Investigation of rooting and growth characteristics of poplar clones in hydroponic and soil cultures

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Abstract

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In this study, rooting and growth characteristics of different poplar clones from six species including Populus deltoides Bartram ex Marshall clone Lux, Populus nigra subsp. betulifolia (Pursh) W. Wettstein clone 17/13, Populus euramericana (Dode) Guinier clone 561/41, P. deltoides clone Samsun, Populus alba Linnaeus clone 49/9, Populus caspica (Bornmüller) Bornmüller, and Populus euphratica Olivier in hydroponic and soil cultures have been evaluated. In hydroponic culture, poplar cuttings were grown in plastic tanks and in soil culture, poplar cuttings were planted into plastic pots with 12 replications for each clone. The pot experiment was a Complete Randomized Design. Root length, stem diameter, stem height, and root and shoot dry matter of poplar plants were studied in hydroponic culture after 84 days and in soil culture three times at 6, 12, 18 weeks in 2017. In hydroponic culture, the cuttings of P. deltoides Lux and P. nigra betulifolia 17/13, and of P. deltoides Samsun and P. euphratica were among the first and last clones that rooted, respectively. Also, the lowest rate of rooting was observed in P. deltoides Samsun and P. euphratica clones. The highest values of all parameters except root length were obtained in P. euphratica. The highest root length and stem diameter were observed in clones of P. deltoides Lux, P. nigra betulifolia 17/13, P. euramericana 561/41, and P. deltoides Samsun. In soil culture, P. deltoides Lux, P. nigra betulifolia 17/13, and P. alba 49/9 showed the highest percentage of rooting compared to the other clones at the first measurement. All the clones except the clone of P. euphratica reached above 40 cm root length in each of the three measurement periods. The highest stem diameter, stem height, and shoot dry matter were obtained in clone of P. deltoides Lux and root dry matter in clone of P. alba 49/9.

Keywords: growth parameters; numbers of rooted cuttings; Populus caspica; Populus euphratica; plastic pots

The genus *Populus* Linnaeus belongs to the family Salicaceae. *Populus* is highly valued for a variety of purposes, such as their fast growth, broad range of genetic variation, coppice production potential, ecological importance, suitable potential for the production of cellulose derived biofuels, electricity, and agroforestry, sources of valuable raw material for fibre, lumber, and plywood. It is also used for reme-

diation phytotechnologies (Zalesny, Bauer 2007), riparian buffer systems (Schultz et al. 2004), and to increase carbon sequestration (Johnson et al. 2007). Poplars enrich the surface soil in a short rotation of 6–12 years by adding leaf litter and high productivity (25–50 m³·ha⁻¹·yr⁻¹) (Sharma et al. 2014). There is a high potential to introduce them into other parts of the country due to their wide adaptability.

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Studying the rooting ability may provide information for the development of improved cultural technologies and growth enhancement (HEILMAN et al. 1994). Such practices may enhance the potential for success of commercial plantation deployment because rooting is the first biological prerequisite to stand establishment. It is reported however that not all species root equally well as the species Populus nigra Linnaeus introduces greater rooting ability than Populus deltoides Bartram ex Marshall. WILCOX and FARMER (1968) conducted early rooting experiments of P. deltoides cuttings based on root weight (0.36-0.58 g), root number (0.44-0.56) and root length (0.33-0.52 cm) and found significant broad-sense heritabilities for all characteristics. They attributed most clonal variation of rooting ability to two primary factors. Clonal differences were a result of inherent variability and unique physiological/morphological characters. They concluded that variation in the rooting ability of *P. deltoides* is under fairly strong genetic control. On the other hand, Heilman et al. (1994) reported that genotype and environment interactions affect rooting. Rooting ability of poplars is highly variable and complex, and the extensive variation in genotype and environment could result in the ability of roots to develop and grow rapidly from cuttings (HAISSIG et al. 1992). Factors such as physiological status of the cutting, propagation conditions, heterogeneity of soils, soil and air temperature affect the rooting ability (ZALESNY et al. 2005).

Now, in Iran, the area of lands under poplar cultivation reached more than 230,000 ha. Various nursery and field trials of *Populus* spp. have been conducted in many parts of the country. Ghassemi et al. (2003) studied the variables of diameter, height, biomass production and leaf characteristics of 24 clones of different poplar species in a nursery at the Alborz Research Station, Karaj, during the growing season. Goodarzi and Modir Rahmati (2002) in Markazi province, Yousefi and Modir Rahmati (2004) in Kordestan province, Talebi et al. (2007) in Chaharmahal and Bakhtiari, Amin Amlashi and Salehi (2011) in Guilan province performed investigations on one-year-old seedlings of different poplar clones at selection nurseries.

RAWAT et al. (2001) in studies of 75 clones at the nursery stage in eastern Uttar Pradesh selected the best eleven clones. In studies of 108 clones of *P. deltoides* on the basis of growth performance, clones S7C8, 82-35-4, 113324 and G-48 were the best four clones (KUMAR et al. 1999). KHURANA et al. (1992) studied the planting of cuttings of 35 *P. deltoides* clones at the nursery stage under four differ-

ent climatic conditions of Himachal Pradesh. They observed significant differences between clones with respect to survival, height, diameter, and leaf area. Sharma et al. (2014) studied 26 clones at the nursery stage in Nauni, Solan district (Himachal Pradesh, India) when maximum height (385.75 cm) of one-year-old plants was reached by clone T-33 followed by clones T-50 (378 cm), 5503 (376.5 cm), 6503 (375.75 cm), L-200/86 (368 cm) and H-14 (364.3 cm) and maximum basal diameter (22.6 mm) was reached by clone H-11 followed by clones 6503 (22.2 mm), L-22/86 (21.7 mm) and 8800 (21.6 mm). In order to study growth performance, MIR et al. (2017) selected 15 clones of P. deltoides in a nursery during two years. Clone L-34 attained maximum height of 284 cm followed by clone 65/27 (273 cm), W-A/26 (271 cm), L-34 (TC) (268 cm) and clone L-34 showed maximum collar diameter of 27.51 mm followed by clone W-A/26 (25.53 mm), clone L-34 (TC) (24.94 mm) and clone 65/27 (24.79 mm), clone W-22 attained maximum total dry matter of 545 g followed by clone L-34 (TC) (431 g).

Type and amount of roots can affect root hydraulic conductivity (RÜDINGER et al. 1994). In spite of roots development effect on seedling vigour and survival after planting, very little knowledge existed on the roots growth behaviour of Populus. Understanding the growth behaviour of species enhances the potential for successful commercial deployment and adventitious root formation is crucial for plantation development because rooting is the first biological requirement for stand establishment (ZALESNY et al. 2005). Recognition of the growth behaviour of species and clones of *Populus* as initial information has a fundamental role in planning programs of breeding. Asadi and Ghassemi (2007) studied growth parameters for clones of Populus caspica (Bornmüller) Bornmüller, P. deltoides, Populus euramericana (Dode) Guinier and Populus alba Linnaeus after 12 weeks in soil culture. Different growth behaviours are a reflection of the genetic and internal factors of the clones and external factors (environmental).

Therefore, the present study was undertaken to investigate the growth behaviour of 7 clones of *Populus* in hydroponic and soil cultures to compare the root development of these clones and to achieve growth and dry matter production. Also, the goal was to find out the best clone with high growth performance and dry matter production for further research on development of poplar plantations. This study can have practical implications for poplar growers and nursery managers and helps researchers gain fundamental knowledge of the physiology of *Populus* rooting.

MATERIAL AND METHODS

Plant material and growing condition. This study was conducted at the Alborz Research Station, Karaj, Iran (latitude 35°48'N, 50°54'E, 1,320 m a.s.l.) with a semi-arid climate. Mean annual temperature and precipitation are 13.7°C and 230 mm, respectively. On 15 March 2017 cuttings (15 cm long, about 1 cm in diameter) of *Populus* were collected from one-year-old seedlings in a nursery. They were tested in hydroponic and soil cultures as described below.

Hydroponic culture. Cuttings were grown in a hydroponic culture in plastic tanks and the solution was continuously aerated by aquarium pumps. We used clones from the section Aigeiros with the origin from Italy (P. deltoides Lux, P. nigra betulifolia 17/13, P. euramericana 561/41), the section Aigeiros with the origin from Turkey (P. deltoides Samsun), and the section Louce with the origin from Iran (P. alba 49/9 and P. caspica) and the section Turanga with the origin from Iran (*Populus euphra*tica Olivier) for these studies. For each clone, there were 12 cuttings in a Complete Randomized Design (CRD). The cuttings were grown for 84 days in the greenhouse conditions under natural daylight. In each clone, cuttings were checked for the number of rooted cuttings at 3-day intervals. After 84 days, parameters of root length, stem diameter, stem height, root dry matter, and shoot dry matter were recorded.

Soil culture. The cuttings of 7 clones of *P. deltoides* Lux, *P. nigra betulifolia* 17/13, *P. euramericana* 561/41, *P. deltoides* Samsun, *P. alba* 49/9, *P. caspica*, and *P. euphratica* were planted into plastic pots $(15 \times 22 \text{ cm}, \text{diameter and depth})$ filled with a mixture

of loam, sand and organic fertilizer (2:1:1, volume basis). The pots were kept in a glass-glazed greenhouse under a 16-hour natural photoperiod and irrigation was applied daily 10 days after planting to ensure the rooted cuttings would be established and then it was reduced to every other day. Hand-weeding was conducted several times during the growing season to control weeds. For each clone, there were 12 cuttings in a CRD. Parameters of root length, stem diameter, stem height, root dry matter, and shoot dry matter were recorded three times at 6, 12, 18 weeks in 2017.

Statistical data analysis. Distribution of data was tested for normality by the Kolmogorov-Smirnov test and some data were subjected to arcsine (\sqrt{x}) transformation before statistical analysis. Homogeneity of variance among clones was tested using Levene's test. A one-way ANOVA was performed on the differences between growth parameters and means were analysed by Duncan's multiple range test (P = 0.05) using SPSS (Version 22, 2013).

RESULTS

Hydroponic culture

The cuttings of *P. deltoides* Lux and *P. nigra betu-lifolia* 17/13 clones started rooting on the twenty-fourth day and *P. deltoides* Samsun and *P. euphratica* clones started rooting on the thirty-ninth day and were among the last clones that rooted. Also, the number of rooted cuttings in *P. deltoides* Samsun and *P. euphratica* was 8 and 10, respectively, which had the least number of roots among the clones (Fig. 1).

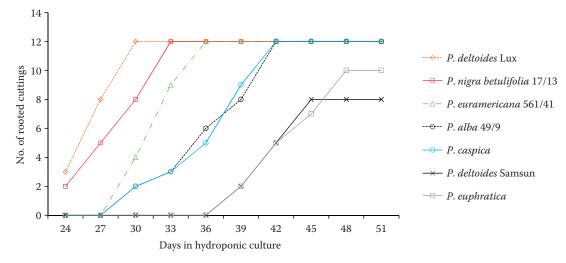


Fig. 1. The number of rooted cuttings at 3-day intervals in 7 clones of *Populus* Linnaeus (*P. deltoides* Bartram ex Marshall clone Lux, *P. nigra* subsp. *betulifolia* (Pursh) W. Wettstein clone 17/13, *P. euramericana* (Dode) Guinier clone 561/41, *P. deltoides* clone Samsun, *P. alba* Linnaeus clone 49/9, *P. caspica* (Bornmüller) Bornmüller, *P. euphratica* Olivier) in hydroponic culture

Responses of cuttings of different clones in hydroponic culture were significantly different in terms of statistics (P < 0.000). The highest values of all parameters except root length were obtained in P. euphratica and the lowest values of all parameters were obtained in P. caspica (Table 1). The highest root length and stem diameter were observed in clones of P. deltoides Lux, P. nigra betulifolia 17/13, P. euramericana 561/41, and P. deltoides Samsun (Table 1).

Soil culture

Clones of *P. deltoides* Lux, *P. nigra betulifolia* 17/13, and *P. alba* 49/9 showed the highest percentage of rooting compared to the other clones of *Populus* in soil culture at the first measurement period (6 weeks) (Fig. 2). The highest root length with more than 80 cm was obtained in *P. deltoides* Lux clone. All the clones except the *P. euphratica* clone reached above 40 cm root length (Fig. 3a).

All clones showed stem diameter ranging from 10 to 16 mm when the highest was in the clone of *P. deltoides* Lux (Fig. 3b). Stem height in the clone of *P. deltoides* Lux was more than 160 cm, while in *P. deltoides* Samsun it was 80 cm, which is almost half its maximum value in *P. deltoides* Lux (Fig. 3c).

Clone of *P. alba* 49.9 had the highest root dry matter compared to the other clones. Although the root dry matter of this clone was very low at the first measurement period (6 weeks), in the following

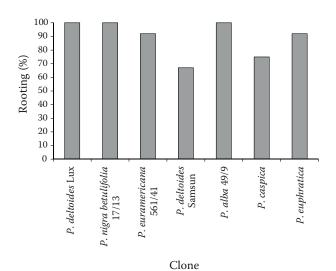


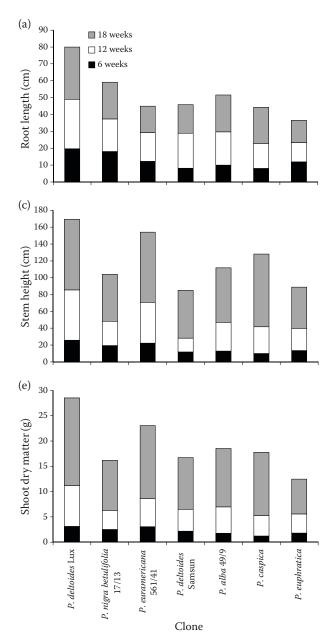
Fig. 2. Rooting percentage for 7 clones of *Populus* Linnaeus (*P. deltoides* Bartram ex Marshall clone Lux, *P. nigra* subsp. betulifolia (Pursh) W. Wettstein clone 17/13, *P. euramericana* (Dode) Guinier clone 561/41, *P. deltoides* clone Samsun, *P. alba* Linnaeus clone 49/9, *P. caspica* (Bornmüller) Bornmüller, *P. euphratica* Olivier) in soil culture during 6 weeks

months the clone showed a great increase in root dry matter (Fig. 3d). The maximum values of shoot dry matter (28.53 g) were reached by *P. deltoides* Lux and *P. euramericana* 561.41 (23.1 g) clones with 28.53 and 23.1 g, respectively. The lowest value of shoot dry matter was observed in the clone of *P. euphratica*, although this species had the highest increment at intervals of 18 weeks (Fig. 3e).

Table 1. Measurement of some growth parameters in 7 poplar clones in hydroponic culture after 84 days (mean \pm SE)

Clone	Root length (cm)	Stem		Dry matter (g)	
		diameter (mm)	height (cm)	root	shoot
F-test	13.62**	8.1**	12.31**	6.5**	3.94*
Populus deltoides Bartram ex Marshall clone Lux	23.87 ± 1.43ª	4.48 ± 0.1^{a}	25.7 ± 3.31 ^b	0.03 ± 0.00^{cd}	0.39 ± 0.04^{ab}
Populus nigra subsp. betulifolia (Pursh) W. Wettstein clone 17/13	25.87 ± 2.12 ^a	3.89 ± 0.02^{a}	22.13 ± 0.94 ^b	0.07 ± 0.00^{a}	0.31 ± 0.03^{abc}
Populus euramericana (Dode) Guinier clone 561/41	21.73 ± 1.36^{a}	4.44 ± 0.18^{a}	24.17 ± 1.18^{b}	$0.05 \pm 0.00^{\rm bcd}$	0.31 ± 0.05^{abc}
P. deltoides Samsun	23.2 ± 1.79^{a}	4.49 ± 0.07^{a}	24.73 ± 2.67^{b}	0.07 ± 0.00^{a}	0.39 ± 0.06^{ab}
Populus alba Linnaeus clone 49/9	17.2 ± 0.7^{b}	3.77 ± 0.32^{a}	28 ± 1.25^{b}	0.06 ± 0.01^{abc}	0.27 ± 0.01^{bc}
Populus caspica (Bornmüller) Bornmüller	10.4 ± 1.64^{c}	2.22 ± 0.6^{b}	27.83 ± 0.6^{b}	$0.02 \pm 0.00^{\rm d}$	0.21 ± 0.01°
Populus euphratica Olivier	16.67 ± 0.16^{b}	3.83 ± 0.17^{a}	42 ± 1.52^{a}	0.07 ± 0.00^{a}	0.43 ± 0.02^{a}

^{**}P < 0.01,*P < 0.05, all values with different letters are significantly different at $P \le 0.05$ using Duncan's test, "a" is the highest value



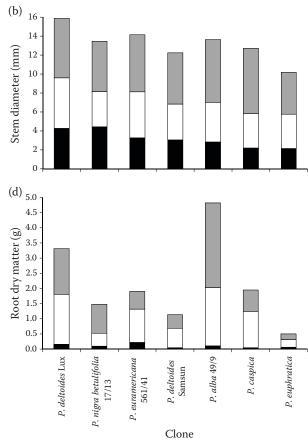


Fig. 3. Measurement of the root length (a), stem diameter (b), stem height (c), root dry matter (d), shoot dry matter (e) in 7 clones of *Populus* Linnaeus (*P. deltoides* Bartram ex Marshall clone Lux, *P. nigra* subsp. *betulifolia* (Pursh) W. Wettstein clone 17/13, *P. euramericana* (Dode) Guinier clone 561/41, *P. deltoides* clone Samsun, *P. alba* Linnaeus clone 49/9, *P. caspica* (Bornmüller) Bornmüller, *P. euphratica* Olivier) in soil culture at three measurement periods

DISCUSSION

Cutting rooting in hydroponic culture

The rooting of few cuttings is usually one of the limiting factors of the cutting planting technique. In hydroponic culture, all of the parameters except root length in *P. euphratica* and the lowest values of all parameters in *P. caspica* differ from soil culture. The root length and the stem diameter in species and clones of *P. deltoides* Lux, *P. nigra betulifolia* 17/13, *P. euramericana* 561/41, and *P. deltoides* Samsun are also different from the first time of measurement in soil culture. Initial growth most likely depended on reserves of carbohydrates stored in the cutting and how the cutting

responded to environment. Continual assessment of the growth of rooted cuttings under different soil culture could be designed for future studies. In nature, *P. euphratica* species exhibited drought resistance following the development of a root system (Harvey, van den Driessche 1999). Future studies could be designed to test for rooting ability during periods of drought and to further test our hypothesis of the need for water consumption.

Soil culture

The highest rooting percentage of cuttings was in clones of *P. deltoides* Lux, *P. nigra betulifolia* 17/13, and *P. alba* 49/9 and the lowest rooting

percentage was in clones of P. deltoides Samsun and P. caspica. This shows a difference in rooting ability between the clones. ZSUFFA (1976) suggested that the rooting differences between clones of different geographic origins may be caused by genotype-environment interactions. The rooting ability of forest tree cuttings is also genetically controlled (Haissig, Riemenschneider 1988). Also, environmental conditions (PEARCE et al. 1990), exogenous and endogenous supply of hormones (BARTOLINI et al. 1986), and physiological parameters such as carbohydrate content, starch content and nutrient levels (SNEDDEN et al. 2010) affect the rooting ability of clones. Also, success or failure of rooting depends upon the establishment of a vascular link between the source and the new sink that is dependent on anatomical characteristics of the cutting. Porosity and density of cutting texture are among the factors that affect the rooting percentage of cuttings (Gнаssемі et al. 2003). Clone of P. deltoides Lux having a porous cutting tissue and low density and P. caspica having a rigid cutting tissue and high density have shown the highest and the lowest rooting, respectively, which proves the effect of porosity and density of cutting texture on rooting.

There are other factors such as differences in structural compounds like cellulose or lignin and C content that likely contribute to the success of rooting (Vieitez et al. 1980). Although the rooting of P. alba 49/9 clone was successful in the present research, but contrary to the present results, HANSEN and TOLSTED (1981) on P. alba stated that the rooting of hardwood cuttings is very difficult because they have a low genetic or physiological capacity for adventitious root formation. In assessment of successful rooting, ASADI and GHASSEMI (2007) reported the percentage rooting of 24.66, 27.81, 40.85, and 50.31% for clones of *P. caspica*, P. euphratica, P. deltoides, and P. alba, respectively, after 12 weeks. This is why we have achieved higher rooting rates than their results. P. caspica, an indigenous valuable species, existing naturally in plain areas of northern forests of Iran, also has a low rooting (Asadi, Mirzaie-Nodoushan 2011), which is in line with the results of this research. Rooting of cuttings may not be the same because the physiological requirements for initiation, growth and elongation are variable. Root initiation is a function of root primordia formation and rate of cell division (Dykeman 1976; Preece 1993) which varies in different species, although in the present study, it has been shown that it varies among clones. The main regulators of the formation of roots in plant tissue are plant hormones that affect the rooting ability. Species and clones of *Populus* differ with respect to the distribution of food reserves and the presence of phloem fibres within the shoot of cutting which affect the emergence and number of the roots (Bloomberg 1959). Future studies could be designed for the continual assessment of rooting under different environmental conditions.

Root length in the clone of *P. euphratica* was significantly shorter than in other species and clones of Populus. It has been suggested that the reduction of root length may be caused by the presence of phloem fibres in the basal shoot region which obstruct the emergence of the root. On the other land, species and clones of Populus differ with respect to the distribution of food reserves and the presence of phloem fibres within the shoot of cutting which affect the emergence and number of the roots. Due to the differences in carbohydrate reserves, root length can be different. There is a correlation between the initiation and activity of vascular cambium with auxin transport along the stem and root development (NIEMINEN et al. 2015). In our study, probably an increase in the root length of P. deltoides Lux and P. nigra betulifolia 17/13 is in relation to the higher activity of vascular cambium and amount of auxin in cutting texture compared to the other clones.

The highest stem diameter was in the clone of P. deltoides Lux. The results SINGH et al. (2001) and DHILLON et al. (2010) showed that inherent genetic differences may be held responsible for the variation in diameter among clones of P. deltoides and ISIK and TOPLU (2004) among clones of P. nigra. In the present research, a highly significant difference in stem height between species and clones of Populus was obtained. ISIK and TOPLU (2004) and RAMESH and KHURANA (2008) considered height as the most variable trait at seedling stage because a difference in height is related to genetic differences between the clones, distinguishing clones from each other. The results are in line with PALMBERG (1977), who reported a highly significant difference in height growth between 32 clones of P. deltoides in Australia. PANWAR and SHARMA (2001) reported that 7 clones performed better in terms of their growth among 68 clones in a nursery under midhill conditions of Himachal Pradesh while searching out superior poplar clones. Based on the growth performance during nursery evaluation, RAWAT et al. (2001) stated that variation in height and diameter may be attributed to differences in hormonal signals, climatic and edaphic conditions along with the genetic makeup. KRABEL et al. (2015) showed

an increase in growth for clones that leaf out early. The appearance of leaves was investigated by regular observations in the present study and revealed that with respect to the leaf-out date, both P. deltoides Lux and *P. nigra betulifolia* 17/13 showed the same date but *P. caspica* was the first species that leafed out and P. deltoides Samsun was the last clone (data not shown). However P. caspica showed modest stem height and P. deltoides Samsun showed the lowest stem height which might lead to a delay in stem development. Douglas et al. (2016) in a study of the effects of planting material and genotype on cuttings of six poplar clones concluded that the role of the cutting mass in contributing to shoot and root growth is uncertain, which is consistent with our research. P. deltoides Lux and P. deltoides Samsun had the lower cutting mass than *P. euphra*tica whereas the two clones of P. deltoides differed with respect to stem length, shoot dry matter and root dry matter.

In the present research, the maximum value of root dry matter in clone of *P. alba* 49/9 and shoot dry matter in clone of *P. deltoides* Lux was followed by clone of *P. euramericana* 561/41 showing the variations in rooted cutting matter. Larger root length has a greater capacity for reserve storage and therefore more energy for increased growth rates, which is true of clones of *P. deltoides* Lux and *P. euramericana* 561/41. Genetics plays a role in determining the distribution of mass to leaves, stems, and roots (POORTER et al. 2005). Also, KARIM and HAWKINS (1999) provided a circumstantial evidence that a genetic basis exists for above- and belowground dry mass distribution.

GOODARZI and MODIR RAHMATI (2002) observed the mean height of 1.65, 1.33, 1.79, and 1.68 m, diameter of 1.1, 0.95, 1.5, and 1.4 cm, survival of 88, 28, 87, and 97% for P. nigra betulifolia 17/13, P. alba 49/9, P. deltoides Lux, and P. deltoides Samsun, respectively, in one-year-old seedlings in Markazi province, Iran. Gнаssемі et al. (2003) studied the variables of diameter, height, biomass production and leaf characteristics of 24 clones of different poplar species in the nursery at the Alborz Research Station, Karaj, Iran during the growing season; they stated that P. deltoides Samsun clone was introduced as the most successful clone and its increment in diameter and height was continuous until late October. In results of Yousefi and Modir Rahmati (2004), the clone of P. deltoides 63/3 with mean height of 234.4 cm and P. euphratica with mean height of 78.8 cm showed the tallest and lowest height among the studied clones, respectively, at the end of the growth period. The difference in their growth may be related to the genetic potential of clones in terms of increment in height and also the difference in their response to environmental stimuli. Results of TALEBI et al. (2007) showed the mean height of 1.07 and 1.44 m, and diameter of 0.58 and 0.85 cm for the one-year clones of P. nigra betulifolia 17/13 and P. euramericana 561/41, respectively, in the Chaharmahal and Bakhtiari province, Iran. In evaluation of the quantitative and qualitative performance of 10 poplar clones in nurseries in the seedling production of the Guilan province for two clones of P. deltoides Samsun and P. caspica, AMIN AMLASHI and SALEHI (2011) reported survival of 72.2 and 26.9%, height of 2.44 and 0.94 m, diameter of 1.8 and 0.8 cm, respectively.

ASADI and GHASSEMI (2007) reported the mean height of 21.15, 43.88, 36.45, and 55 cm, root length of 76.13, 382.18, 51.77 and 395.32 cm, root number of 9.53, 28.97, 11.5 and 33.73 roots, root weight of 5.58, 18.15, 3.19 and 16.29 g, shoot weight of 1.85, 9.59, 2.24 and 7.79 g. They stated that the clones of *P. alba* did not have a good performance due to their slow growth in early years. However, in the present study, the species of *P. euphratica* has not shown good growth due to its physiological conditions.

CONCLUSIONS

In the present study it seems that different species and clones in the soil culture have shown better growth characteristics in their ecological conditions. In our experiments under hydroponic and soil cultures which differed in temperature, moisture and medium it was indicated that rooting and growth differences may be genetically conditioned.

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