Effect of planting interval and soil type on qualitative and quantitative characteristics of poplar (*Populus nigra*) plantations in Diwandareh (Kurdistan province, western Iran)

A. Alijanpour, A.B. Shafiei, R. Latify

Faculty of Natural Resources, University of Urmia, Iran

ABSTRACT: We investigated the effects of planting interval and soil type on qualitative and quantitative characteristics of seven poplar (*Populus nigra*) plantations with 1 × 1 m and 2 × 2 m planting intervals in Diwandareh. Parameters including diameter at breast height (DBH), total height, crown height, stem height, number of suckers and crown vitality were measured and compared regarding soil characteristics and planting intervals. A transect method with 10% sampling intensity was used for collecting data. Results showed significant differences in the qualitative and quantitative characteristics of poplar trees between planting intervals and soil physical characteristics. An increase of the interval decreased total height and crown height, while stem height, number of suckers and crown vitality of poplar trees increased. But DBH of poplar trees did not increase in these areas. Vegetative characteristics showed the strongest correlation with physical properties of soil rather than with the chemical ones. Soil properties had higher effects on quantitative and qualitative characteristics of the studied stands in comparison with planting intervals.

Keywords: plantation; stand; soil properties; growth; height; diameter

Destruction of natural forests, increasing human population and the slow growth of most broadleaf forest species cause the wood requirements of various industries not to be satisfied in Iran. It justifies the importance of afforestation with fast-growing and native species, including *Populus nigra* (Pourbabaei et al. 2004). At present, there are 190,000 ha of wood farming (150,000 ha of poplar and 40,000 ha of eucalyptus) that are mostly scattered in northern, northwestern and western regions. The current level of wood farming is only related to 25% of suitable lands for poplar plantations and about 75% of the potency of these areas is not utilized. The country's per capita consumption of wood products, particularly paper, is 0.2 m^3 (global average is 0.3 m^3), so that regarding this amount and the population of 70 million, the current need of the country is 14 million cubic meters and about 3 million cubic meters comes from poplar plantations (Anonymous 2008). In afforestation systems, solving many problems before afforestation would be economical. One of the difficulties is maintaining a uniform distance between the trees in a large plantation (Radcliffe et al. 1981). Understanding the proper pattern of spacing is very important to increase performance and reduce weeds (Baki et al. 1995; Murphy et al. 1996; Knezevic et al. 2003). Harvest time and the dimensions of wood products depend on the plantation distance. If the purpose of poplar plantation is to produce the raw material for making plywood and for plywood mills or sawmills, the exploitation period will be longer and production will be increased. If the aim is to use wood of smaller diameter and for local uses such as beams for buildings, electrical and telephone poles, and cellulose industries, it will require a shorter harvest period, so that the important factor in achieving this goal is shorter plantation distances (Hemmati, Modir Rahmati 2003). In this vein, Riahifar et al. (2008) observed the maximum height and diameter growth for two species *Populus deltoides* and *Paulownia fortunei* at the spacing of 3 × 3 m. Shushtari et al. (2008) calculated the highest average crown diameter at the distance more than 5 × 5 m. In another study, Rezayi (2011) achieved the smallest average diameter at breast height and total height at 2 × 2 m, 2 × 3 m and 3 × 3 m distance while Burgess et al. (2004) indicated the maximum diameter at breast height and the minimum height for the four poplar hybrids at 6 × 10 m distance. Soil is an important source of nutrients such as nitrogen, phosphorus, sulphur, sodium, magnesium, calcium and several micronutrients for vegetation (Donegan et al. 2001; Lal 2005). In some cases, soil characteristics such as pH and available nutrients influence the vegetation, and vegetative conditions and distribution of vegetation types in areas with slopes and different heights can be controlled through a variety of soil nutrients (Wenqiang et al. 2010). It has been reported that poplar grows best on deep soils with medium texture (Schreiner 1959) and on light sandy soil (Wood, Hanover 1972). Kiadeliri et al. (2004) concluded that grey-brown podzolic and brownish forest soils with high organic matter are suitable for cultivation and development of the poplar forests. According to the research by Jaster (2005), the most appropriate growth status for hybrid poplar is achieved in soils with high pH (7 or higher). Therefore, the present study tries to investigate these two factors and answer the question whether the soil type and different planting interval have any effect on the qualitative and quantitative characteristics of poplar plantations.

MATERIAL AND METHODS

The study area for this research is located in Diwandareh, Kurdistan province. In this study, seven poplar plantation stands have been studied. One of the stands is in the village of Zaghe-Sofla, and two stands are in the village of Taze-Abad and four stands are located in the village of Gharedarre in the city of Diwandareh. A summary of the characteristics of the stands is presented in Table 1.

Regarding Table 1, it is to explain that those plantations which were selected for the study, were already planted by villagers in different plantation intervals of 2 × 2 or 1 × 1 m. So it was not possible to find the stands equally in number in the two intervals and running an experimental design. According to the statistics of the Zarrineh synoptic meteorological station (2001–2011), maximum and minimum temperatures in the region were 36.5°C and –23°C, respectively, and there were 272 dry days and 140 frost days. The average annual rainfall is 350–450 mm (Majidi 2010). There are five dry months that are June, July, August, September and October, and the average annual relative humidity is 54% (Anonymous 2011). Because there is just one climate station in the study area, the poplar stands were chosen close to each other, so differences in climate data between the stands could be ignored. A transect sampling method with 10% intensity was used for sampling. The investigated information for each stand included geographical coordinates, altitude, stand area, slope, diameter at breast height (DBH), number of suckers around the collar, crown vitality, and the diameter of the thickest and thinnest sucker. Geographical coordinates, altitude, area were measured with GPS; slope and height of trees with Suunto clinometers; diameter at breast height in centimetres with a calliper; and the thickest and the thinnest diameter in millimetres was determined with calliper and the values were recorded in data collection sheets. For expressing the freshness, trees were classified into four categories of excellent (large crowns, healthy and shiny green leaves), good (healthy crowns, less span and

Table 1. General properties of the studied stands

Stand	Name	Area (m^2)	Planting interval (m)	Altitude (m)	Slope (%)	Aspect	Latitude and longitude	Year of planting
1	Kani Sheykh	1,800	1 × 1	1,380	5	north	35°45'9''N 47°5'32''E	2006
2	Bishe Mohammadi	2,320	2 × 2	1,440	2	north	36°6'5''N 47°5'3''E	2006
3	Bishe Ola	3,020	2 × 2	1,200	5	west	36°6'6''N 47°5'9''E	2006
4	Bishe Hasani	3,000	2 × 2	1,320	3	west	36°6'7''N 47°5'0''E	2006
5	Bishe Fattahi	1,740	2 × 2	1,270	3	east	36°6'5''N 47°5'5''E	2006
6	Taze-Abad No.1	3,400	2 × 2	1,540	0	–	36°6'11''N 47°6'9''E	2006
7	Taze-Abad No.2	1,500	1 × 1	1,330	4	north	36°6'8''N 47°6'0''E	2006

shiny green leaves), medium (sparse crown, several dry branches and light green leaves) and weak ones (very sparse canopy, dried branches and leaves) and each of them was given a code. Using the information of data sheets, total height, stem height (trunk height without branches) and crown height were calculated (Zobeyri 2005). For the investigation of the soil status in each stand three soil samples and a total of 21 samples were taken. To take the soil samples, a pit was dug (40 × 40 cm^2 in size and 0–30 cm in depth) and approximately one kilogram soil was taken as the sample and was transferred to the agrological laboratory. In examining the characteristics of the soil, its texture, bulk density, lime, pH, organic carbon, total nitrogen, phosphorous, potassium, soil porosity percentage and C/N ratio were measured. For the analysis, quantitative and qualitative characteristics of stands and physiographic characteristics (direction, slope and altitude) as a file and the information regarding the physical and chemical properties of taken soil samples as a separate file were entered into the computer and SPSS software version 18 (SPSS, Tulsa, USA) was used for data analysis. Having controlled the normality of the data, one-way ANOVA test was employed for continuous data and chi-squared (χ^2) test was used for discrete data. In the case of significance of the differences between the means of the stands, Duncan's test was used for comparison.

RESULTS

Based on the analysis of variance and performed Duncan's test, there are significant differences between the mean diameters at breast height, total height, stem height, crown height of the studied stands at a 5% level (Table 2).

From among the seven studied stands, poplars have suckers in stands No. 2–4. In order to estimate the significance of the number of suckers in these three stands, the chi-square test was used and its results are provided in Table 3.

Table 3. Frequency of suckers in the studied stands (planting interval 2 × 2)

No.	Observed frequency	Expected frequency	Remaining	χ^2	*P*
2	137^{a}	95.3	41.7	91.94^{a}	0.00
3	130^{a}	95.3	34.7		
4	19^{b}	95.3	–76.3		
Total	286				

There is a significant difference at a 5% level in the number of suckers between all mentioned stands. Considering Table 4, in terms of the tree crown vitality, stand No. 2 is the best while stand No. 7 is the worst.

Table 4. Crown vitality of trees in the studied stands (%)

Vitality	Studied stands							Total
	1	2	3	4	5	6	7	
Excellent	16.7	43.3	10.0	9.7	8.6	4.0	0.0	10.1
Good	60.0	46.7	27.5	54.8	31.4	32.0	0.0	29.4
Medium	20.0	10.0	37.5	29.0	37.1	50.0	10.0	26.7
Weak	3.3	0.0	25.0	6.5	22.9	14.0	90.0	33.8
Total	100	100	100	100	100	100	100	100

Based on the analysis of variance and performed Duncan's test, there is a significant difference at a 5% level in the mean saturation, TNV (Total neutralizing value), organic carbon, available potassium, sand, silt, clay content percentage, bulk density, porosity and total nitrogen content between the studied stands (Table 5). In stand No. 1, TNV, organic carbon and total nitrogen are significantly higher than in the others. Stands No. 1 and 7 have the highest saturation and clay percentage

Table 2. Quantitative characteristics of the studied poplar plantations

Vegetative properties	Stand No.						
	1	2	3	4	5	6	7
DBH Mean (cm)	11.59^{ab} (0.55)	9.10^{c} (0.37)	9.40^{c} (0.19)	12.23^{a} (0.27)	10.2^{b} (0.34)	12.46^{a} (0.31)	11.38^{ab} (0.29)
Total height Mean (m)	13.19^{b} (0.66)	7.06^{d} (0.25)	6.37^{d} (0.14)	11.05^{c} (0.29)	11.38^{c} (0.34)	12.88^{b} (0.28)	14.69^{a} (0.36)
Stem height Mean (m)	4.49^{bc} (0.38)	2.74^{d} (0.06)	2.77^{d} (0.08)	4.99^{b} (0.1)	6.12^{a} (0.19)	5.62^{a} (0.14)	4.43^{c} (0.13)
Crown height Mean (m)	8.70^{b} (0.66)	4.28^{fe} (0.22)	3.56^{f} (0.12)	5.81^{d} (0.25)	5.26^{ed} (0.24)	7.31^{c} (0.25)	10.05^{a} (0.38)

in the parenthesis are standard errors, different letters indicates significant differences at α = 0.05

Table 5. Mean of soil factors in the studied stands

Mean of soil factors	Stand No.						
	1	2	3	4	5	6	7
Saturation (%)	43.33^{a} (2.67)	20.67^{c} (1.20)	22.00^{c} (1.00)	33.33^{b} (3.48)	34.00^{b} (2.51)	35.33^{b} (2.60)	45.00^{a} (3.00)
Electrical conductivity (ds·m^{-1})	.77 (0.07)	0.71 (0.02)	0.56 (0.12)	0.88 (0.06)	0.67 (0.06)	0.67 (0.04)	0.60 (0.03)
pH	8.04 (0.04)	7.87 (0.06)	7.60 (0.15)	7.90 (0.12)	7.95 (0.11)	8.04 (0.10)	7.82 (0.03)
TNV (%)	26.20^{a} (1.76)	11.64^{c} (1.18)	18.47^{b} (3.56)	14.63^{bc} (1.08)	19.53^{b} (1.29)	17.23^{bc} (0.63)	15.83^{bc} (1.12)
Organic carbon (%)	2.05^{a} (0.23)	0.89^{bc} (0.08)	0.62^{c} (0.23)	1.32^{b} (0.24)	1.08^{bc} (0.06)	0.91^{bc} (0.12)	1.15^{bc} (0.12)
Available P (ppm)	5.97 (3.70)	4.63 (0.92)	5.40 (1.50)	6.78 (1.60)	5.17 (2.70)	2.37 (0.16)	2.18 (0.23)
Available K (ppm)	334.00^{ab} (12.18)	147.67^{c} (4.09)	121.33^{c} (7.47)	199.00^{c} (18.82)	144.33^{c} (9.52)	169.00^{c} (3.00)	356.00^{a} (125.00)
Sand (%)	30.33^{c} (6.00)	74.33^{a} (2.60)	80.00^{a} (3.60)	52.67^{b} (5.20)	54.33^{b} (3.33)	52.33^{b} (3.28)	37.00^{c} (4.60)
Silt (%)	37.00^{a} (3.60)	13.00^{b} (1.70)	8.33^{b} (1.80)	28.33^{a} (6.43)	26.33^{a} (2.90)	26.67^{a} (2.60)	32.67^{a} (2.33)
Clay (%)	32.67^{a} (2.40)	12.67^{c} (0.88)	11.67^{c} (1.76)	19.00^{b} (2.60)	19.33^{b} (1.33)	21.00^{b} (1.00)	30.33^{a} (1.85)
Bulk density (g·cm^{-3})	1.41^{cd} (0.01)	1.39^{d} (0.02)	1.48^{abc} (0.01)	1.46^{cd} (0.01)	1.55^{a} (0.01)	1.51^{ab} (0.02)	1.45^{bc} (0.02)
Porosity (%)	43.92^{ab} (1.34)	46.94^{a} (0.05)	42.16^{bc} (1.19)	42.41^{bc} (1.50)	38.36^{c} (1.42)	40.48^{bc} (0.24)	41.93^{bc} (1.04)
Total nitrogen (%)	.20^{a} (0.02)	0.09^{b} (0.01)	0.07^{b} (0.03)	0.13^{b} (0.02)	0.11^{b} (0.01)	0.09^{b} (0.01)	0.11^{b} (0.01)
C/N ratio	10.44 (0.27)	9.58 (0.34)	9.90 (0.70)	10.22 (0.47)	9.85 (0.99)	9.77 (0.19)	10.18 (0.47)

TNV – total neutralizing value, in parentheses are standard errors, different letters indicates significant differences at $\alpha = 0.05$

and stands No. 2 and three have the lowest sand amount (significant difference) (Table 5).

Table 6 shows the highest positive correlation between pH and diameter at breast height, between crown height and saturation, between absorbable potassium and clay, between stem height and pH and bulk density, between total height and saturation, clay and silt, between crown vitality and saturation, absorbable potassium, clay, and finally, between the number of suckers and true density. Diameter at breast height, total height, and crown height with sand percentage, stem height with porosity, crown vitality with true density and number of suckers with absorbable phosphorus, and C/N ratio have the highest negative correlation.

DISCUSSION

The highest diameter at breast height (DBH) mean was observed in stands No. 6, 4, 1, 7 while the lowest DBH mean was observed in stands No. 2 and 3 (Table 2). Since stands No. 1 and 7 had the 1 × 1 m planting interval, and stands No. 4, 6, 2 and 3 had the interval 2 × 2 m, it can be concluded that the planting interval does not have a significant effect on increasing DBH. Regarding the soil properties and the positive correlation between DBH and saturation, silt, clay, and the negative correlation between DBH and sand, it can be concluded that the greatest DBH occurs in soils with high saturation, silt, and clay and also with low sand (Table 6).

Moreover, it can be understood that regarding DBH, soil properties are more influential than the planting interval and physical properties of soil are more effective than its chemical characteristics. This finding is in harmony with the study conducted by Damavandi Kamali (2000) in Gorgan, who reported the DBH mean of ten-years-old poplars to be 21–32 cm in soils with medium texture that were partially drained. However, the results of the present study are different from the study of Burgess et al. (2004), who concluded that the DBH would be larger for trees with larger planting inter-

Table 6. Pearson's correlation between chemical and physical properties of soil and the stand characteristics

Soil factors	DBH (cm)	Crown height (m)	Stem height (m)	Total height (m)	Crown vitality	No. of suckers in each stand
Saturation	0.584**	0.933**	0.448*	0.972**	0.730**	–0.856**
Electrical conductivity	0.443*	–0.258	0.272	–0.090	–0.636**	–0.521
pH	0.698*	0.138	0.766**	0.410*	0.325	–0.152
TNV (%)	–0.047	–0.033	0.342	0.094	0.009	–0.399
Organic carbon (%)	0.414*	0.432*	0.283	0.491**	–0.009	–0.586
Available P	–0.301	–0.729**	–0.104	–0.636**	–0.673**	–0.968**
Available K	0.266	0.916**	–0.090	0.746**	0.734**	–0.617
Total nitrogen	0.385*	0.381*	0.319	0.462*	–0.052	–0.558
Ratio C/N	0.245	0.518**	–0.066	0.433	0.426*	–0.997**
Sand	–0.622**	–0.908**	–0.460*	–0.957**	–0.606**	0.704*
Silt	0.718**	0.816**	0.603**	0.939**	0.481**	–0.688*
Clay	0.465*	0.961**	0.257	0.917**	0.720**	–0.744*
Porosity	–0.243	0.015	–0.804**	–0.330	–0.286	0.876**
Bulk density	0.163	–0.223	0.756**	0.107	0.068	0.797*
True density	–0.382*	–0.711**	–0.553**	–0.827**	–0.759**	0.987**

DBH – diameter at breast height, TNV – total neutralizing value, *significant at $\alpha = 0.05$, **significant at $\alpha = 0.01$

val. Alcorn et al. (2007) and Rezayi (2011) also observed that an increase in the density of planting will decrease the diameter at breast height. The highest total mean height was observed in stand No. 1 while the lowest was observed in stands No. 2 and 3 (Table 2). Considering the 1 × 1 m planting interval in stand No. 7 and 2 × 2 m planting interval in stands No. 2 and 3, it can be concluded that decreasing the planting interval is effective for increasing the total mean height. Investigations of soil properties proved that there was a positive correlation between total mean height and saturation, silt, and clay while there was a negative correlation between total mean height and the percentage of sand (Table 6), which can be an indicator of this fact that in the soil with high saturation, silt and clay and with a low percentage of sand, the total mean height has increased. The total mean height in stand No. one (1 × 1 m planting interval) does not show a significant difference from the total mean height in stand No. 6 (2 × 2 m planting distance) although the chemical properties of soil were better in stand No. 1 than stand No. 6. However, stand No. 6 had a better condition in terms of the physical soil characteristics. Therefore, it can be concluded that the physical properties of soil are more influential than its chemical characteristics in terms of total height. These findings are consistent with the findings of Schreiner (1959), who reported the best growth for poplar in deep soils with medium texture. Similarly, the findings of this study are in agreement with the research by Riahifar et al. (2008), who observed the greatest height increment at the smaller planting distances and with the study by Burgess et al. (2004), who concluded that trees with larger planting distance (10 × 6 m) have the lowest height (9.5 m). However, this study is in contradiction with the study by Wood and Hanover (1972), who reported the best growth for Carolina poplar in the light loamy sand soils.

As it is shown in Table 2, the tallest mean crown height is related to stands No. 1 and 7 and the lowest crown height was observed in stands No. 2 and 3. Since stands No. 1 and 7 have the 1 × 1 m planting distance and stands No. 2 and 3 have the 2 × 2 m planting distance, the decrease of planting distance can be considered as one of the important factors in the enhancement of crown height. Considering the investigation of soil properties and the positive correlation between crown height and saturation, silt, and clay and the negative correlation with sand percentage (Table 6), it can be concluded that in the soil with high saturation, silt, and clay and with low sand, the mean crown height of poplars is increased. Furthermore, this conclusion can be drawn that the physical properties of soil are more effective on the crown height of the investigated poplar stands than the chemical properties of soil. With respect to Table 2, the mean stem height was the tallest in stands No. 5 and 6 while it was the lowest in stands No. 2 and 3. Regarding the investigated properties of soil and the positive correlation between the stem height and silt percentage (Table 6), this result can be obtained that the increase in silt percentage can lead to the increase in stem height. However, regarding the fact that the amount of silt does not show a significant difference in stands No. 5, 7 and 1, and stands No. 5 and 6 have the 2 × 2 m planting distance and stands No. 1 and 7 have the 1 × 1 m planting distance, it can be concluded that the planting distance as well as the high percentage of silt can lead to the enhancement of mean stem height in the investigated poplar stands. With respect to Table 3, the highest number of suckers is related to stands No. 2 and 3 while the lowest amount of suckers was found in stand No. 4. The investigation of other stands did not reveal any suckers. As there were both 1 × 1 m and 2 × 2 m planting distances in the stands without suckers, it can be said that the planting distance does not have any effect on the production of suckers in the poplar plantations. Regarding the soil properties and the positive correlation between the number of suckers and sand percentage, and the negative correlation between the number of suckers and saturation, silt and clay percentage (Table 6), it can be concluded that poplars will produce suckers in the stands whose soil has high levels of sand and low levels of saturation, silt and clay. As Table 4 indicates, the highest crown vitality percentage is related to stands No. 2, 1, and 4 and the lowest crown vitality is related to stand No. 7. Regarding the fact that the planting distance is 2 × 2 m in stands No. 2 and 4 and 1 × 1 m in stand No. 7, it can be concluded that increasing the planting distance is effective on the vitality of tree crowns. Based on the investigations of the soil properties and the positive correlation between crown vitality and saturation, silt and clay content and the negative correlation of crown vitality with sand percentage (Table 6), it can be said that another reason for the crown vitality of poplar trees is the high percentage of saturation, silt and clay. However, considering the fact that the highest crown vitality has been observed in stand No. 2 despite the high sand percentage and low saturation, silt and clay amounts, it can be caused by the stronger effect of planting distance compared to the physical properties of soil, by the continuous formation of suckers in these stands in difficult conditions (high sand percentage), and by the slow growth of trees since the trees in this stand have smaller dimensions than the trees in other stands despite being of the same age. Trees with more vital crowns were seen in stand No. 1 with 1 × 1 m planting distance as the soil of this stand has high organic carbon and nitrogen as well as high saturation, silt and clay percentage. It is an indicator of the fact that the chemical properties of soil are more effective factors on the tree crown vitality of the investigated poplars. The research by Shujauddin and Mohan Kumar (2002) supports this issue. In the present study, leaf area index and biomass production were the highest at a 2 × 2 m distance and dense masses show a higher concentration of P, N and K. The present results are consistent with the findings of the research by Salehe Shushtari et al. (2008), who showed that mean crown diameter as a vegetative factor is the highest at planting distances larger than 5 × 5 m.

CONCLUSION

Finally, it can be concluded that the 2 × 2 m planting distance can lead to the increase of stem height, number of suckers, and crown vitality, and the 1 × 1 m distance can increase total height of trees and crown height. However, in the soil with high saturation, silt and clay and low sand, total height, crown height, stem height, and crown vitality (if chemical properties of soil are appropriate) will increase and the number of suckers will decrease since the fertility of soil is high. From among the total investigated vegetative factors (except for the crown vitality), soil properties are more important than planting interval, and also, physical properties of soil are more crucial than chemical properties of soil. If the purpose of afforestation with poplar species is the production of thick timber for the industries, it will be recommended that this species be planted in the soil with high silt and 2 × 2 m distance; however, if the purpose is to get thin wood, the species can be planted at higher density (1 × 1 m).

References

Alcorn P., Pyttel P., Bauhus J., Smith G., Thomas D., James R., Nicotra A. (2007): Effects of initial planting density on branch development in 4-year-old plantation grown *Eucalyptus pilularis* and *Eucalyptus cloeziana* trees. Forest Ecology and Management, ***252***: 41–51.

Anonymous (2008): Strategic Program for Wood Forming. Tehran, Research Institute of Forests and Rangelands: 93.

Anonymous (2011): Explanatory Poplar Plantation Plan. Diwandareh, Natural Resources and Watershed Management Office of Diwandareh: 30.

Baki B.B., Suhaimi S., Monir J.A. (1995): Path analysis of two sympatric graminoids (*Echinochloa crus-galli* spp. *crus-galli* (L.) Beauv. and *Ischaemum rugosum* Salisb.) in competition with rice (*Oryza sativa* L. var. MR84). In: Proceedings of the 15th Asian-Pacific Weed Science Society Conference. Tsukuba, 24.–28. July 1995. Tsukuba, APWSS: 546–556.

Burgess P.J., Incoll L.D., Corry D.T., Beaton A., Hart B.J. (2004): Poplar (*Populus* spp.) growth and crop yields in a silvorable experiment at three lowland sites in England. Agroforestry Systems, ***63***: 157–169.

Damavandi Kamali A. (2000): The importance of poplar and the need of local industries to the fast growing species in Golestan province. In: Proceedings of the 1st Conference on Afforestation with Fast Growing Species in North of Iran. Kalarabad, 8.–10. August 2000**.** Kalarabad**,** Ministry of Jihad: 72.

onegan K.K., Watrud L.S., Seidler R.J., Maggard S.P., Shiroyama T., Porteous L.A. DiGiovanni G. (2001): Soil and litter organisms in Pacific northwest forests under different management practices. Applied Soil Ecology, ***18***: 159–175.

Hemmati A., Modir Rahmati A. (1999): Investigation of the most appropriate planting distance of the poplars in Gilan province. Iranian Journal of Forest and Poplar Research, ***2***: 53–78.

Jaster M. (2005): Growth of Hybrid Poplar on Soils with Varying pH and Nitrogen and Phosphorus Fertilization. [Ph.D. Thesis.] Saskatoon, University of Saskatchewan: 39.

Kiadeliri S., Tabari M., Sarmadian F., Ziayi Ziabari F. (2004): Effect of soil type on some quantitative and qualitative charactristics of *Populus* × *euramericana*. Pajouheshva-Sazandegi, ***17***: 45–50.

Knezevic S.Z., Evans S.P., Mainz M. (2003): Row space influences the critical timing for weed removal in soybean (*Glycine max*). Weed Technology, ***17***: 666–673.

Lal R. (2005): Forest soils and carbon sequestration. Forest Ecology and Management, ***220***: 242–258.

Majidi H. (2010): Investigating the Ecologic Factors of Medicinal Herbs of Saral Region in Diwandareh. [MSc Thesis.] Sari, Sari Agricultural Sciences and Natural Resources University: 58.

Murphy S.D., Yakub Y., Weise S., Swanton C.J. (1996): Effect of planting patterns and inter-row cultivation on competition between corn (*Zea mays*) and late emerging weeds. Weed Science, ***44***: 856–870.

Pourbabaei H., Shadram S., Khorasani M. (2004): Comparison of plant biodiversity in *Alnus subcordata* L. and mixed *Fraxinus coriariifolia – Acer insigne* plantations, Tanian region, Someasara, Guilan. Iranian Journal of Biology, ***17***: 357–368.

Radcliffe R.C., Matson E.D., Mattson J.A. (1981): Tree-planting interval indicator. Tree Planters' Notes, ***32***: 13–14.

Rezayi S.A. (2011): Impact of distance on quantitative and qualitative characteristics of walnut (*Juglans regia* L.) plantation. Iranian Journal of Forest and Poplar Research, ***19***: 206–221.

Riahifar N., Fallah A., Mohammadi Samani K., Gorji Mahlabani Y. (2008): Comparing the growth of Paulownia and poplar species with different planting distances in north of Iran. Iranian Journal of Forest and Poplar Research, ***16***: 444–454.

Salehe Shushtari M., Amani M., Behnamfar K., Yusefnanayi S. (2008): Survey on optimum planting spacing with three leguminous species in rain fed system (pure and mixed) on sandy hills of Khouzestan, Iran. Iranian Journal of Forest and Poplar Research, ***16***: 74–86.

Schreiner E.J. (1959): Production of Poplar Timber in Europe and its Significance and Application in the United States. Agriculture Handbook No. 150. Washington, DC, USDA Forest Service: 124.

Shujauddin N., Mohan Kumar B. (2003): *Ailanthus triphysa* at different densities and fertilizer regimes in Kerala, India: growth, yield, nutrient use efficiency and nutrient export through harvest. Forest Ecology and Management, ***17***: 135–151.

Wenqiang Xu Chen X., Luo G., Zhang Q., Lin Q. (2010): Soil properties at the tree limits of the coniferous forest in response to varying environmental conditions in the Tianshan Mountains, Northwest China. Environmental Earth Sciences, ***63***: 741–750.

Wood R.F., Hanover J.W. (1972): Growth of imperial Carolina poplar over a range of soil types in lower Michigan. Tree Planters Notes, ***33***: 8–13.

Zobeyri M. (2005): Forest Inventory. Tehran, Tehran University Press: 401.

Received for publication January 19, 2014
Accepted after corrections February 17, 2014

Corresponding author:

Dr. Ahmad Alijanpour, Urmia University, Natural Resources Faculty, Pardis Nazloo, Urmia, West Azarbayjan, Iran; e-mail: a.alijanpour@urmia.ac.ir, ahmad.alijanpour@yahoo.com