DOI: 10.17707/AgricultForest.65.2.03

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ASSESSING THE PERFORMANCE OF POPULUS CASPICA AND POPULUS ALBA CUTTINGS UNDER DIFFERENT IRRIGATION INTERVALS

SUMMARY

Understanding the function of poplar species under different irrigation regimes is critical for water resources and ecosystem sustainable management. This study was conducted in order to understand the performance (survival and height growth) of two poplar species (*Populus alba* L. and *Populus caspica* Bornm.) cuttings in two lengths (15 cm and 25 cm) under three irrigation treatments (7-day, 14-day and 21-day intervals). One trial was established using split-split-plot design with three replications. Every two weeks height and number of remaining cuttings were measured. Results showed the survival average at the end of periods for 7-day, 14-day and 21-day irrigation treatments were 83.33 %, 22.08 % and 0 %, respectively, for *P. alba* and *P. caspica* were 25.89 % and 44.39 %, respectively and for cuttings in 15 and 25 cm were 29.61 % and 40.66 % respectively. The results of two-way analysis of variance of the survival among cuttings indicated that the differences survival among cuttings were all marked under the four treatments and analysis of variance of the height growth indicated that except under the size treatment, the differences height growth among cuttings were all marked under the other three treatments.

Keywords: *Populus caspica, Populus alba, irrigation interval, height growth, survival.*

INTRODUCTION

Poplar is an excellent candidate for short rotation coppice cultures, which rely on species that is characterized by fast growth and dynamic production of biomass (Payamnour *et al*, 2013). This species as an alternative source for wood production (Alimohamadi *et al*. 2012) have been planted in Iran for many years. Annual production of poplar plantations, according to available statistics, is more than triple the production of Caspian forests (the only commercial forests in Iran) while their area is less than 10 percent of Caspian forests area (Bozorgmehr *et al*. 2014). Poplar growth is highly dependent on the moisture content of the soil (Bagheri *et al*. 2012) and soil water can exert an important control on poplar growth (Dong *et al*. 2011, Hogg *et al*. 2013). Accordingly having a permanent resource of water is a primary need of poplar plantation. Since Iran is in the arid

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Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

zone which receives less than a third of world average precipitation (Badripour, 2006), shortage of water resources is a major obstacle to successful poplar cultivation. In order to increase the productivity of poplar plantations in arid and semiarid lands, high efficiency irrigation strategies must be used. The efficiency of water use can be examined through assessment of poplar responses which differ from one species to another and from one age to other age. Various indices have been used to find the poplar responses to irrigation which consist of: a) growth traits such as diameter at breast height (Bagheri *et al*. 2012, Shock *et al*. 2005), basal area at breast height (O'Neill and Allen 2015, Voltas *et al*. 2006), total height (Bagheri *et al*. 2012, Shock *et al*. 2005), stem height (Bagheri *et al*. 2012), crown diameter (Bagheri *et al*. 2012), relative growth rate (Karačić and Weih 2006), volume (O'Neill and Allen 2015, Bagheri *et al*. 2012, BaoFang *et al*. 2007, Shock *et al*. 2005), biomass (Monclus *et al*. 2009, Karačić and Weih 2006), survival (O'Neill and Allen 2015, Saeidi and Azadfar 2009, Van den Driessche *et al*. 2003), radial growth (Giovannelli *et al*. 2002), root number (BaoFang *et al*. 2007); b) physiological characteristics such as foliar nutrition (Shock *et al*. 2005), mesophyll-to-stomatal conductance ratio (Rancourt *et al*. 2015), photosynthetic performance (Zhu *et al*. 2014; Saeidi and Azadfar, 2009, Fengjun *et al*. 2006), transpiration (Samuelson *et al*. 2007), leaf-specific hydraulic conductance (Samuelson *et al*. 2007), canopy stomatal conductance (Samuelson *et al*. 2007), stem water potential (AiHong *et al*. 2009); c) morphological traits such as leaf area (Monclus *et al*. 2009, BaoFang *et al*. 2007, Samuelson *et al*. 2007); d) phenology events such as bud-burst (Bagheri *et al*. 2012, Sera and Pons 2013), leaf expansion (Bagheri *et al*. 2012), leaf abscission (Bagheri *et al*. 2012), flowering (Bagheri *et al*. 2012; Sera and Pons 2013) and e) anatomical characters such as wood anatomy (Cocozza *et al*. 2011).

In order to develop efficient water use strategies in poplar plantations, different irrigation regimes can be conducted. Irrigation regime which is determined by the rate of irrigation, irrigation frequency (intervals), and time of water applications to crops. Some research has been undertaken on high efficiency irrigation regime in poplar plantations. Zhu *et al* (2014) investigated the effects of changed irrigation (water-saving irrigation and flood irrigation) on two poplar species (*P. euphratica* and *P. russkii*) growing in arid ecosystems. Results showed that reduced water availability during water-saving irrigation had a moderate but not significant impact on the photosynthesis of the two poplar species. Sera and Pons (2013) analyzed the dynamics of poplars between 2002 and 2008 which comprised periods of water surplus and water scarcity. No difference was observed between periods of water scarcity and water surplus. Bagheri *et al* (2012) showed significant difference between the 4, 8 and the 12 day irrigation intervals in respect to growth parameters of *P. euramericana*, *P. trichocarpa*, *P. alba*, *P. nigra* and *P. deltoids*. Cocozza *et al* (2011) investigated the correlation between the main ring traits of young poplar clones (*P* × *canadensis* and *P. deltoides*) and irrigation regimes (irrigated with 70 mm of water every week and no-irrigated). Results showed *P. deltoides* has the potential to recover promptly after drought stress. AiHong *et al* (2010) in temperate desert zone analyzed the change of water potential of *Populus euphratica* Oliv. and *P. Russkii* Jabl under different irrigation volumes. Saeidi and Azadfar (2009) investigated the effect of drought and hydromorphy stresses on net photosynthesis rate and survival of *P. nigra* , *P. deltoides* and *P. euramericana*. Result showed *P. deltoides* and *P. nigra* had more resistance to drought stress than hydromorphic. Zomer *et al* (2007) irrigated their poplar plantations during April to June, when the atmospheric temperature is high with a low level of relative humidity. Fengjun *et al* (2006) applied four water treatments: well-watered condition, slight water stress, moderate water stress, and severe water stress. The results revealed that the clones with higher long-term water use efficiency always had strong photosynthetic capacity and optimum root/shoot ratio. Shock *et al* (2005) applied five irrigation treatments for hybrid poplar consisted of three water application rates using micro sprinklers and two water application rates using drip tape during five years. Result showed drip irrigation with two tapes per tree row resulted in higher tree growth than micro sprinkler irrigation.

In Iran, most of the researches about efficient irrigation management have been done on agricultural crops. Furthermore, there is no research available to determine growth response of *P. alba* and *P. caspica* as a local and critically endangered species in Caspian forest of Iran (Falah *et al* 2011) under different irrigation treatments. Given the importance of Poplars and for optimum use of water resources in arid season, in this study we explored the growth response and survival of *P. caspica* and *P. alba* cuttings in two lengths to different irrigation intervals.

MATERIAL AND METHODS

Site

Experiments were carried out in the Chamestan forest and rangeland research station located in Noor city (36° 25’ N & 51° 55’ E, 70 m a.s.l), Mazandaran province, Iran. Mean annual temperature and precipitation are 15.8 C° and 840 mm, respectively. Absolute minimum and maximum temperature are -8.5 C° and 36 C°, respectively. Average relative humidity is 78%.

Experiment design

Cuttings of *P. caspica* and *P. alba* in two lengths (15 and 25 cm) were established in a field trial, as a split-split-plot design with three replications. The species as factor A was assigned to whole plots, then the cutting length as factor B was assigned to split-plots within the applications of Factor A, and then split the experimental units used for factor B into sub-sub-plots to receive different irrigation intervals as factor C. For this purpose a total of 108 (three treatments of irrigation intervals, two treatments of cutting lengths, two kinds of species, three pots and three replications) plastic bags were put into a water container with 15 cm depth and 46 cm diameter (Figure 1). The culture medium was a soil with 33 percent clay, 47 percent loam and 21 percent sand. Soil pH and electrical conductivity were 6.58 and 0.57 ds/m, respectively. Percentage of lime, organic carbon and total nitrogen were 1.19, 2.78 and 0.29, respectively and finally the amounts of phosphorus, potassium, calcium and magnesium were 23.78, 420, 175.5 and 37.5 ppm, respectively (Rouhi Moghadam, 2008). The cuttings were planted on February with one cutting in each pot. Weeding operation was done during the growing season. Three different irrigation intervals were applied: 7-day intervals, 14-day intervals and 21-day intervals. The amount of irrigation water at each time was 2000 mL for per pot.

Figure 1: Cuttings in plastic bags under different treatments

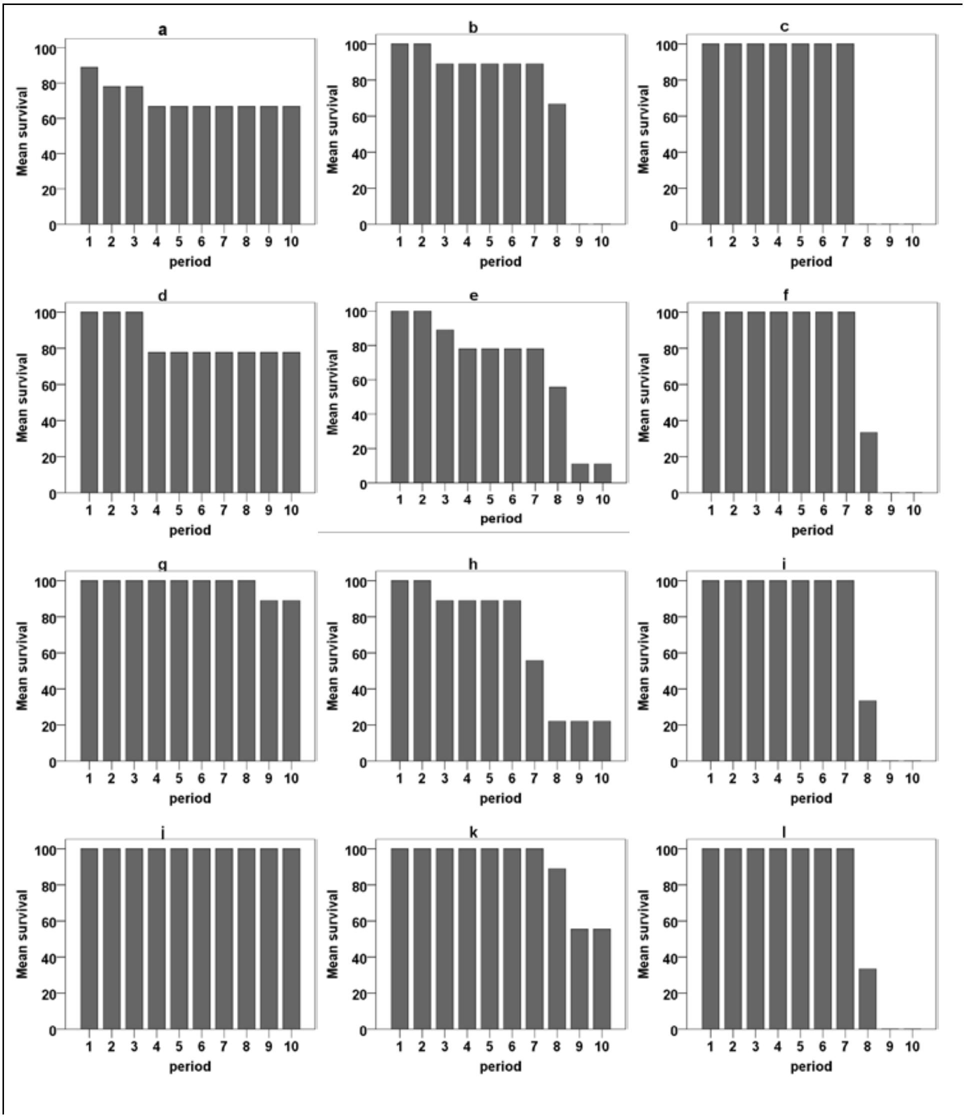
Measured objects and statistical analyses

In order to calculating the seedling height growth as an appropriate indicator for evaluating the effects of stress (Sadati *et al*. 2011) and survival under different treatments, every two weeks height and number of remaining cuttings were measured. Ten measurements were performed on April 27th, May 11th, May 25th, June 8th, June 22th, July 6th, July 20th, August 3rd, August 17th and August 31th.

Data were evaluated by Kolmogorov-Smirnov test for assessing the normality, two-way analysis of variance for analyzing the effects of applied treatments on height growth and survival, Duncan's multiple range test for measuring the differences between irrigation and period treatments. Statistical analyses were conducted using SPSS 21.0.

RESULTS AND DISCUSSION

Results showed (Figures 2 and Figure 3) the percentage survival of cuttings under five treatments (in total twelve treatments).



a: *P. alba* cuttings in 15 cm under 7-day irrigation, b: *P. alba* cuttings in 15 cm under 14-day irrigation, c: *P. alba* cuttings in 15 cm under 21-day irrigation, d: *P. alba* cuttings in 25 cm under 7-day irrigation, e: *P. alba* cuttings in 25 cm under 14-day irrigation, f: *P. alba* cuttings in 25 cm under 21-day irrigation, g: *P. caspica* cuttings in 15 cm under 7-day irrigation, h: *P. caspica* cuttings in 15 cm under 14-day irrigation, i: *P. caspica* cuttings in 15 cm under 21-day irrigation, j: *P. caspica* cuttings in 25 cm under 7-day irrigation, k: *P. caspica* cuttings in 25 cm under 14-day irrigation, l: *P. caspica* cuttings in 25 cm under 21-day irrigation

Figure 2. The percentage survival under different treatments during measured periods

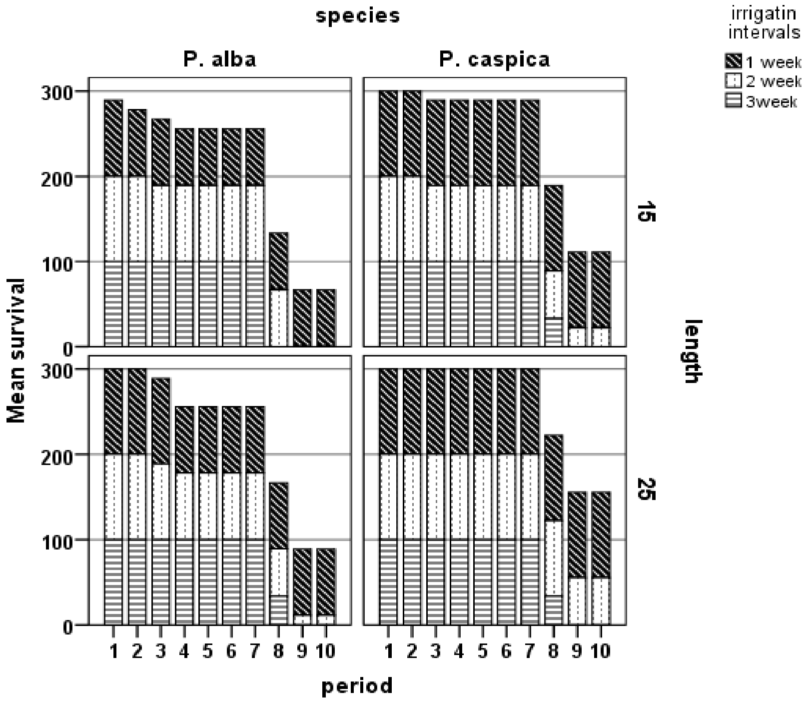
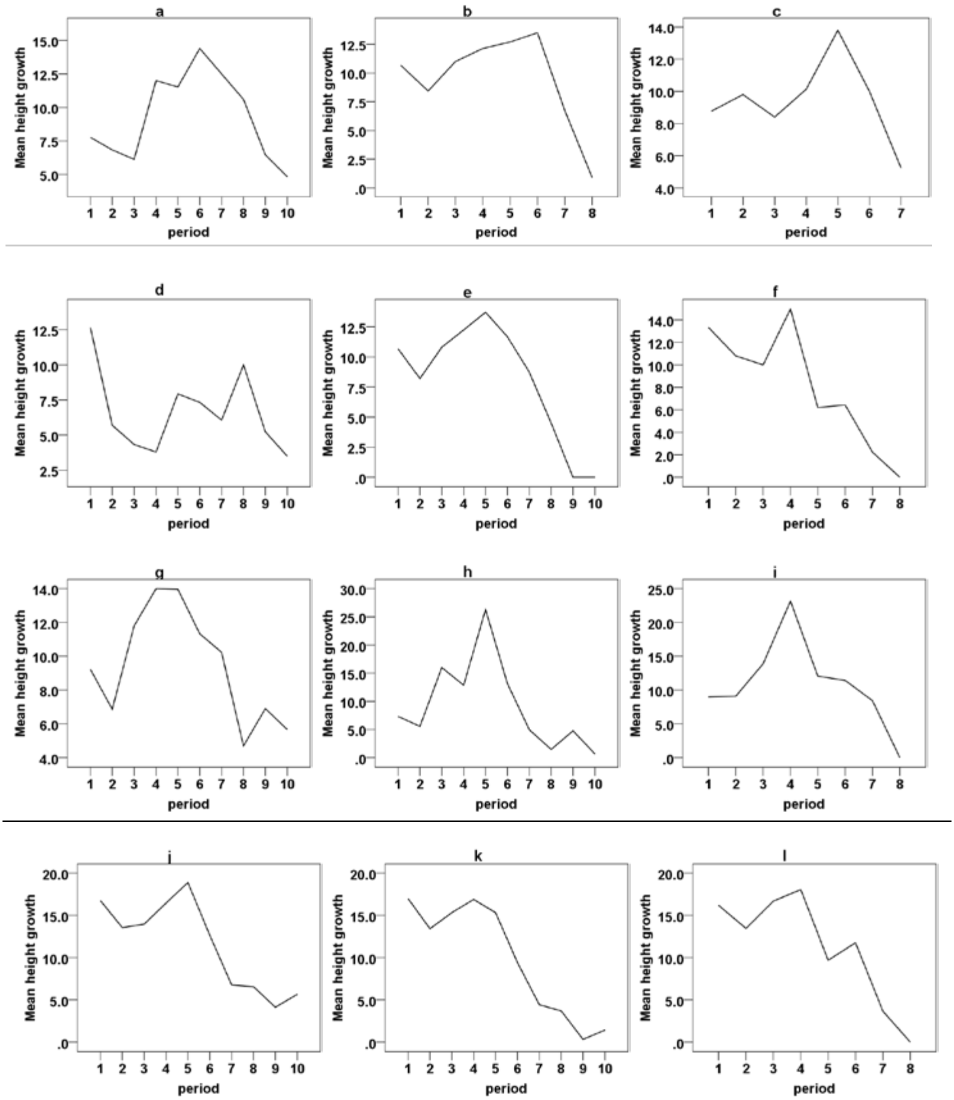


Figure 3. Survival of study species under three irrigation intervals and two sizes

The percentage survival was zero of which three treatments were related to P. alba include the cuttings in 15 cm under 14 and 21-day irrigation intervals and the cuttings in 25 cm under 21-day irrigation intervals and two treatments were related to P. caspica include the cuttings in 15 cm under 21-day irrigation intervals and the cuttings in 25 cm under 21-day irrigation intervals.At the end of periods there was no zero percent survival in any 7-day irrigation treatments but all cuttings under 21-day intervals (all treatments related to two species and two sizes) had died that four deaths had occurred at the ninth period and the *P. alba* cuttings in 15 cm under 21-day irrigation intervals had died at the eighth period. The only treatment with 100 percent survival at the end of periods was related to *P. caspica* cuttings in 25 cm under 7-day irrigation intervals.

The survival average at the end of periods for 7-day, 14-day and 21-day irrigation treatments were 83.33 %, 22.08 % and 0 %, respectively, for *P. alba* and *P. caspica* were 25.89 % and 44.39 %, respectively and for cuttings in 15 and 25 cm were 29.61 % and 40.66 % respectively.

The average height growth of *P. alba* and *P. caspica* were 7.44 cm and 9.62 cm. Furthermore, for 7-day, 14-day and 21-day irrigation intervals were 9.25 cm, 8.68 cm and 7.67 cm, respectively and the average height growth of cuttings in 15 cm and 25 cm were 8.50 cm and 8.56 cm (Figures 4 and Figure 5). The maximum height growth of four treatments occurred during the fourth period, for four others occurred during fifth period, two treatments during sixth period had maximum height growth and two treatments during first period had maximum height growth (Figure 4).



a: *P. alba* cuttings in 15 cm under 7-day irrigation, b: *P. alba* cuttings in 15 cm under 14-day irrigation, c: *P. alba* cuttings in 15 cm under 21-day irrigation, d: *P. alba* cuttings in 25 cm under 7-day irrigation, e: *P. alba* cuttings in 25 cm under 14-day irrigation, f: *P. alba* cuttings in 25 cm under 21-day irrigation, g: *P. caspica* cuttings in 15 cm under 7-day irrigation, h: *P. caspica* cuttings in 15 cm under 14-day irrigation, i: *P. caspica* cuttings in 15 cm under 21-day irrigation, j: *P. caspica* cuttings in 25 cm under 7-day irrigation, k: *P. caspica* cuttings in 25 cm under 14-day irrigation, l: *P. caspica* cuttings in 25 cm under 21-day irrigation

Figure 4. The height growth under different treatments during measured periods

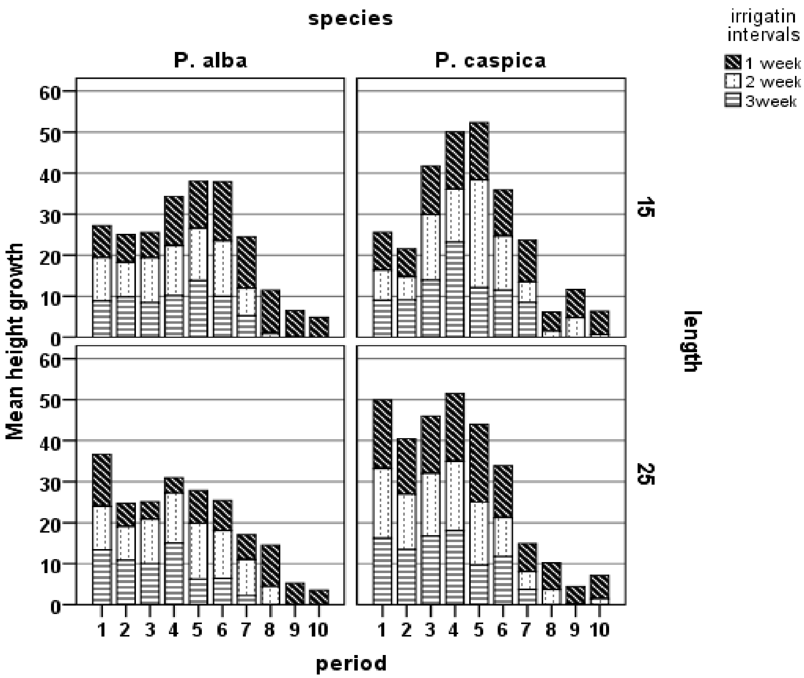


Figure 5: Height growth of study species under three irrigation intervals and two sizes

The results of two-way analysis of variance of the survival among cuttings (Table 1) indicated that the differences among cuttings were all marked under the four treatments (length, species, irrigation intervals and periods). Based on Duncan's multiple range test, irrigation intervals were classified in two separate groups: 21-day and 14-day irrigation treatments as first group and 7- day irrigation treatment as second group. Furthermore, periods based on multiple comparisons were divided into 3 groups (Figure 6).

Table 1: Two-way analysis of variance for survival of study species under irrigation and size treatments

Treatment	df	F	*p* Value
species	1	40.385	.000**
length	1	7.666	.006**
irrigation	2	26.754	.000**
period	9	75.899	.000**
species × length	1	.160	.690ns
species × irrigation	2	9.162	.000**
species × period	9	1.108	.357ns
length × irrigation	2	.939	.392ns
length × period	9	.521	.859ns
irrigation × period	18	18.170	.000**

Significance values are indicated as: * $P<0.05$, ** $P<0.01$ and ns non-significant

The results of two-way analysis of variance of the height growth among cuttings (Table 2) indicated that except under the size treatment, the differences height growth among cuttings were all marked under the other three treatments (species, irrigation intervals and periods). Based on Duncan's multiple range test, irrigation intervals were classified in two separate groups: 21- day irrigation treatment as first group and 14- day and 7- day irrigation treatments as second group. Furthermore, periods based on multiple comparisons were divided into 5 groups (Figure 7).

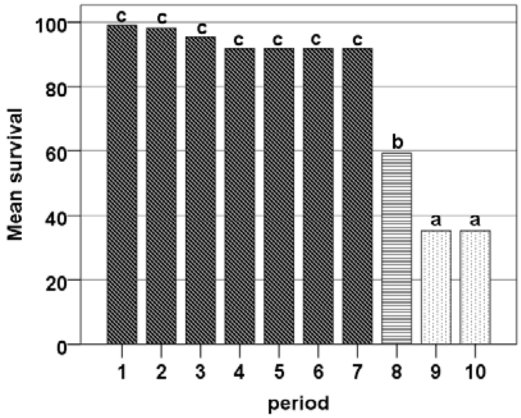


Figure 6: Grouping of periods based on mean survival

Table 2: Two-way analysis of variance for height growth of study species under irrigation and size treatments

Treatment	**df**	**F**	***p* Value**
species	1	31.505	.000**
length	1	2.077	.151ns
irrigation	2	6.997	.001**
period	8	64.840	.000**
species × length	1	2.992	.085ns
species × irrigation	2	.398	.672ns
species × period	8	5.883	.000**
length × irrigation	2	.497	.609ns
length × period	8	2.990	.003**
irrigation × period	16	6.516	.000**

Significance values are indicated as: * P<0.05, ** P<0.01 and ns non-significant

Owing to limited water resources, irrigation interval is more important than irrigation volume in conventional and industrial poplar plantation systems (Bagheri *et al*. 2012). According to this our goal was to examine the more efficient irrigation regime for *P. caspica* and *P. alba* plantations. The results of applying three irrigation intervals during four months indicated that all cuttings under 21-day irrigation intervals after about three months died. Furthermore the only 22 percent of the cuttings under 14-day irrigation intervals survived at the end of period, but 83 percent of cuttings under 7-day irrigation intervals survived, therefore it might be concluded that these irrigation regimes (14-day and 21-day) are not appropriate for poplar wood production. This conclusion is comparable with the work of Bagheri *et al* (2012) that showed all the clones of *P.euramericana*, *P.trichocarpa*, *P. alba*, *P. nigra* and *P. deltoides* have intensive growth reduction at the 12-day interval irrigation in comparison 4-day and 8-day regime, but there was no difference between 4-day and 8-day irrigation intervals. Moreover Hara (2004) suggested weekly irrigation during the dry months for high intensity production of poplar. Chaghaii (2016) believed in areas where there is no groundwater the irrigation intervals may be reduced to 10-day and soil should be completely full of water, but on windy sites with sandy soil the irrigation intervals may be reduced to 7-5 day. Some researchers suggest that the irrigation intervals should not be considered the same and according to local conditions should be given more flexibility on warm days (Bagheri *et al*. 2012, Zomer *et al*. 2007).

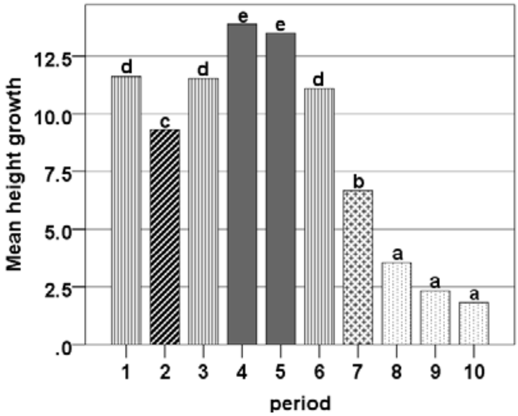


Figure 7: Grouping of periods based on mean height growth

Unlike this fact that *P. alba* is known as high drought tolerance species (Edward *et al*. 1994) the present result showed the survival average at the end of periods and average height growth of *P. alba* cuttings are significantly less than *P. caspica* cuttings and therefore *P. alba* than *P. caspica* are more sensitive to longer intervals of irrigation, but Bagheri *et al* (2012) showed *P. alba* clones than other study poplar clones are less affected by drought conditions and have the same performance at three irrigation intervals (4, 8 and 12-day).

The results showed the survival of cuttings in 25 cm length are significantly more than cuttings in 25 cm length, although there was no significant difference between height growths of cuttings in two lengths. These results are confirmed by some studies that showed the longer the cuttings, the higher are the survival (Singh Thakur *et al*. 1995, Rossi, 1991).

Since potential growth of poplar is highly dependent on the amount of applied irrigation (Shock *et al*. 2002) and soil moisture (Kharytonov *et al*. 2017) therefore the improvement of water use efficiency especially in arid areas with regard to limited water supply is a key objective to improve the sustainability of cultivated poplar (Rancourt *et al*. 2015).

Water-saving irrigation (Zhu *et al*. 2014) and increasing the intervals of irrigation (Bagheri *et al*. 2012) could be as economical practices for managing water use in such areas, As our goal was to examine the effect of different irrigation intervals on survival and height growth of two poplar species. Furthermore, management of irrigation intervals owing to water influence on pest management is very important. As the work of Tahriri Adabi *et al* (2013) showed high provided amount of water in 4 days interval in comparison to 8 and 12 days, make poplar species and clones more susceptible against pest. It is worth mentioning that today using treated wastewater for poplar irrigation is suggested as an alternative strategy for water supply problems in semi-arid to arid areas (Houda *et al*. 2016).

CONCLUSIONS

Our study revealed that 1) survival of study poplar was found to be dependent on irrigation intervals; 2) the best performance (survival and height growth) of study poplar was under 7-day irrigation interval; 3) *P. caspica* has relatively higher water-stress resistance than *P. alba*; 4) longer cuttings than shorter cuttings had higher survival.

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