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Production potential of black poplar rooted cuttings (section Aigeiros Duby) on alluvial soil

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Abstract: The paper shows the possibility of producing planting material of three black poplar clones: *Populus* x *euramericana* cl. I-214, *Populus* x *euramericana* cl. Pannonia and *Populus deltoides* cl. GE2077 on alluvial soil. The examined soil is in the zone of the root system of the texture class of loam, while the lower layer is sandy loam. The chemical properties indicate that the tested soil is strongly carbonated and moderately alkaline, slightly humous, well supplied with nitrogen and moderately supplied with easily accessible phosphorus and potassium. Survival rate of cuttings ranged from 76.22 to 89.78%, and there were no statistically significant differences between clones. Rooted cutting root neck diameter ranged from 19.14 mm to 22.46 mm with significant differences between clones. Rooted cutting heights of the tested clones differ significantly between clone GE2077, with the lowest height of 2.18 m compared to clones I-214 and Pannonia with heights of 2.56 and 2.43 m, respectively. Clone GE2077 has the worst rooted cutting structure, i.e. the highest percentage of rooted cuttings in lower height classes up to 2.0 m high. For rooted cuttings above 2.0 m in height, clones I-214 and Pannonia had 92.29% and 88.49% of rooted cuttings, respectively, in contrast to clone GE2077 with 65.26% of rooted cuttings, which was statistically significantly different from the other two clones.

Keywords: black poplar, clone, alluvial soil, production potential.

1. Introduction

The black poplar species inhabits moist lowland riparian habitats (Abramović, 2017). It is well known for its rapid growth and short rotation period. Efforts are ongoing to preserve the gene pool of the native black poplar in Serbia, which is rather poor and limited to small areas along riverbanks where it naturally occurs (Orlović, 2005). Since the development of poplar cultivation in Serbia in 1958, many varieties or clones of black poplars have been created and recognized. Various genotypes of Euramerican poplar (*Populus* x *euramericana*) and Eastern cottonwood (*Populus deltoides*) have been tested and recognized as new varieties, being regularly used in forestry ever since (Orlović et al. 2006). Black poplar clones have various uses that significantly contribute to environmental conservation, primarily phytoremediation (Abramović, 2017; Pilipović et al. 2020; Kovačević et al. 2025; Kesić et al. 2025). Additionally, due to their rapid growth, they are used in short rotation plantations for biomass production and wood chips, reducing fossil fuel consumption (Klašnja et al. 2006; Drvodelić, 2015; Tomić, 2018; Pilipović, 2022), and as pioneer forest species for afforestation and reclamation of landfills and quarries (Kesić et al. 2024; Perić et al. 2009). Their importance is also reflected in protecting riverbanks from water erosion and defensive embankments through black poplar clone plantations planted between watercourses and embankments (Ivanišević et al. 1998; Ivanišević et al. 1999). Furthermore, black poplar clones play an important role in agroforestry ecosystems and the establishment of windbreaks (Ivanišević, 2005; Pekeč et al. 2007; Pekeč et al. 2008). Black poplar clones are found in alluvial plains along river courses, both in flooded and embankment-protected parts of the alluvial plain (Pekeč, 2010). The distribution of black poplar is directly related to the flooding regime, groundwater, and the distribution of gravelly, sandy, and sandy-loamy alluvial deposits where black poplar has almost no competitors (Orlović et al. 2005). In the process of poplar cultivation, nursery production represents the first technological phase, significantly influencing the success of plantation establishment, their subsequent development, quality, and the utility value of the produced raw material, as well as the overall economic effect of poplar cultivation (Andrašev et al. 2001). To establish poplar plantations, it is necessary to produce a sufficient number of quality planting materials in nursery production (Stojanović and Pekeč, 2017). Therefore, it is important to test the soil for planting material production and select poplar clones according to the appropriate soil type. To obtain quality black poplar planting material, it is necessary to choose favorable soil for nursery production (Živanov and Ivanišević, 1986; Pekeč et al. 2011; Pekeč et al. 2019). Considering the Italian school of nursery production applied in this region, the primary measure of planting material quality is plant height (Rončević et al. 2002). By measuring the parameters of different poplar clones on specific soil, the potential of the soil for each individual clone is determined. Given that the natural distribution of poplars is on alluvial soil types such as fluvisol and humofluvisol, poplar nursery production is based on these soil types (Rončević et al. 2002; Pekeč et al. 2019), whose fertility is closely related to accessible water (Nikolić Jokanović et al. 2024). Considering the different reactions of black poplar clones to soil, the aim of this study is to evaluate the characteristics of three black poplar clones on alluvial soil, and to examine whether there are differences between the clone in the selection process of *Populus deltoides* cl. GE2077 compared to the reference clones *Populus* x *euramericana* cl. I-214 and Pannonia on the examined soil.

2. Material and methods

2.1. Plant material and experimental design

The nursery trial was established in the nursery in Bački Monoštor (the vicinity of Sombor, Serbia) managed by Public Water Management Company "Vode Vojvodine" (N 45°48′57.56", E 18°55′25.03"). The examination was conducted on three black poplar clones: *Populus* x *euramericana* cl. I-214, *Populus* x *euramericana* cl. Pannonia, and *Populus deltoides* cl. GE2077. The altitude of the nursery trial is 79 meters. The climatic characteristics of the area, obtained from the Sombor measuring station, show that in 2023 the air temperature ranged from -9.3 to 38.2°C with an average value of 13.3°C, while the annual precipitation total was 679.0 mm, with a maximum value of 41.1 mm according to the data of RHMZ, (2025).

The trial was established in March 2023, with a planting distance of 0.35 x 0.7 m, in three replications, with 150 cuttings per replication. After the end of the vegetation period in 2023, the survival rate was determined, and the dimensions of the rooted cuttings were measured. The heights of the seedlings were measured using a height measuring rod with an accuracy of 1 cm, and the diameters of the seedlings were measured at the root collar using a "Mitutoyo" calliper with a digital display and an accuracy of 0.01 mm (Figure 1). A total of 1350 seedlings were measured. In the nursery trial, necessary cultivation measures were carried out, as in the entire nursery, including weeding around the seedlings, removing lateral shoots (branches), and irrigation as needed during the dry periods.

Figure 1. a) Sample area, b) height and c) diameter measurements of rooted cuttings of age 1/1 (Photo: Msc Milivoj Stojanović, 27 November 2023).

Based on the measured values, the following parameters were calculated: rooted cutting structure and the partition of rooted cuttings higher than 2.0 m (the height of rooted cuttings suitable for planting). Based on the achieved heights, the rooted cuttings were classified into height classes: >2.5 m (Class I), 2-2.5 m (Class II), 1.5-2.0 m (Class III), and less than 1.5 m (discard) (Ivanišević, 1991). A pedological profile was also opened on the trial surface, and the external and internal morphology of the profile was described, while disturbed samples were taken for the following physical and chemical soil analyses. The following analyses were performed: mechanical composition analysis, by B-pipette method with sample preparation for analysis in sodium pyrophosphate according to Bošnjak et al. (1997); CaCO3 content was determined volumetrically using the "Scheibler" calcimeter (Belić et al. 2014); pH value was determined in a soil-water suspension, potentiometrically (Belić et al. 2014); Humus content according to Tyurin, modified by Simakova (1957) (Belić et al. 2014); Total nitrogen by the Kjeldahl method (1883); Easily accessible phosphorus and potassium according to the AL method (Egner-Riehm-Domingo, 1960).

2.2. Statistical analysis

The data were statistically processed using the one-factor analysis of variance and Tukey's test with the help of the STATISTICA 14 software package (TIBCO Software Inc., 2020). All data describing the partition are transformed by arcsine-transformation before the analysis to meet the normal distribution of frequencies.

3. Results and discussion

Analyzing the granulometric composition of the tested soil (Table 1), it can be seen that down to a depth of 75 cm prevails the content of total clay, while the lower layer from 75 to 150 cm has an increased share of total sand. Soil with 30-50% dust and clay (total clay) fraction is considered as optimal soil for growing poplars (Živanov et al. 1985), while the tested soil has a slightly higher value in its surface Ap horizon. The granulometric composition depends on the distribution of soil in the area of the alluvial plain, so the soils in the coastal part contain more sand (Pekeč and Katanić, 2019).

According to the chemical composition, the examined soil is highly calcareous, with active acidity decreasing with depth, and on average, it is moderately alkaline (Table 1). In terms of humus content, it is low in humus, except in the surface Ap horizon where it is moderately humus-rich (Belić et al. 2014). The nutrient content indicates that this soil is well-supplied with nitrogen and moderately supplied with easily accessible phosphorus and potassium, especially in Ap and IGso layers (from surface to a depth of 75 cm) (Predić, 2011).

Table 1. Physical and chemical properties of soil.

Horizon	Depth (cm)	Total sand (%)	Total clay (%)	$CaCO_3$ (%)	pH (in H_2O)	Humus (%)	Total N (%)	P (mg/ 100g)	K (mg/ 100g)
Ap	0-30	36.12	63.88	12.55	8.52	3.13	0.142	13.35	10.85
IGso	30-75	34.52	65.48	10.57	8.24	1.26	0.146	13.63	11.09
IIGso	75-150	64.36	35.64	17.80	7.99	0.72	0.075	8.28	6.62
Average	0-150	45.00	55.00	13.64	8.25	1.70	0.121	11.76	9.52

The analysis of the variance of rooted cutting properties (Table 2) shows a significant influence among the studied clones for all the examined properties, except for the survival rate where there were no significant differences.

Table 2. Results of the variance analysis of rooted cutting properties of the tested black poplar clones.

Traits	F-value	p-value
Survival rate	2.401	0.171^{ns}
Rooted cutting height	22.221	0.002^{**}
Rooted cutting diameter	8.541	0.0176^{*}
Partition of rooted cuttings shorter than 1.5 m	6.104	0.0358^{*}
Partition of rooted cuttings with height of 1.5-2.0 m	25.536	0.001^{**}
Partition of rooted cuttings with height of 2.0-2.5 m	7.833	0.021^{*}
Partition of rooted cuttings higher than 2.5 m	30.558	0.001^{**}
Partition of rooted cuttings higher than 2.0 m	25.237	0.001^{**}

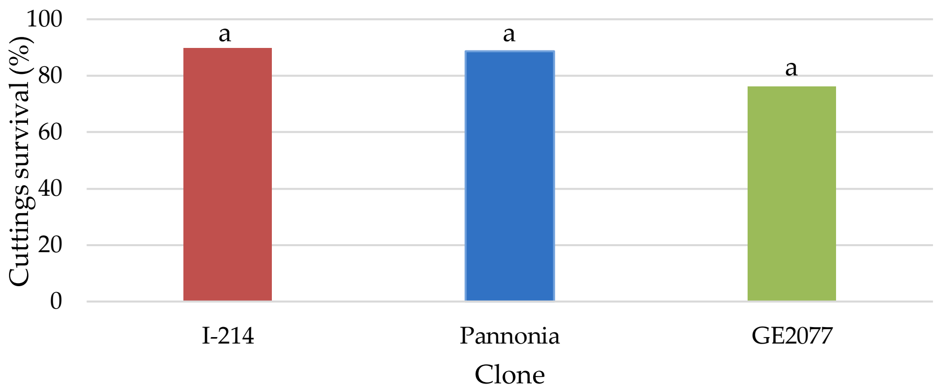

Figure 2. Tukey's test for cuttings' survival. Difference between clones with the same letter is not significant at the level of α=0.05.

Observing the survival of cuttings (Figure 2), the highest survival rate of 89.78% was achieved by clone I-214, slightly lower survival of 88.67% was found in clone Pannonia, while the lowest survival was achieved by clone GE2077 at 76.22%. There were no significant differences in the survival of cuttings among the three clones. Marković and Rončević (1986) note that Eastern cottonwood clones (*Populus deltoides*) have a problem with more difficult rooting of cuttings. Nonić et al. (2021) evaluating the survival of black poplar clones, concluded that the survival rate ranged from 41.7% to 78.6%, influenced by the flood wave. Kovačević et al. (2003) report an exceptionally high rooting potential for the Pannonia clone, while Andrašev et al. (2006) determined the survival of clones I-214 and Pannonia to be over 90%.

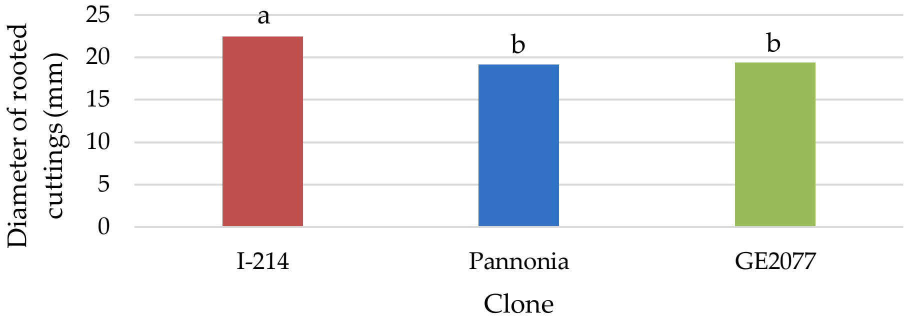

Figure 3. Tukey's test for diameter of rooted cuttings. Difference between clones with the same letter is not significant at the level of α=0.05.

According to the results of Tukey's test for the heights of rooted cuttings of the examined clones (Figure 4), significant differences exist between clone GE2077 with the lowest height (2.18 m) compared to clones I-214 and Pannonia with heights of 2.56 and 2.43 m, respectively. In examining clones I-214 and Pannonia and selected clones of *Populus deltoides* (NS-1, NS-2, and NS-3), Kovačević et al. (2021) did not find significant differences in rooted cutting heights. Nonić et al. (2021) at the end of the vegetation period present the average values of heights of one-year-old black poplar seedling clones ranging from 1.62 to 2.34 m. Andrašev et al. (2002) state that the average heights of clones I-214, Pannonia, and PE19/66 at different planting distances were mostly grouped in the height class of 2.5 to 3.0 m.

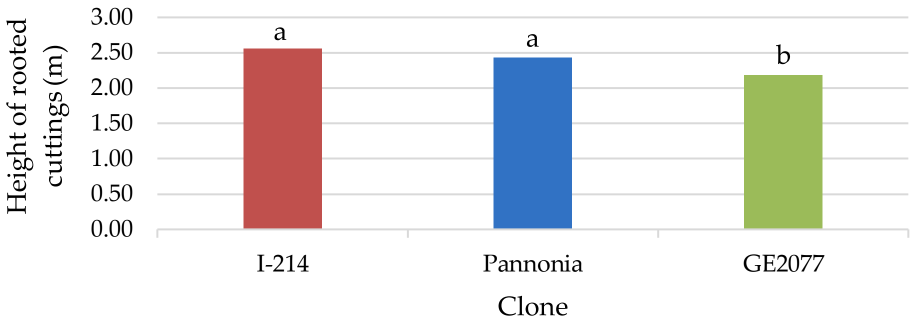

Figure 4. Tukey's test for height of rooted cuttings. Difference between clones with the same letter is not significant at the level of α=0.05.

According to Tukey's test for partition parameters related to rooted cutting structure (Figure 5), significant statistical differences are clear between clone I-214 and GE2077 for partition of rooted cuttings shorter than 1.5 m, with the highest value for this class being found in clone GE2077 (8.7%). For rooted cuttings 1.5 to 2.0 m high, clone GE2077 had the highest value (25.01%), significantly higher than in the other two clones. The highest partition of 2.0 to 2.5 m high rooted cuttings was achieved in clone Pannonia (38.06%), and clone GE2077 (37.36%), while significantly lower value was found in clone I-214 (27.1%). In the height class of rooted cuttings higher than 2.5 m, Tukey's test shows that all examined clones significantly differed, with the highest partition of rooted cuttings in this class in clone I-214 (65.02%), followed by Pannonia (49.62%), and clone GE2077 (27.52%). Presented results suggest that clone GE2077 achieved the highest partition (33.71%) of rooted cuttings of lower classes (height less than 1.5 m and 1.5-2.0 m) compared to clones I-214 and Pannonia, as well as lower partition of the higher rooted cutting classes, especially over 2.5 m in height. Studying the structure of rooted cuttings, Kovačević et al. (2021) found significant statistical differences between the participation of different clones only in the lower classes, with values ranging from 4.6 to 21.4%. Examining the height classes of rooted cuttings of different clones of *Populus deltoides* on gley soil, Pekeč et al. (2011) highlighted that the majority of rooted cuttings were in the height class of 1.5 to 2.0 m, which are lower values compared to this study, which could be related to the heavier granulometric composition of gley soil in their study. Pilipović et al. (2023) stated that clones I-214 and Pannonia, which they studied in short-rotation plantation conditions tolerate heavier marginal soils that are not optimal for poplar cultivation.

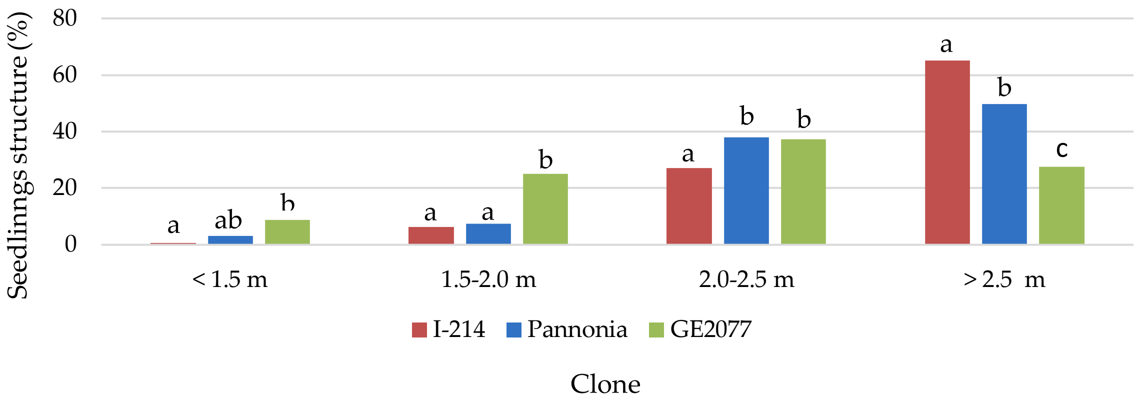

Figure 5. Tukey's test for rooted cuttings structure. Difference between clones with the same letter is not significant at the level of α=0.05.

Considering the results of Tukey's test for partition of rooted cuttings higher than 2 m, the rooted cuttings that are regarded as the most suitable for planting, it is noticeable that clones I-214 and Pannonia had significantly higher partition of rooted cuttings of this class (92.29% and 88.49%, respectively) than clone GE2077 had (65.26%). These results suggest that the nursery technology of clone GE2077 should be additionally optimized in order to achieve better dimensions of rooted cuttings of this clone.

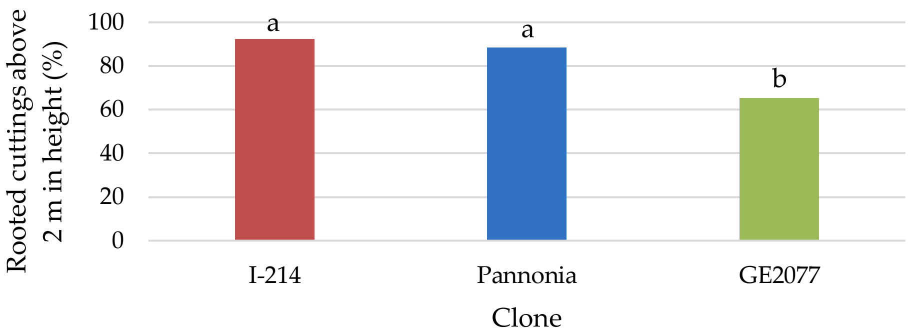

Figure 6. Tukey's test for all rooted cuttings above 2 m in height. Difference between clones with the same letter is not significant at the level of α=0.05.

Kovačević (2003) obtained similar results on soil with a higher sand content, with a relative proportion of such rooted cuttings ranging from 60 to 90%, depending on the examined black poplar clones. However, Kovačević (2021) did not find significant differences in the partition of rooted cuttings higher than 2 m between the examined clones I-214, Pannonia, and selected clones of *Populus deltoides*. Kesić et al. (2024) indicate that studying willow and poplar rooted cuttings on landfill soil of heavier granulometric composition, black poplar clones, especially *Populus deltoides* PE 4/68 and S 1-8, suggest good growth potential on this type of soil. According to Stojnić et al. (2023), planting material that has achieved the required height can be used in the further process for establishing poplar plantations by rooted cuttings (type 1/1), or using one-year old stools (type 1/0) as a modification of deep planting.

4. Conclusions

The study examined seedlings of three black poplar clones: *Populus* x *euramericana* cl. I-214, and Pannonia, as well as the clone in the selection process *Populus deltoides* cl. GE2077 on alluvial soil. The investigated soil profile's surface layer has an increased total clay content, while the lower layer is dominated by total sand, is poorly humus-rich, and moderately supplied with nutrients. Analysis of variance showed no significant differences in the survival rate of cuttings, while there were significant differences between clones in other measured parameters. Clone GE2077 achieved a significantly lower average height compared to the tested clones I-214 and Pannonia. According to the height structure of the seedlings, it has a higher proportion in the lower structural classes (<1.5 m and 1.5-2.0 m), an equal proportion with the tested clones at heights of 2.0-2.5 m, and a lower proportion at seedling heights above 2.5 m. Considering all planting material taller than 2 m used for planting, clone GE2077 has a statistically significantly lower share of these seedlings compared to the tested clones. These results suggest that the nursery technology of clone GE2077 should be additionally optimized to achieve higher proportion of rooted cuttings that are suitable for plantation establishment.

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