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Role of planting density on the growth efficiency of *Juniperus virginiana* L. under open-air hydroponic conditions of the Ararat Valley

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Abstract. *Juniperus virginiana* (*J. virginiana*) is an evergreen coniferous tree, which has wide usage not only in green construction, but also in folk medicine as a source of valuable bioactive substances. The high demand for the tree forces the development of new methods for plant cultivation. Hydroponics is considered to be one of the most popular methods. As the soilless growing perspectiveness of *J. virginiana* in Armenia has previously been confirmed by our experiments, the optimization of growing conditions, which bests suits for the enhancement of the growth efficiency and accelerated production of viable trees remains an actual issue. Optimization of the planting density (PD) is one of them. Taking into account the above-mentioned in the frame of this study the role of PD on the growth efficiency of *J. virginiana* has been studied in open-air hydroponic conditions of the Ararat Valley for the first time. The saplings of the tree were planted in volcanic red slag with three different PDs: 10, 12 and 14 plants per square meter. According to the biometrical measurements, no significant differences between the variants were observed at the end of the experimental period. In October an average height and stem diameter of the plants grown in various PDs were fluctuated between 71.7–76.5 cm and 13.9–14.5 mm, accordingly. Positive relationship between the plant height and stem diameter of *J. virginiana* during the whole vegetation period has been observed. Our preliminary studies showed, that all the applied PDs are preferable for early years of hydroponic growing of *J. virginiana* in open-air hydroponic conditions of the Ararat Valley.

Key words: *J. virginiana*, hydroponics, planting density (PD), plant height, stem diameter.

INTRODUCTION

Junipers are coniferous trees and shrubs in the genus *Juniperus* of *Cupressaceae* family. The genus consists of approximately 76 species and 27 varieties. The representatives of the genus are geographically wide distributed. Depending on taxonomic viewpoint, they are widely distributed throughout Eastern and Western Hemisphere, Europe, Central Asia, China, Far East, Continental North America, United States and Canada, Mexico and Guatemala, Caribbean, Africa (Adams, 2014; Adams, 2019).

Junipers are widespread in Armenia as well. In addition to use in landscaping *Juniperus virginiana* (*J. virginiana*) is also widely used in folk medicine as a source of valuable biologically active substances. In the paper of Zhang & Yao (2018) anxiolytic effect of essential oil from *J. virginiana* has been established. Semerdjieva et al. (2019) approved antioxidative capacity of the essential oil from *J. virginiana*. It should be noted, that the composition of essential oil from *J. virginiana* is differed depending on the sampling place. Cantrell et al. (2013) studying the chemical composition of the essential oil of the trees, which were sampled from 49 locations of Mississippi, Alabama, Tennessee and North Dakota, divide the accessions of the plant into different groups. Based on essential oil composition the *J. virginiana* accessions were divided into various chemotypes: safrole-limonene-linalool, safrole-β-pinene-limonene-linalool, β-pinene-limonene, limonene, limonene-linalool, limonene-safrole, limonene-safrole-β-pinene, β-pinene-limonene-bornyl acetate, β-pinene-limonene-linalool-bornyl acetate, and myrcene-limonene. Moreover, various chemotypes showed different antioxidative activity. Leaves (needles) of *J. virginiana* also contains a natural product - podophyllotoxin, which is used to manufacture drugs for treatment of cancer, rheumatoid arthritis, psoriasis, genital warts, and multiple sclerosis. It's important to note that *J. virginiana* is distinguished with highest concentration of podophyllotoxin compared to the other representatives of the genus (Cushman et al., 2003; Gawde et al., 2009; Cantrell et al., 2013). Eller et al. (2014) approved that essential oil from *J. virginiana* may also be used for pest control, as it showed high efficiency against synthetic acaricides for *I. scapularis*. In another study Eller et al. (2010) approved that *J. virginiana* wood extract conferred resistance against subterranean termites and wood-rot fungi.

The high value and demand of *J. virginiana* requires new methods of production. Soilless culture represents a suitable method for cultivation of plants (Ebrahimi et al., 2012; Dehnavard et al., 2017) that can also be applied for tree species like *J. virginiana*.

In our previous studies the growth efficiency and perspectiveness of *J. virginiana* in open-air hydroponic conditions of the Ararat Valley has been confirmed (Mayrapetyan et al., 2021).

Among the many advantages, hydroponics allows to increase planting density (PD) per unit surface compared to the traditional method of cultivation, which is one of the most critically important factors in agriculture.

Many studies were done around the influence of PDs on biomass efficiency of various crops (Maboko & Du Plooy, 2012; Katrevičs et al., 2018; Marziliano et al., 2018; Berbeć & Matyka, 2020; Postma et al., 2021; Zhang et al., 2021). Berbeć & Matyka (2020) showed that yield parameters of plants cultivated as short rotation coppice are strongly depending on PDs and came to the conclusion that the optimal PD should be chosen to best suit the needs of the plants and industry as well. Zhang et al. (2021) showed that various cultivars response differently to the PD and that the optimization of PD is a promising approach for sustainable development of agriculture in semiarid climate. In the paper Postma et al. (2021) several comparisons between the influence of PD were presented for different decades. And as it shown in modern agriculture crops are planted with higher PDs than in traditional agriculture which is due to the improved management, increased fertilization, etc.

Taking into account the above-mentioned, the aim of this work was to study the influence of different PDs on the growth peculiarities and efficiency of *J. virginiana* in open-air hydroponic conditions of the Ararat Valley for the first time. This will allow to develop the optimal PD, which best suits for the accelerated production of high-quality and maximum number of trees per unit surface.

MATERIALS AND METHODS

The experiments were carried out at G.S. Davtyan Institute of Hydroponics Problems of National Academy of Sciences of the Republic of Armenia. Two-year-old planting materials were introduced from nursery into open-air hydroponic conditions of the Ararat Valley. The planting was done in the vegetational experimental station of the Institute. As a growing substrate volcanic red slag with 3–15 mm diameter of particles was used. During the vegetation period the plants were nourished with nutrient solution elaborated by academician Davtyan (Davtyan & Mairapetyan, 1976). The following PDs were applied in the experiments:

A) 10 plants per square meter,
B) 12 plants per square meter,
C) 14 plants per square meter.

During the vegetation biometrical measurements were done. The plant height was measured with ruler, as the length from the collar to the apex. The diameter of the stem was measured near the base with caliper. At the moment of the measurements the age of the trees were two years old.

The obtained data were subjected to the statistical elaboration with GraphPad Prism 8 Software Package. Standard deviations (SD) were calculated for each variant.

RESULTS AND DISCUSSION

No significant differences were observed between the variants regarding *J. virginiana* (Fig. 1) height and stem diameter at the end of the experimental period.

The heights of the plants grown with different PDs were fluctuated in May between: 36.5–38.9 cm, June: 45.4–49.2 cm, July: 53.4–56.3 cm, August: 61.5–65.9 cm, September: 68.2–72.6 cm, October: 71.7–76.5 cm. The diameters of the stems were fluctuated in May between: 7.3–7.5 mm, June: 8.0–8.4 mm, July: 9.7–10.1 mm, August: 11.3–11.9 mm, September: 12.4–13.6 mm, October: 13.9–14.5 mm. From May to October an average heights and diameters of the stems of the plants grown in 10, 12, 14 plants sqm^{-1} PDs increased 37.6, 37.6 and 34.1 cm and 7.2, 6.9,

Figure 1. *J. virginiana* in hydroponic conditions.

6.6 mm, correspondingly (Figs 2, 3). Survival rate of the plants was 100%.

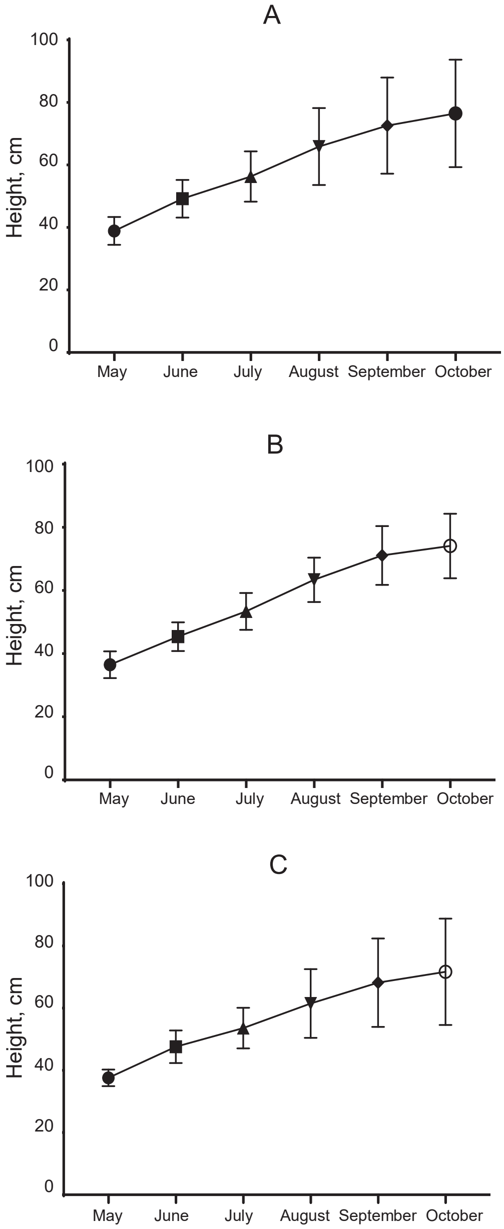

Figure 2. Height of *J. virginiana* during vegetation, grown in various PDs: A – 10 plants sqm^{-1}; B – 12 plants sqm^{-1}; C – 14 plants sqm^{-1}.

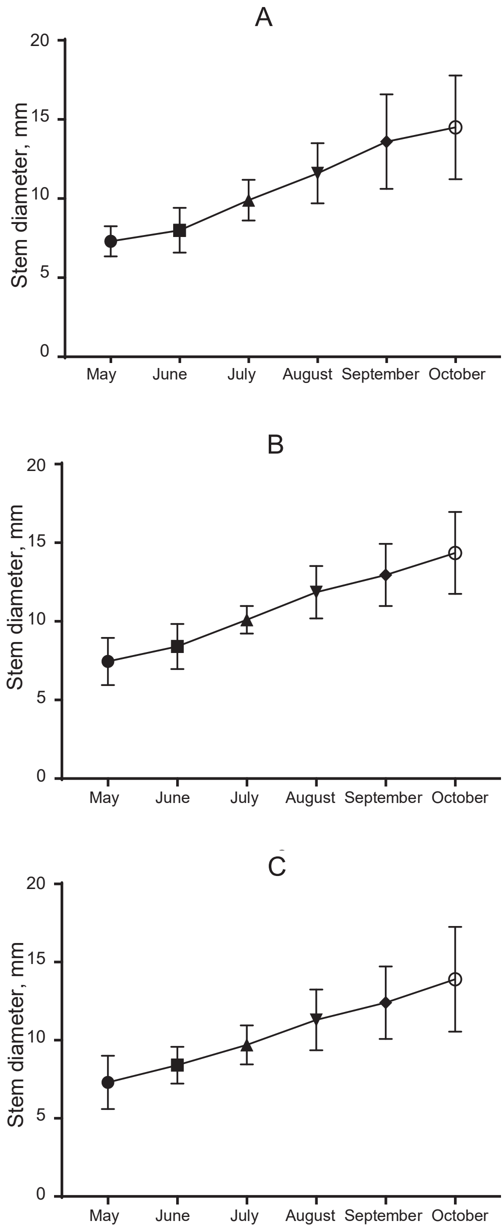

Figure 3. Stem diameter of *J. virginiana* during vegetation, grown in various PDs: A – 10 plants sqm^{-1}; B – 12 plants sqm^{-1}; C – 14 plants sqm^{-1}.

The linear regressions between the plant height and stem diameter for each variant during the vegetation were calculated and the graphs built (Fig. 4). For all the variants positive relationships between them are exist. $R^2 = 0.9692$, $R^2 = 0.9835$ and $R^2 = 0.9755$ for 10, 12, 14 plants sqm^{-1} variants, accordingly.

Zhao et al. (2011) showed that during the first two years after planting no significant differences were observed between PDs of loblolly pine. In later years PDs affected significantly on average diameter at breast height.

Gadow & Kotze (2014) find out that maximum densities of *Pinus patula* and *Pinus elliottii* may differ depending on the growing site. At the same time maximum densities of the two species, which were grown in different sites were also greatly differ.

Dong et al. (2016) demonstrated the responses of *Cunninghamia lanceolata* to a high PD. As a result, *Cunninghamia lanceolata* showed less growth, biomass accumulation and lower photosynthetic rate.

Although the number of the trees between the selected variants does not differ strongly calculated per one square meter surface, and no significant differences were observed regarding plant height and stem diameter at end of the experimental period, meanwhile the difference may be visible in case of large-scale production. For example: in case of 100% survival rate, by applying 10, 12, 14 plants sqm^{-1} PDs, per 1 ha surface it will be possible to obtain 100,000, 120,000 and 140,000 trees, accordingly.

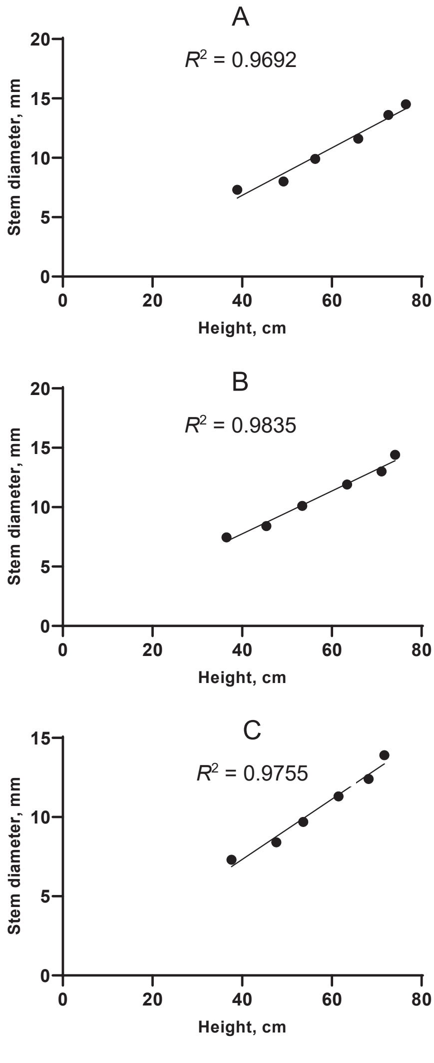

Figure 4. Linear relationship between the plant height and stem diameter of *J. virginiana* during the vegetation, grown in various PDs: A – 10 plants sqm^{-1}; B – 12 plants sqm^{-1}; C – 14 plants sqm^{-1}.

CONCLUSIONS

The high value and demand of *J. virginiana* is forcing to the development of new biotechnological ways for accelerated production of the saplings. Plant soilless culture or hydroponics is considered to be one of the most effective methods for obtaining tree-shrubs planting material, and enhancement plant productivity. Among the many advantages, hydroponics allows to increase PD per unit surface compared to the traditional method of cultivation, which is one of the most critically important factors in agriculture.

From May to October, during the one vegetation period the trees with 71.7–76.5 cm height, 13.9–14.5 mm stem diameter and well developed root system are possible to obtain. For the early years of cultivation all the applied PDs are preferable for hydroponic growing of *J. virginiana* in open-air hydroponic conditions of the Ararat Valley.

Though no significant differences were observed between PDs for our experimental period, the results may differ for big trees. Moreover, for large-scale production, by increasing the PD the biomass yield from the unit surface could be visible. Positive relationship between the plant height and stem diameter of *J. virginiana* during the whole vegetation period has been observed.

As the conducted experiments are preliminary, PDs were choosed randomly to understand the dependence of the plant growing pecularities on the PD. For further studies the fluctuations between the number of the trees per unit surface should be changed more strictly in order to determine the upper and the lower borders, where the plant growth could reach critical state.

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