Woody biomass and elements uptake in phytoremediation of compost leachate

TOOBA ABEDI1,*, NAZI AVANI2,***
1Environmental Research Institute, Academic Center for Education, Culture and Research. Rasht, I.R. Iran. *email: tooba.abedi@gin.ac.ir, abeditooba@gmail.com
2Teaching fellow, School of Distance Education, Universiti Sains Malaysia, Penang, Malaysia. **email: avani.nazi@yahoo.com

Manuscript received: 9 May 2018. Revision accepted: 4 June 2018.

Abstract. Abedi T, Avani N. 2018. Woody biomass and elements uptake in phytoremediation of compost leachate. Asian J For 2: 20-24. This paper describes a pot experiment aimed at obtaining data on the response with respect to biomass accumulation Alnus glutinosa and Taxodium distichum which underwent leachate irrigation of Rasht Compost Plant. In mid-March 2013, one-year-old seedlings of Alnus glutinosa and Taxodium distichum were planted in a greenhouse at Safrabaste Poplar Research Station and since then, this study began. The compost leachate was taken from the collection reservoir of leachate coming from open composting of organic municipal wastes and various gardening and plant wastes. Three treatments were applied to the plants, namely the irrigation using: tap water (control / C), pure leachate (P) and the mixture of one volume unit of leachate with one volume unit of running water (1: 1). It was concluded that leachate had a positive influence on the growth of Alnus glutinosa and Taxodium distichum namely an increase in diameter and height of seedlings in the measurement period which occurred to be caused by fertilization properties of leachate. Statistically, there was no difference in the development of aboveground biomass in the treatment of P, 1:1 and C. This indicated that both irrigations by pure leachate and mixture liquid stimulate growth in the same way as irrigation by water. The dry mass of root showed the same result as aboveground mass. The total dry mass of the leachate treatment for Alnus glutinosa and Taxodium distichum were, respectively, 83.89 g and 78.68 g. The total root dry mass of leachate treatment for Alnus glutinosa and Taxodium distichum was, respectively, 11.98 g and 9.09 g. The results of elements absorption showed no statistical difference between the aboveground species. The absorption of Ca concentration in root was higher than the absorption of other elements and showed significant difference in 1:1 treatment.

Keywords: Treatment, growth, compost leachate, seedling

INTRODUCTION

The production of renewable energy sources, also in the form of biomass has been increasingly proposed in Iran. Providing sufficient plant nutrients (artificial fertilizers) for their optimal growth is essential importance. At the same time, fertilizers represent an important production cost. Their substitution with waste sources could be a promising option with regard to the reduction of production costs and the simultaneous reduction of spending on the treatment of waste sources like landfill leachate, wastewater from compost production, sludge, etc. (Justin et al. 2010; Holm and Heinsoo 2013). This paper describes a pot experiment with the aim of obtaining data on the response with respect to biomass accumulation Alnus glutinosa and Taxodium distichum to different concentrations of compost leachate. Several studies report positive effects of leachate irrigation on tree growth, showing its fertilizing potential. Zalesny and Bauer (2007b) found that Salix clones S287 and S566 exhibited responses favoring leachate irrigation over water. Justin et al. (2010) detected that the use of landfill leachate treatments resulted in a considerably increased aboveground biomass compared to the control tap water treatment and the growth and biomass accumulation in compost wastewater treatments were reduced compared to tap water and landfill leachate treatments. Abedi et al. (2014, 2015) investigated Populus deltoides, P. euramericana, and Salix alba in phytoremediation.

In both biomass and other forms, the procurement of renewable sources of nutrients is increasingly being proposed in Iran. For optimal plant growth, adequate supply of nutrients for plants is essential. Artificial fertilizers as the main supply of nutrients for plants become the largest absorber factor in production costs in agriculture or plantations. Replacement of artificial fertilizer with alternative fertilizer becomes the most favorable option for farmers in reducing the cost of artificial fertilizer procurement and the cost of the treatment of waste sources like landfill leachate, wastewater from compost production, sludge, etc. (Justin et al. 2010; Holm and Heinsoo 2013). This study attempts to illustrate experiments with pots aimed at obtaining data on the response of biomass accumulation of Alnus glutinosa and Taxodium distichum with compost leachate with different concentrations.

Due to its economic and ecological usefulness, Taxodium distichum becomes one of the most well-known conifer trees and it is thought to have high tolerant to flooding and waterlogging. Although, it and its associated species are more famous for their usefulness in flooding and salinity (El-Dayem 2003).

Alnus glutinosa has toleration to prolonged submergence of its roots in water for up to 30cm deep. This plant can also grow in much drier sites, though, in such
condition, it will usually not live for a long period and will die soon. *Alnus* can grow well in heavy clay soils, and is in tolerance to lime and very infertile sites. It tolerates a wide range of soils but prefers an above 6 pH. It is very tolerant to maritime exposure and can grow very rapidly in early stage. (http://www.pfaf.org/user/plant.aspx).

**MATERIALS AND METHODS**

Safrabaste Poplar Research Station was used as a place of experimentation. It is located in eastern part of Gilan province in north of Iran (37° 19´N, 49º 57´E) and the experiment was done in growing season in 2013.

One-year-old seedlings of *Alnus* and *Taxodium* were used as plants of experimentation and they were collected from the nursery of the Safrabaste Poplar Research Station. Their high biomass production capacity and their function as endemic species of Hyrcanian forests of Iran made them chosen as the objects of experimentation. At the beginning of the planting season, i.e. in the middle of March 2013, the seedlings were planted in experiment pots filled with loamy-sandy soil from around the area with a depth of 40 cm. The initial substrate used in the experiment was analyzed in the soil laboratory. In accordance with the standard procedure described by the Soil Science Society of America, the main physical and chemical characteristics of the soil were determined (Page et al. 1982). Table 1 shows a list of substrate analysis, physical characteristics, and analytical methods applied in this study.

Compost leachate was gathered from a leachate reservoir belonging to Compost Plant of Municipal Waste Management of Rasht, North of Iran (37° 10´N, 49º34´E). The analysis for its chemical content was performed in the Laboratory of Guilan Department of Environment (Rasht, North of Iran) using approved Standard Methods for the Examination of Water and Wastewater (Eaton et al. 2005).

Table 2 shows the composition of leachate for the experiment. It was dark brown with smelly odor. A 20 l plastic tank was used to store the leachate while it was mixed with tap water to create a mixture with specified degree of dilution. Before the filling of the tank, chemical analysis of leachate was performed.

For as long as eight weeks, in the beginning, tap water was used to water the plants. When the experiment started in mid-May 2013, three treatments were applied to the plant, namely the watering treatment with: (C) tap water (control), (P) pure leachate, and (1: 1) the mixture of one unit of leachate with one unit of tap water (by volume). The experiment layout is a completely random design consisting of five treatments with ten replicates for each treatment. The experiment lasted until early December. The pots with the plants inside were placed randomly on an experiment field under a transparent roof to avoid rainfall but still exposed to sunlight. The plants were irrigated with a mixture of water for as much as the absorption capacity of substrate against water (0.5 l per pot) in the first week of the experiment. Pure leachate is leach without dilution. Tap water for C treatment and for the preparation of the water mixture is from the public drinking water supply.

Table 1. Soil analyses and physical characteristics of the substrate used in the experiment

| Component | Unit      | Amount  |
|-----------|-----------|---------|
| pH        |           | 8.31    |
| EC        | mS cm⁻¹   | 0.128   |
| Corg      | %         | 0.08    |
| Ntot      | %         | 0.01    |
| P         | mg kg⁻¹   | 0.69    |
| K         | mg kg⁻¹   | 57.60   |
| Ca        | mg kg⁻¹   | 400     |
| Mg        | mg kg⁻¹   | 24      |
| Soil texture |      | Loamy sand |
| sand      | %         | 86      |
| silt      | %         | 5       |
| clay      | %         | 9       |

Table 2. Composition of pure compost leachate

| Parameter | Unit | Amount  |
|-----------|------|---------|
| pH        |      | 5.22    |
| EC        | mS cm⁻¹ | 1.26   |
| Ntot      | mg L⁻¹ | 21.384  |
| NO₂      | mg L⁻¹ | 0.08    |
| NO₃      | mg L⁻¹ | 21.3    |
| SO₄      | mg L⁻¹ | 7101    |
| PO₄-P    | mg L⁻¹ | 22.11   |
| Na       | mg L⁻¹ | 310     |
| K        | mg L⁻¹ | 250     |
| Ca       | mg L⁻¹ | 152     |
| Mg       | mg L⁻¹ | 1103    |
| Pb       | mg L⁻¹ | 0.27    |
| Ni       | mg L⁻¹ | 0.342   |
| Cd       | mg L⁻¹ | 0.0047  |
| Cr       | mg L⁻¹ | Trace   |
| COD      | mg L⁻¹ | 260500  |
| BOD      | mg L⁻¹ | 130000  |
| TSS      | mg L⁻¹ | 3060.6  |
| Turbidity | mg L⁻¹ | 12500   |

The growth on diameter and height of the trees was monitored bi-monthly. At breast high, the diameter was measured, and from the soil surface to the apical bud at the terminal shoot, the height was recorded (Zalesny et al. 2007a). For eight months of the growth phase, the average growth rate of diameter and height of the trees for each treatment was calculated bi-monthly (Figure 1 and 2).

After eight months, all trees were cut down and were separated into 2 parts, namely: aboveground (stems, branches, and leaves) and root system. The parts of the root system were separated carefully and washed thoroughly with distilled water. Next, the roots and the stems were dried in an oven at 60° C for 48 hours. The biomass (Figure 5 and 6) and absorbed elements (Figure 7 and 8) of aboveground and of root were calculated carefully. Data were calculated using SPSS 16.0 statistical package. The statistical dissimilarity among treatments is ascertained by the analysis of variance. The outcomes were regarded remarkable at p <0.05. The tree growth rate was displayed on graphs of the diameter and of height against time.
RESULTS AND DISCUSSION

High quantity of contents of components were given to plants in the pots. The contents of N, P and K were much greater in number in leachate treatments than in soil, but Ca content was lower compared to that in soil (0.128 mS cm$^{-1}$). Metal contents were low in collected leachate. For eight months, by P treatment, A. glutinosa and T. distichum showed the highest diameter growth with an average of 1.356 and 1.128 cm respectively (Figure 1). Over a period of eight months, a higher rate of height growth was found in the treatment of P and 1:1 (Figure 2).

For aboveground biomass, the greater mean was in the treatment of 1:1, but it was not significantly different from other treatments (p<0.05) (Figure 5). For root biomass, the greater mean was in the treatment of 1:1, which was not significantly different from the treatment of C, but gave a significant difference from P treatment (p<0.05) (Figure 6).

Discussion

The positive effects of leachate irrigation on tree growth and its fertilizing potential for plants have been reported by many studies. Justin et al. (2010) found that utilization of landfill leachate treatment increased the amount of surface biomass significantly compared with the control tap water treatment, but tree growth and biomass accumulation in wastewater compost treatment decreased compared to the treatment of tap water and compost leachate. The results of Abedi et al. (2014, 2015) showed a positive effect of compost leachate on tree species. Depend on the constituents of the leachate and soil, as well as the nutrient demands of the genotypes tested, the concentrations and amounts of leachate will be determined (Zalesny and Bauer 2007b).

In all treatments, no statistically significant differences between the aboveground biomass could be found (Figure 5). High concentration in the P treatment turned out to be toxic, meaning that the water mixture in P treatment already had too high concentration of salts and other elements (Table 2).

The compost leachate was a by-product of composting of organic matter, having a low pH (5.22) which is a sign of unfinished degradation processes of raw organic matter, where due to the inadequate oxygen levels. The comparison of the plants growth in the several treatments showed apparently normal and healthy-looking trees. The compost leachate was a by-product of the decomposition process of organic matter and it has a low pH (5.22) which shows a sign of incomplete decomposition processes of raw organic matter due to the insufficient oxygen levels. The differentiation of the plant growth in some treatments indicated apparently normal and healthy-looking trees.

The practice level of nitrogen was also elevated in compost leachate. There is acknowledged patency in common agricultural practice that supplementary nitrogen is utilized to manage distinctive toxicity issues and boost vegetation growth (Ayers and Westcot 1994). Kadlec and Wallace (2009) notified that more elevated concentrations of sulfate (402 mg SO$_4$/L) in compost leachate could bring negative effect on plant accretion in water-saturated root part and should also be highlighted. In this study, the sulfate concentration was 7101 mg SO$_4$/L. Still, the plant continued to accrue.
Fung et al. (1998) Abedi et al. (2014) stated that elevated rates of salt (1.0% NaCl) quickly lessened the accretion of Populus and owned an instantaneous result on predawn leaf water potency, photosynthesis and stomata resistance. It has been notified that the Populusis was sensitive to salt, but A. glutinosa which was hardwood tree species and T. distichum which was softwood tree species have no negative reactions to elevated concentrations of salts. It is obvious that pure compost leachate can be used without treated for study species. However, transferring the experiment to the field would enable leaching of the excess water from the root zone, and the washing-out of salts by precipitation to the lower soil layers, thus better survival with the same amounts of pure compost leachate as used in the pot experiment. The development of aboveground biomass is important from the leachate consumption and phytoremediation point of view (Justin et al. 2010). It is crystal clear that the unspoiled compost leachate can be exerted without being carried out for study species. Nevertheless, redeploying the trial to the field would enable leaching of the excess water from the root zone, and the washing-out of salts by precipitation to the lower soil layers, thus better survival with the same amounts of pure compost leachate as used in the pot experiment. The
establishment of aboveground biomass is necessary from the leachate usage and phytoremediation viewpoint (Justin et al. 2010).

The outcome of elements absorption shows no statistical variation between above-ground species. Lower K absorption was found on C treatment while the most elevated absorption of Ca happened above ground (Figure 7). The absorption of Ca concentration on root was higher than the absorption of other elements and show significant variance in 1:1 treatment (Figure 8). There was a conclusion that compost leachate positively affected the development of A. glutinosa and T. distichum in their diameter and height in measuring time due to the leachate’s property of fertilization (Figure 1 and 2). The diameter and height of trees have no significant differentiation (p< 0.05) in all treatments (Figure 3 and 4).

In the treatment of 1:1, the highest aboveground biomass was yielded by both species. There was statistically no differentiation between the treatment of P, 1:1 and C in establishing aboveground biomass. This shows that leachate watering with P or 1:1 mixtures boosted the growth in the same way as the watering with pure water. The root dry mass indicated the same results as that of aboveground mass. Total aboveground dry mass of leachate treatments for A. glutinosa and T. distichum was 83.89 and 78.68 g, respectively. The amounts for water treatments were 47.12 and 35.90 g, respectively. Total root dry mass of leachate treatments for A. glutinosa and T. distichum was 11.98 and 9.09 g, respectively. The amounts for water treatments were 5.57 and 2.75 g, respectively. Zalesny and Bauer (2007b) chose fast-accretion Populus and Salix clones and their genomic groups after doing watering with waste leachate for one growing season. In this experiment, Populus resulted greatest in diameter and dry mass. The highest level of phytoremediation showed no significant relation with the highest biomass yield (Greger and Landberg 1999; Klang-Westin and Eriksson 2003; Zalesny and Bauer 2007b), and the concentration of iron and nutrients is piled up in the bark which is higher than the wood tissue (Pulford and Dickinson 2005; Dimitriou et al. 2006; Adler et al. 2008). This should be examined in the future elemental analysis of the plant material.

ACKNOWLEDGEMENTS

We would like to thank Afshin Azizi head of the Natural Disaster Control and Management Center of Guilan Province for their financial support and Safrabaste Poplar Research Station for their scientific council.

REFERENCES

Abedi T, Moghaddami Sh, Laskar Bolouki E. 2014. Growth of Populus and Salix species under compost leachate irrigation. Ecologia Balcanica 6 (2): 57-65.

Abedi T, Moghaddami Sh. 2015. Phytoremediation concept: Biomass production and growth of Populus deltoides under compost leachate irrigation, J For Sci 61 (6): 250-254, DOI: 10.17221/1212014-JFS .

Adler A, Dimitriou I, Aronsson P, Verwijst T, Weih M. 2008. Wood fuel quality of two Salix viminalis stands fertilised with sludge, ash and sludge-ash mixtures. Biomass Bioenergy 32 (10): 914-925. DOI: 10.1016/j.biombioe.2008.01.013.

Ayers RS, Westcot DW. 1994. Water Quality for Agriculture. FAO, Rome.

Dimitriou I, Aronsson P, Weih M. 2006. Stress tolerance of five willows clones after irrigation with different amounts of landfill leachate. Bioresource Technol 97: 150-157. DOI: 10.1016/j.biotech.2005.02.004.

Eaton AD, American Public Health Association, American Water Works Association, Water Environment Federation. 2005. Standard Methods for the Examination of Water and Wastewater. American Public Health Association: 1325, Washington, D.C.

El-Dayem A. 2003. Effect of Fertilizer Treatments on Taxodium distichum Seedlings Grown in Alkali Soil. XII World Forestry Congress. 21-28 September 2003, Quebec City, Canada.

Fung LE, Wang SS, Altman A, Hu’terman A. 1998. Effect of NaCl on growth, photosynthesis, ion and water relations of four poplar genotypes. For Ecol Manag 107: 135-146. DOI: 10.1016/S0378-1127(97)00328-9.

Greger M, Landberg T. 1999. Use of willow in phytorextraction. Intl J Phytoremed 1: 115-123. DOI: 10.1080/15226510701709689.

Holm B, K. Heinsoo. 2013. Influence of composted sewage sludge on the wood yield of willow short rotation coppice. Environ Protect Eng 39 (1): 17-32.

Justin MZ, PajkN, Zupanc V, Zupancic M. 2010. Phytoremediation of landfill leachate and compost wastewater by irrigation of Populus and Salix: Biomass and growth response. Waste Manag 30: 1032-1042. DOI: 10.1016/j.wasman.2010.02.013.

Kadlec RH, Wallace SD. 2009. Treatment Wetlands, 2nd ed. CRC Press, Boca Raton, FL.

Klang-Westin E, J. Eriksson. 2003. Potential of Salix as phytoretractor for Cd on moderately contaminated soils. Plant Soil 249: 127-137. DOI: 10.1023/A:1022585404481.

Navarro JM, Tomoro OP, Morte A. 2014. Alleviation of salt stress in citrus seedlings inoculated with arbuscular mycorrhizal fungus depends on the rootstock salt tolerance. J Plant Physiol 171: 76-85. DOI: 10.1016/j.jplph.2013.06.006.

Page AL, Miller RH, Keeney DR. 1982. Methods of Soil Analysis. Part 2, Chemical and Microbiological Properties. American Society of Agronomy, Inc. Soil Science of America, Inc. Madison, Wisconsin, USA.

Pulford ID, Dickinson NM. 2005. Phytoremediation technologies using trees. In: Prasad MNV, Naidu R (eds.). Trace Elements in the Environment. CRC Press, Boca Raton, FL.

REFERENCES