008 and on April 7 in 2009.

**Table 2.** Some heavy metals standards and contents of the soils and sun dried sludge (SDS) (mg kg$^{-1}$).

| Parameters | Standards | | Original Soil | SDS |
|---|---|---|---|---|
| | Soil | Sludge | | |
| Pb | 300 | 1200 | 21.3 | <20 |
| Cd | 3 | 40 | <1 | <1 |
| Cr | 100 | 1200 | 450 | 144 |
| Cu | 140 | 1750 | 47.8 | 100 |
| Ni | 75 | 400 | 129 | 80.4 |
| Zn | 300 | 4000 | 80.1 | 615 |
| Hg | 1.5 | 25 | <2 | <2 |

The pots were irrigated with a hand-held watering, and the amount of water applied was the same as the amount of ET for daily, 4 and 7 intervals days after seeding during forty days. Crop water requirement (CWR, g) was calculated as the total evapotranspiration (ET, g/d) during the whole growing period. Evapotranspiration (ET), which determines crop water requirement, was measured by weighing a pot every day. A pot acted as a weighing lysimeter that hydrologically isolates soil surface lateral inflow/outflow. Daily evapotranspiration was calculated by the following formula: ET = Wdi - Wdi-1 where Wdi (g) = the weight of container at day (i), and Wdi-1 (g) = the weight of the container at day (i - 1) (Allen et al., 1998).

The numbers of emergence (in tenth day) and numbers of seedling (in fortieth days) were measured with quadrat sampling (5 x 5 cm). Average plant heights from 10 plants and clipping yield from 0.05 m$^2$ in each pot were recorded at the end of the fortieth day in each season. Clippings were collected and dried at 70 °C for 24 h, and then weighted to determine clipping yield as an indication of shoot growth. Temperature and relative humidity were measured every day. Mean temperatures were 28.8°C in 2008 and 30.2°C in 2009, and relative humidity 66.3% in 2008 and 70.5% in 2009.

Heavy metal analysis of the sun dried sludge and soil samples were done in triplicate samples at the accredited laboratory (TUBITAK, Bursa Test and Analysis Lab). Lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), zinc (Zn) and mercury (Hg) contents of soil and SDS samples were analyzed by energy Dispersive X-Ray Fluorescence (EDXRF) spectrometer (Spectro X-Lab 2000, Spectro Analytical Instruments, Germany) equipped with a 300W Pd end window X-ray tube, a liquid nitrogen cooled Si(Li) detector (<150 eV Mn $K_{\alpha}$) and three targets which are molybdenum (Mo) as the secondary target, $Al_2O_3$ and High Oriented Pyrolytic Graphite (HOPG) as polarization targets.

Fecal coliform counts were performed in accordance with the most probable number method (APHA, AWWA and WEF, 1998). Brilliant green bile broth was used as a growth medium. Inoculated tubes were incubated at 44.5 ± 0.2°C for 24 ±2 h. The results were obtained as MPN per 100ml. and converted to MPN per gram dry matter.

Analysis of variance, least significant difference (LSD) tests among means, and regression analysis were performed on the measured data using the MINITAB (Minitab, Inc. USA, Minitab Release, 12.1). Statistically significant means were separated by the LSD test at the 0.05 level.

## RESULTS AND DISCUSSION

The data presented in Table 1 depicted that the SDS was slightly acidic (pH 6.3) in reaction and the electrical conductivity was 1910 $\mu$S cm$^{-1}$. Total N content of SDS was 25800 mg kg$^{-1}$ (2.58%) total N, indicating the probable nitrogen fertilizer value of SDS product. SDS contained relatively low quantities of mineral N (622 and 27.6 mg kg$^{-1}$ ammonium-N and nitrate-N, respectively). SDS may also provide an apparent contribution to soil-plant system with respect to total and available P (7318 and 628 mg kg$^{-1}$, respectively). SDS showed a high organic C value (22.3%). The C/N ratio of SDS was calculated as 8.6. The 15.2 mg kg$^{-1}$ soluble boron (B) was detected in SDS sample, whereas free and exchangeable sodium (Na) and potassium (K) concentrations were measured as 2095 and 1812 mg kg$^{-1}$, respectively. In general, the examined parameters were in the range of expected values for wastewater sludge (Tchobanoglous and Burton, 1991; Mc Farland, 2001).

The sludge generally have high metal concentrations (Su and Wong, 2003; Udom et al., 2004; Dai et al., 2007). Table 2 gives the maximum allowed heavy metal content in the soil and SDS. Total Pb, Cd, Cr, Cu, Ni, Zn and Hg concentrations were in the range of 1-450 mg kg$^{-1}$ in the soil and 1-615 mg kg$^{-1}$ in the SDS. The soil has slightly higher in Cr content than the standards. Bursa region soils are generally rich in Cr content. Large chromite deposits are found near Bursa and several Cr mines are being operated by the State or private companies. Heavy metal contents of the SDS were all lower than the recommended limit values in sewage sludge as stated by USEPA 40 CFR Part 503 regulations (USEPA, 1994). Although some researchers (Cheng et al., 2007) reported that composted sewage sludge improved the soil nutrient supply for turfgrass growth without accumulation of heavy metal and soluble salt contents of the soil, however, our results are not in accordance with the results obtained by above mentioned researchers who reported that heavy or toxic metals in sewage sludge caused accumulation of certain heavy metals and threatened long-term soil quality. Probably the main reason could be the collection of SDS samples used in this study from the activated sludge system of Food Company. Therefore, heavy metal contents of SDS samples were lower than the standards and even than those in the base soil.

To demonstrate that a given SDS meets EPA Class B pathogen requirements, the density of fecal coliform from at least seven samples of SDS must be determined and the geometric mean of the fecal coliform density must not exceed 2 million CFU or MPN per (dry weight) gram of total solids (USEPA, 1999). As seen in Table 3, the geometric mean of bacterial numbers in SDS (5,60x10$^{1}$ MPN g$^{-1}$) was apparently below this required level (USEPA, 1999).

Analysis of variance indicated that the differences in number of emergence, number of seedling, plant height and clipping yield among the irrigation frequencies (IF), amendments (A) and cover mixtures rate (CMR) treatments, and their interactions were significant (P<0.01) in both years (Table 4).

**Table 3.** Dry matter and fecal coliform content of the sun-dried sludge, and its USEPA standards.

| | Sun-dried sludge | USEPA Standards | |
|---|---|---|---|
| | | Class A | Class B |
| Dry Matter (%) | 93.80 | - | - |
| Fecal coliform (MPN g$^{-1}$) | 5,60 x 10$^{1}$ | 1 x 10$^{3}$ | 2 x 10$^{6}$ |

**Table 4.** Results of variance analysis of numbers of emergence, number of seedling, plant height and clipping yield of perennial ryegrass (*Lolium perenne* L.) under different irrigation frequencies (IF), amendments (A), and cover mixtures rates (CMR) in 2008 and 2009 experimental years.

| Source of Variation | DF | Number Of Emergence (%) | Plant Height (cm) | Number Of Seedling | Clipping Yield (g) |
|---|---|---|---|---|---|
| | | 2008 | | | |
| IF | 2 | ** | ** | ** | ** |
| A | 1 | ** | ** | ** | ** |
| CMR | 4 | ** | ** | ** | ** |
| IF x A | 2 | ** | ** | ** | ** |
| IF x CMR | 8 | ** | ** | ** | ** |
| A x CMR | 4 | ** | ** | ** | ** |
| IF x A x CMR | 8 | ** | ** | ** | ** |
| | | 2009 | | | |
| IF | 2 | ** | ** | ** | ** |
| A | 1 | ** | * | ** | ** |
| CMR | 4 | ** | ** | ** | ** |
| IF x A | 2 | ** | ** | ** | ** |
| IF x CMR | 8 | ** | ** | ** | ** |
| A x CMR | 4 | ** | ** | ** | ** |
| IF x A x CMR | 8 | ** | ** | ** | ** |

The number of emergence, number of seedling, plant height and clipping yield appeared affected by irrigation frequencies x amendments interaction, as indicated in Table 5. The highest data in all measured characters were obtained from daily irrigation and SDS interaction, while lowest data were obtained from 7 days irrigation interval and P interaction in the both experimental years. Fry and Butler (1989) obtained the best results for cool-season species of turfgrass when it was irrigated as much as 75% or 100% of potential ET at 2- and 4-day intervals. Ervin and Koski (1998) also found that acceptable turfgrass quality, in part influenced by color and leaf firing, could be maintained in semiarid regions by irrigating every three days at ET rates of 60 to 80% for Kentucky bluegrass and 50 to 80% for tall fescue. Recent research with deficit irrigation treatments has

**Table 5.** The numbers of emergence, number of seedling, plant height and clipping yield of perennial ryegrass (*Lolium perenne* L.) at irrigation frequencies x amendments interaction in 2008 and 2009 experimental years.

| Irrigation Frequencies | Amendments | | | |
|---|---|---|---|---|
| | Sludge | Peat | Sludge | Peat |
| | 2008 | | 2009 | |
| | Number of Emergence | | | |
| Daily | 29.0 a | 13.3 d | 49.3 a | 34.8 b |
| 4 Days | 18.9 b | 16.5 c | 34.8 b | 22.9 c |
| 7 Days | 16.9 bc | 15.2 cd | 18.5 d | 17.3 e |
| | Number of Seedling | | | |
| Daily | 77.1 a | 41.7 b | 70.4 a | 62.3 b |
| 4 Days | 42.8 b | 29.7 c | 48.1 c | 27.1 d |
| 7 Days | 13.9 d | 11.7 d | 20.7 e | 4.1 f |
| | Plant Height (cm) | | | |
| Daily | 19.7 a | 11.8 c | 18.2 a | 10.9 c |
| 4 Days | 14.2 b | 6.6 e | 14.9 b | 5.9 e |
| 7 Days | 7.6 d | 5.1 f | 7.0 d | 4.2 f |
| | Clipping Yield (g) | | | |
| Daily | 4.6 a | 2.5 b | 3.5 a | 2.7 b |
| 4 Days | 2.6 b | 0.5 d | 2.7 b | 1.3 cd |
| 7 Days | 2.2 c | 0.2 e | 1.5 c | 1.1 d |

demonstrated that acceptable turfgrass quality can be maintained with irrigation amounts significantly less than regular replacement of 100% of moisture lost to evapotranspiration (ET) (Fu et al., 2004; DaCosta and Huang, 2006; Fu et al., 2007a; Fu et al., 2007b).

In irrigation frequencies x cover mixture rates interactions, the numbers of emergence, number of seedling, plant height and clipping yield generally increased with increasing of the amendments in cover mixtures in all irrigation frequencies in both experimental years (Table 6). Apparently, 50% amendments in cover mixture and daily irrigation interaction was optimum for number of germination vigor in 2008. The best growth of perennial ryegrass was provided from soils with 50-100% SDS and daily irrigation interaction. The most favorable clipping yield of the *Lolium perenne* L. was achieved while 50% cover mixture rate with SDS and daily irrigation interaction (3.9 g). Hua et al. (2008) reported that the responses of fescue and ryegrass indicated that the effect of sewage compost on the growth of turfgrass largely depended on the character of the grass. For fescue, a low dosage of sewage compost can enhance its growth, but excessive sewage compost could have a negative effect. For ryegrass, the positive effect of sewage compost predominated over any negative effect even at high sewage compost loading. Generally, SDS in high cover mixture rates (75% and 100%) with daily irrigation had highest values in measured characters, whereas lowest values were obtained from increasing SDS with deficit irrigation condition (4 and 7 interval). This result was due to washing of salt in SDS in daily irrigation. The detrimental effects on seedling emergence and turfgrass growth observed on substrates with high (≥50%) SDS contents were mainly attributed to the presence of high soluble salt concentrations. The effects of soluble salts and ammonium on the germination and growth of *Lolium perenne* in compost were investigated by O'Brien and Barker (1996); data suggested that the inhibition of seed germination could be avoided by delaying the sowing of seeds into substrates amended with compost. A case study concerning the revegetation of a saline sludge disposal site was reported by Salo et al. (1996). Landschoot, (1996) also reported that the seedling death was primarily attributed to the presence of excessive soluble salts, which cause injury to turfgrass by reducing root water absorption, by toxicity, or by a combination of both.

Effects of amendments on number of emergence, number of seedling, plant height and clipping yield depended on cover mixture rates in 2008 and 2009. Increasing SDS rate in cover mixture significantly increased all measured characters throughout the study (Table 7). These results suggested that SDS acted as N fertilizer throughout the growing depending on the amount of nutrients provided to the turf. Angle et al. (1981) showed that the improvement in turfgrass growth and quality by composted sewage sludge amendment is related to the amount of nutrients that the compost provided to the turf. Previous studies have reported that the amendments with different kinds organic composts and sludge can enhance turfgrass establishment, color and quality (Norrie and Gosselin, 1996 and Loschinkohl and Boehm, 2001). However, highest clipping yields were obtained from 50% amendments in cover mixture and daily irrigation interaction in both years. As regards to the number of seedling best results were obtained in 25% amendments in cover mixture by daily irrigation interaction in 2009. Soils amended with composted sewage sludge are expected to have elevated soluble salt contents because relatively high concentrations of soluble salts are typically present in composted sewage sludge (Sanchez-Monedero et al., 1997; Eklind et al., 2001). Germination and seedling development are generally the most salt-sensitive stages during plant ontogeny, and rankings of cultivars and species for salt tolerance during these stages are often different from those of mature turf (Sanda, 1978; Marcar, 1987; Marcum, 2001). Therefore, the soluble salt contents in composted sewage sludge also determine that it should only be added to soils at moderate levels to avoid detrimental effects on turf growth (Cheng et al., 2007).

**Table 6.** The number of emergence, number of seedling, plant height and clipping yield of perennial ryegrass (*Lolium perenne* L.) at irrigation frequencies x cover mixtures rates interaction in 2008 and 2009 experimental years.

| Irrigation Frequencies | Cover Mixtures Rates (%) | | | | |
|---|---|---|---|---|---|
| | 0.0 | 0.25 | 0.50 | 0.75 | 1.00 |
| | 2008 | | | | |
| | Number of Emergence | | | | |
| Daily | 19.3 ef | 25.0 b | 28.5 a | 17.2 fg | 15.7 gh |
| 4 Days | 9.7 j | 11.8 ij | 20.8 c-e | 23.7 bc | 22.7 b-d |
| 7 Days | 10.0 j | 13.7 hi | 15.0 g-I | 19.7 d-f | 22.0 b-e |
| | Number of Seedling | | | | |
| Daily | 53.5 c | 60.3 ab | 58.7 b | 61.2 ab | 63.3 a |
| 4 Days | 20.2 g | 29.2 f | 39.0 e | 46.5 d | 46.5 d |
| 7 Days | 13.2 h | 12.8 h | 12.7 h | 13.0 h | 12.5 h |
| | Plant Height (cm) | | | | |
| Daily | 12.4 c | 14.0 d | 16.3 b | 16.7 b | 19.5 a |
| 4 Days | 9.8 e | 11.4 d | 12.5 d | 8.8 ef | 9.6 e |
| 7 Days | 5.7 h | 7.9 fg | 7.1 g | 5.4 h | 5.7 h |
| | Clipping Yield (g) | | | | |
| Daily | 3.1 c | 3.4 bc | 3.9 a | 3.7 ab | 3.7 ab |
| 4 Days | 1.7 de | 2.1 d | 1.8 de | 1.1 fg | 1.1 fg |
| 7 Days | 1.4 ef | 1.5 ef | 1.4 ef | 1.1 fg | 0.7 g |
| | 2009 | | | | |
| | Number of Emergence | | | | |
| Daily | 29.8 e | 37.7 c | 42.0 b | 50.5 a | 50.2 a |
| 4 Days | 21.8 g | 27.0 f | 29.3 e | 32.3 d | 33.7 d |
| 7 Days | 14.0 i | 19.0 h | 19.2 h | 18.2 h | 19.3 h |
| | Number of Seedling | | | | |
| Daily | 52.5 c | 64.8 b | 70.0 a | 72.8 a | 71.5 a |
| 4 Days | 25.3 g | 31.2 f | 44.0 de | 46.2 d | 41.3 e |
| 7 Days | 24.5 g | 16.8 h | 9.0 i | 5.8 i | 5.8 i |
| | Plant Height (cm) | | | | |
| Daily | 11.1 c | 13.1 d | 14.9 b | 15.3 b | 18.2 a |
| 4 Days | 7.8 f | 9.8 e | 11.2 d | 12.8 c | 10.5 de |
| 7 Days | 4.4 i | 5.3 h | 6.1 gh | 6.3 g | 6.1 gh |
| | Clipping Yield (g) | | | | |
| Daily | 2.6 c | 3.1 b | 3.1 b | 3.6 a | 3.0 b |
| 4 Days | 1.7 f-h | 2.3 cd | 1.8 e-g | 2.1 de | 2.0 d-f |
| 7 Days | 1.0 i | 1.4 h | 2.0 d-f | 1.5 gh | 0.6 j |

**Table 7.** The number of emergence, number of seedling, plant height and clipping yield of perennial ryegrass (*Lolium perenne* L.) at amendments x cover mixtures rates interaction in 2008 and 2009 experimental years.

| Amendments | Cover Mixtures Rates (%) | | | | |
|---|---|---|---|---|---|
| | 0.0 | 0.25 | 0.50 | 0.75 | 1.00 |
| | 2008 | | | | |
| | Number of Emergence | | | | |
| Sludge | 15.9 d | 21.0 ab | 26.4 cd | 23.6 a | 21.2 ab |
| Peat | 10.1 e | 12.7 e | 16.4 cd | 16.8 cd | 19.0 bc |
| | Number of Seedling | | | | |
| Sludge | 37.9 c | 42.6 b | 42.0 b | 47.4 a | 49.4 a |
| Peat | 20.0 f | 25.7 e | 31.6 d | 33.0 d | 32.1 d |
| | Plant Height (cm) | | | | |
| Sludge | 12.0 c | 14.1 b | 15.4 a | 12.9 c | 14.7 ab |
| Peat | 6.6 e | 8.0 d | 8.6 d | 7.6 de | 8.5 d |
| | Clipping Yield (g) | | | | |
| Sludge | 3.1 b | 3.6 a | 3.6 a | 2.8 b | 2.4 c |
| Peat | 1.0 d | 1.1 d | 1.1 d | 1.1 d | 1.2 d |
| | 2009 | | | | |
| | Number of Emergence | | | | |
| Sludge | 25.7 e | 32.1 c | 34.9 b | 39.0 a | 39.3 a |
| Peat | 18.1 g | 23.7 f | 25.4 e | 28.3 d | 29.4 d |
| | Number of Seedlings | | | | |
| Sludge | 47.2 ab | 49.4 a | 47.4 ab | 45.9 b | 42.0 c |
| Peat | 21.0 f | 25.8 e | 34.6 d | 37.3 d | 37.1 d |
| | Plant Heights (cm) | | | | |
| Sludge | 9.7 d | 12.1 c | 14.2 b | 15.7 a | 15.1 a |
| Peat | 5.8 g | 6.6 f | 7.2 f | 7.2 f | 8.1 e |
| | Clipping Yields (g) | | | | |
| Sludge | 2.7 bc | 2.8 ab | 3.0 a | 2.3 d | 2.0 e |
| Peat | 0.8 g | 1.8 ef | 1.6 f | 2.5 cd | 1.7 f |

## CONCLUSIONS

Results of this study can serve as a practical guide for field applications of SDS as an organic matter for turf production. SDS in high rates can be used in available irrigation condition. According to the results, the content of plant nutrient matter of SDS was high and its heavy metal contents were found below the critical levels according to the soil pollution control instructions. Based on these observations, we recommend amending soils with 50-75% SDS for optimum *Lolium perenne* L. growth. SDS amendment at these levels can greatly improve the soil nutrient supply without significantly affecting its heavy metal and soluble salt contents. The high soluble salts content in SDS is a major concern for its application as a soil amendment. In practical applications, it may be necessary to remove the soluble salts from SDS (e.g., by rinsing with water) before amending to soils. Both economical and environmental benefits can be obtained by applying SDS as a soil amendment, and it is a practical way to turn sewage sludge into valuable resources for the turf industry. Utilization of SDS as a soil amendment for turfgrass production not only reduces the raw material and nutrient requirements, but also alleviates the waste disposal demand.

Frequent irrigations alone may not be recommended because of the negative effects observed when irrigation is delayed. A schedule of infrequent and deep watering, possibly on a 7-day schedule combined with a light irrigation daily, or every other day, may be a good compromise between the two programs. Then, deep rooting is promoted, but the possible cooling effects, and associated water conservation of frequent irrigations can be realized. The amount of water applied needs to match turfgrass requirements, but rates and frequencies should be chosen to avoid preferential flow.

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