Investigating addition of organic matter at planting in the nursery to assess further growth responses of two poplars

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Abstract

Efficient management practices in the nursery could have positive effects on plantation yield. The aim of this study was to determine the effect of organic matter treatments in the nursery on further growth responses of poplar cuttings. Uniform-in-size cuttings of two fast-growing poplar species (*Populus nigra* L. and *Populus alba* L.) were rooted in three different organic matter over a one-year growing season. Then, the rooted cuttings transplanted into big pots which were filled with loam soil and irrigated for another growing season. At the end of second growing season, stem diameter, stem height, root diameter, root length, TTLA and volume of woody biomass were measured. The results showed that, associated with the applied organic matters, significant productivity increases in biomass parameters of above- and below-ground tissues were observed ($p< 0.01$). In all organic matter treatments, the greatest amounts of biomass parameters were belong to *P. nigra* L. Substrate C showed maximum productivity in biomass parameters among other amended substrates. Addition of organic matters during the establishment years in the nursery can be considered as a great potential for enhancing establishment and biomass production of short rotation poplar plantations and finally fulfillment the purpose of reducing the pressure on natural forests.

Key words: Poplar, Cocopeat, Peatmoss, Leaf litter, Substrate

1. Introduction

There is increasing interest in Establishment and utilization of short-rotation plantation cultures for bioenergy production which can substantially reduce the worldwide use of fossil fuels for energy (Amichev et al., 2010). Also the use of plantation cultures is a promising silvicultural solution for reducing the pressure on natural forests (Paquette and Messier, 2010).

Compare to other forest species, poplars have some characteristics, including fast growth, adaptability to different environmental conditions and suitability for diverse silvicultural systems, make them suitable for plantation culture which enable the production of large amounts of wood in short periods of time (Fang et al., 2007). At present, short-rotation plantation culture activities are mainly based on poplar species (*Populus* spp.) and their cultivars (Johansson and Karacic, 2011).

Efficient management practices during the establishment years in young tree plantations are extremely important for maximizing tree growth, survival (Kabba et al., 2011) and finally biomass production.

That plantation culture productivity is dependent on the preservation of the soil resource including its biological, chemical and physical properties and processes is well known. Reduction of soil fertility resulting from continuous cultivation and soil erosion is a major limitation for plantation culture prosperity. Soil organic matter (SOM), typically measured as content soil organic carbon (SOC), is an important indicator of soil fertility and quality. It is closely associated with many critical soil chemical, physical and biological processes (Mathers et al., 2003). Soil C/N ratio and humus form are other related measures of soil productivity (Kõlli, 2002). The presence of SOM has been demonstrated to be valuable for site productivity through its positive influence on soil porosity, gas exchange reactions, and water holding capacity (Prescott et al., 2000). In addition, SOM facilitates important biological and chemical processes related to the long-term storage and release of nutrients required for growth of trees and crop vegetation (Seely et al., 2010).

We hypothesized that applying of different organic matter at planting in the nursery could have positive effects on growth and biomass performance of poplar plantation projects. More specifically, the objective of the current study was to investigate and compare growth and biomass production of *Populus nigra* L. and *Populus alba* L. two-year old seedlings which were treated with different organic matter at planting in the nursery. The results will serve as a basis for researchers and resource managers making decisions about future plantation projects.

2. Research Methodology

The soil used in this study was collected from depth of 0 to 30 cm from the campus of Agriculture and Natural Resources of University of Tehran. The soil was air dried and passed through 2-mm sieve and mixed uniformly. The results of chemical and physical characteristics of the soil are shown in Table 1.

Parameter	Quantity	Parameter	Quantity
Soil texture	Loam	Total nitrogen (%)	0.076
Clay (%)	24	Available phosphate (mg kg^{-1})	18
Silt (%)	35	Available Potassium (mg kg^{-1})	232
Sand (%)	41	Field Capacity (F.C)	26
pH	7.5	Cu (mg kg^{-1})*	4.002
EC(dS m^{-1})	4.42	Zn (mg kg^{-1})*	1.01
$CaCO_3$%	8.1	Mn (mg kg^{-1})*	7.854
OC%	0.86	Fe (mg kg^{-1})*	5.1
CEC(Cmolkg^{-1})	25	So_4 (meq L^{-1})	37.20

* DTPA-Extractable

Table 1. Physical and chemical characteristics of agricultural soil used in this study before adding organic matters

Cuttings were prepared in Masir-e-Sabz nursery, Karaj, in the north of Iran. 40 homogenously and uniform-in-size cuttings [length (25±3 cm), diameter (8±1 mm) and number of bud (8)] were taken from two single *Populus nigra* L. and *Populus alba* L. trees and rooted in perlit.

To prepare substrates, cocopeat, leaf litter and peatmoss were used as organic matter and passed through a 4-mm sieve. Pots (with 35 cm diameter and 55 cm height) were filled with four air-dried substrates mentioned below: A) Loam soil and cocopeat were mixed in 1:1 (v/v) ratio (P50%), B) Loam soil and peatmoss were mixed in 1:1 (v/v) ratio and C) Loam soil and leaf litter were mixed in 1:1 (v/v) ratio and D) Loam soil (as control, no input organic matter) and then equilibrated for one month. The characteristics of the amendments used in this study were as follow:

Parameter	Leaf litter	Cocopeat	Peat mass
Salt content	1.2 g kg^{-1}	1.12 g l^{-1}	0.95 g l^{-1}

Content of organic matter (%)	38	86	96
pH	6.2	6.1	5.7
K_2O	78 %	264 mg l^{-1}	178 mg l^{-1}
P_2O_5	23.2 mg kg^{-1}	93 mg l^{-1}	83 mg l^{-1}
N	0.74 %	85 mg l^{-1}	81 mg l^{-1}

The cuttings were planted into the pots during fifteenth of February 2010. To avoid nutrient limitation, required fertilizers (according to soil analysis results) were added to each pot. Loss of water was made up daily using tap water. One-year old rooted cuttings were transplanted into bigger pots were filled with air-dried loam soil during January 2011. The plants were destructively harvested at the end of September 2011.
Stem height and root length (to the nearest 1.0 cm) as well as stem and root diameters (to the nearest 0.01 mm) were measured. Height was measured from ground level to the base of the apical bud on the terminal shoot. To reduce experimental error associated with stump swell, stem and root diameters were measured at 10 cm above the soil surface and 5 cm below the soil surface respectively. Volume of woody biomass (cm^3) was estimated using the generalized equation: volume of woody biomass = $diameter^2 \times$ height, according to Zalesny et al., (2007). Total tree leaf area (TTLA) was estimated according to the following equation: TTLA = (area of subsampled leaves/dry mass of subsampled leaves) × total tree leaf dry biomass (Zalesny et al., 2007).
The experiments were arranged in a factorial experimental design with completely randomized basic design. All treatments were replicated five times. Data were processed using SAS statistical software. Statistical differences between treatments were tested by two-ANOVA followed by HSD test to separate level means. All the expressed values are mean ± S.D (standard deviation) of the five replicates. Results were considered significant at $p < 0.01$.

3. Results and Analysis

Analysis of variance showed significant differences between the main effects ($p < 0.01$) for the studied attributes (substrates and species). It would show that there are significant differences between above- and below-ground growing responses as well as the volume of woody biomass per tree. The Sp ×Sub interaction for stem height and root length were not significant meanwhile for other traits were ($p < 0.01$and $p < 0.05$) (Table 2).

Source of Variation		Mean Square					
	df	Stem diameter	Stem height	Root diameter	Root length	TTLA	Volume of woody biomass
substrate	3	70.90**	6988.03**	97.60**	80.96**	1.51**	6852471243**
Species	1	143.64**	15444.9**	97.96**	211.60**	14.13**	3936578803**
Sp ×Sub	3	5.27*	160.16^{ns}	8.23**	13.00^{ns}	0.19**	337186553*
C V	-	7.84	4.63	8.44	6.95	8.33	15.65

ns: not significant. **, *, Significant at a probability level $p < 0.01$, 0.05, respectively.

Table 2. Mean squares of studied traits

Addition of organic matter is a common method for increasing plant biomass (Alizadeh et al., 2012).In the present experiment, the addition of cocopeat, peatmoss and leaf litter to soil was intentionally designed to prove the hypothesis that application of these materials at planting in the nursery would assist the establishment and further growth responses of two poplars in the next growing seasons. The similar order (substrate C> substrate B> substrate A> substrate D) of the amounts of above- and below-ground growing responses as well as the volume of woody biomass production per tree was observed. The results of Above-ground biomass parameters of two *Populus* species are presented in Figs 1 and 2. As shown in Figs 1-5, amendments led to increase in stem diameter, height, root diameter, root length and TTLA of poplars. Among amendments, the differences in stem diameter and height were not significant (Figs 1 and 2). Poplars showed maximum amounts of stem diameter and height in substrate C, whereas minimum amounts of mentioned traits were observed in control.

The root diameter and length ranged from 11.26 cm and 31 cm (produced by *P. alba* in substrate D) to 18.78 cm and 42.6 cm (produced by *P. nigra* in substrate C) respectively. Alternatively, substrates B and C increased root diameter of poplars significantly (p<0.01), but substrate A had insignificant (p<0.01) effects on root diameter (Figure 2a). Root length did not differ among substrates A, B and D (control treatment), whereas there were differences between substrate C and D in both *P. alba* and *P. nigra* (Fig 4).

Since organic matter might be used (with soil analyses) as an indicator of soil fertility (Laclaua et al., 2010), applying organic matters (substrates A, B and C) did exert positive effects on growth responses in both poplar species compare to control (substrate D). In the current study, associated with the organic matter, significant productivity increases in biomass parameters of above-ground tissues were observed (Figs 1 and 2). Amendments promoted the depth of root penetration and caused positive effects on root growth components (Figs 3 and 4). Therefore, there is a great potential for increase of plantation yield using organic matter. Egodawatta et al. (2012) demonstrated that continuous high input of organic matter increases maize yield. Abreu et al. (2012) reported that there is an increase in biomass production by castor oil plant roots and shoots when organic material was added to the soil. They emphasized the increase in biomass production is significantly related to the rates of organic amendments added to the soil.

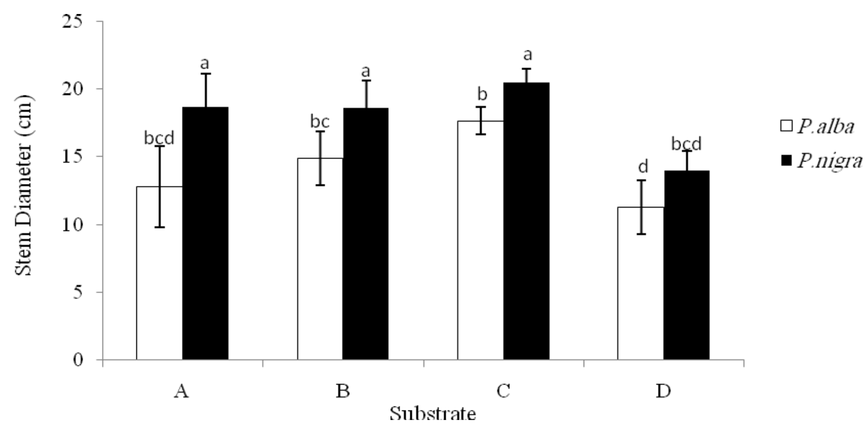

Fig. 1 Stem diameter 19 months after planting during 2010 and 2011 growing seasons. Each bar represents the mean of 5 trees with one standard error. Bars labeled with different letters were different at $p < 0.01$.

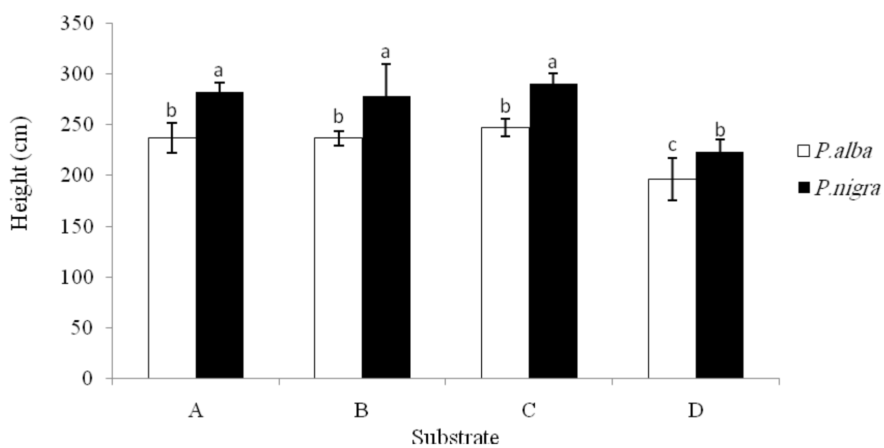

Fig. 2 Plant height 19 months after planting during 2010 and 2011 growing seasons. Each bar represents the mean of 5 trees with one standard error. Bars labeled with different letters were different at $p < 0.01$.

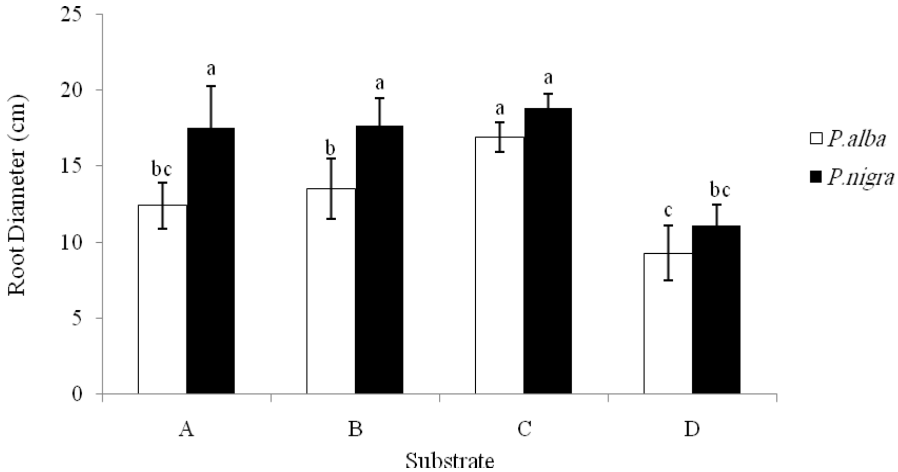

Fig. 3 Root diameter of two *Populus* species 19 months after planting during 2010 and 2011 growing seasons. Each bar represents the mean of 5 trees with one standard error. Bars labeled with different letters were different at $p < 0.01$.

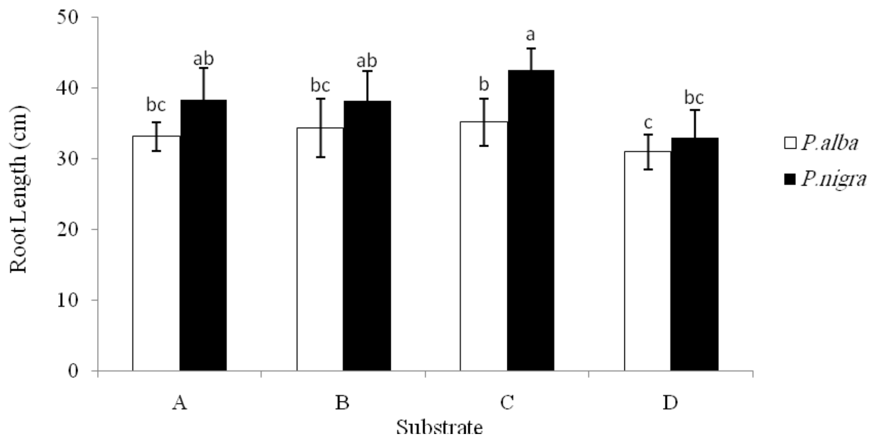

Fig. 4 Root length of two *Populus* species 19 months after planting during 2010 and 2011 growing seasons. Each bar represents the mean of 5 trees with one standard error. Bars labeled with different letters were different at $p<0.01$.

Both two poplars showed similar performances in leaf area index across different organic matter treatments. A distinct species difference advantage for overall total tree leaf area was existent. However, as presented in Figure 3, *P. nigra* exhibited greater total tree leaf area than *P. alba*. In the same cases, the differences between *P. alba* and *P. nigra* were significant ($p<0.01$). Maximum amount of total tree leaf area (3.356 m^2) was produced by *P. nigra* in substrate C while the minimum (1.366 m^2) was produced by *P. alba* in control. Organic matter treatments did affect volume of woody biomass compare to control treatment with the only exception in case of *P.alba* planted in substrate A. Volume of woody biomass did not differ among various organic matter inputs in *P. nigra* but there was a difference between amended substrates A and C in *P. alba* ($p< 0.01$). No significant difference between substrate A and control was observed (Fig 6).
Several studies report positive effects of applying organic matter on crop and tree growth. Quiroga et al. (2001), for example, found that crop yield was associated with soil texture, and in similar textures, yield depended on total soil organic matter content. Laclaua et al. (2010), also reported that tree biomass at the end of the rotation is highly dependent on organic manure mass at planting time. Nutrient contents in organic residues are largely involved in tree growth response. Such increases in growth responses might be because of positive functions of

organic matter including increase cation exchange capacity (CEC) (Lin and Chen, 1998) and aeration as well as structure improvement (Martínez-Fernández and Walker, 2011) in the substrates.

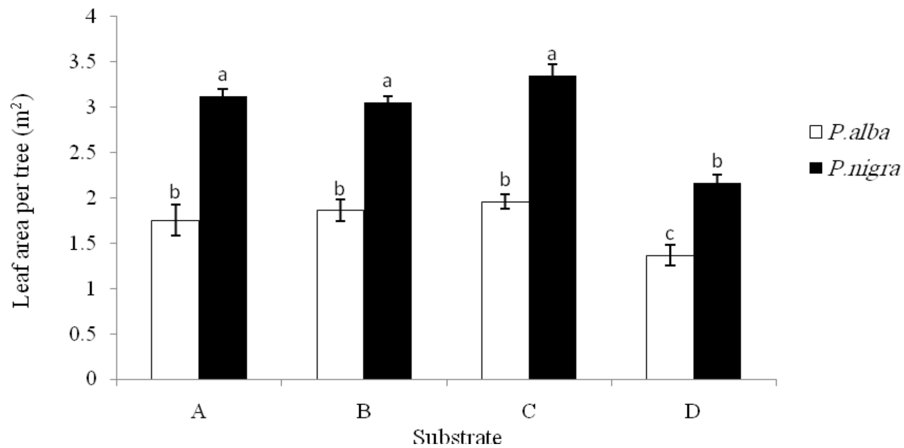

Fig. 5 Leaf area of two *Populus* species. Each bar represents the mean of 5 trees with one standard error. Bars labeled with different letters were different at $p<0.01$.

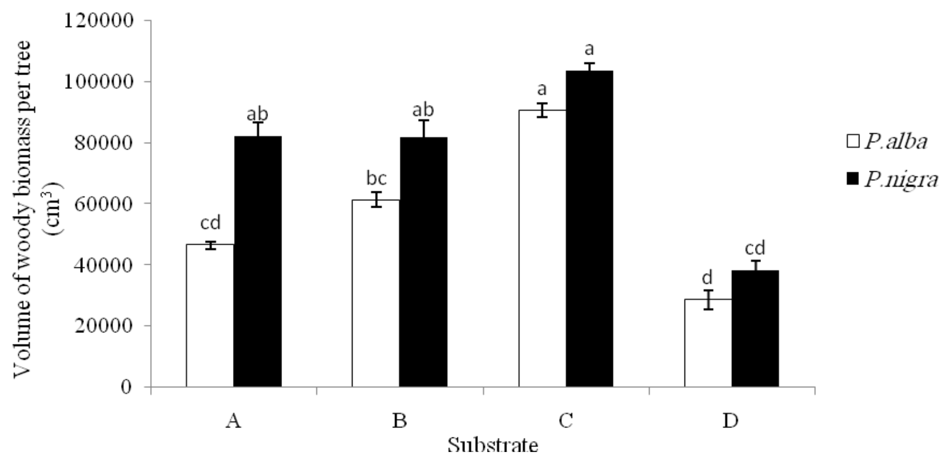

Fig. 6 Volume of woody biomass of two *Populus* species. Each bar represents the mean of 5 trees with one standard error. Bars labeled with different letters were different at $p<0.01$.

4. Conclusions

There is now growing interest in crop production systems in which nutrients are supplied from organic rather than inorganic sources. In this research work, significant plant development increases associated with organic matter inputs were observed. Therefore, using organic matters can be considered as a great potential for enhancing establishment and biomass production of short rotation poplar plantations. Further examinations are needed, however, that investigate similar responses throughout the entire rotation.

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