Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 9 (58) No.1 - 2016

GROWTH PERFORMANCE OF HYBRID POPLARS (*POPULUS* X *CANADENSIS* MOENCH) IN THE DANUBE FLOODPLAIN, SOUTHERN ROMANIA

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Abstract: *Clonal plantations of hybrid poplars (Populus x canadensis Moench) play an important role in the silviculture of many European countries. The choice of hybrid clones to be used in a certain geographic area is of critical importance for the production and stability of plantations. The performance of seven clones of hybrid poplar was evaluated in one experimental plot (Boianu) situated in the Danube floodplains, in southern Romania. We found substantial differences in biomass production between the hybrid clones at 15 years after planting. Clone 'Sacrau 79' confirmed its high-growing capacity and relatively constant growing rate. Clones 'I-154' and 'Veneziano' performed well and reacted positively in a more open stand after thinning. The biomass production of clone 'I-214' was less than the overall average value. A positive and significant correlation was observed between stomatal density and crown size. The stomatal density on the lower surface of the leaf showed a greater influence on biomass production than the density on the upper surface of the leaf. Our results support the importance of periodical measurements in comparative field trials, due to the different temporal growing dynamics of hybrid poplar clones.*

Key words: *hybrid poplar, Populus, clones, biomass, stomatal density.*

1. Introduction

Hybrid poplars refer to trees that are the products of cross-fertilizing individuals of the European and North American species of black poplar. They are also known as Canada poplars [3] and play an important role in the silviculture of many European countries (e.g. Italy, France, Germany, Belgium, and the Netherlands) [10], [12], [26]. Hybrid poplars grow very fast in the first years and are currently used in biomass and bioenergy short rotation plantations [7], [9].

In Romania, there has been developed an important improvement program of hybrid poplars. Many clonal varieties were produced, tested and introduced into the forestry practice. The experiments were conducted by the Romanian Forest

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Research and Management Institute, in two experimental stations: first at Cornetu, in southern Romania, and later in Tulcea, close to the Danube Delta. The total surface area occupied by poplar plantations is currently 58,000 ha, of which 56,000 ha are plantations of hybrid poplars [12]. Hybrid poplar plantations have been mostly established in the floodplains and delta of the Danube river, but also in the floodplains of the main rivers of southern Romania (e.g. Olt, Jiu), in areas characterized by a warm climate during the growing season, which is an important ecological requirement of these poplars [27], [28].

There has been a lot of research done on hybrid poplars in the last decades. The three main directions have been: *i)* production of new hybrids, assessment of their growth performance and selection of cultivars/clones; *ii)* influence of site conditions on the growth characters of hybrid poplar clones; *iii)* identification of hybrids resistant to pest, diseases but also to drought [5], [16], [20].

In general, multi-clonal plantations of hybrid poplars have been preferred to the detriment of monoclonal plantations [14]. In this way, a comparative evaluation of clones growing under similar growth conditions has been done. However, for testing research hypotheses, both multi- and monoclonal cultures are needed [6], [29].

In the present study, we evaluated the performance of hybrid poplar clones at age 15, in one experimental plot. More specifically, we had three specific objectives: *i)* to assess the growth performance of seven clones after $3/4^{th}$ of the rotation period; *ii)* to compare the results with those obtained under different site conditions; *iii)* to analyze the phenotypic correlations between growth performance, on one hand, and crown and leaf traits, on the other hand.

2. Material and Methods

2.1. Material

The measurements were done in Boianu experimental plot (Călăraşi Forest District, UP II Chiciu, compartment 47 B), which is situated in the floodplains of the Danube river. Local site conditions are favorable for hybrid poplars [12]. The experiment consisting of 12 clones was established in the spring of 1997. The planting scheme was 5 x 5 m. In the present study, only seven hybrid poplar clones were considered (Table 1). The other five clones belong to *P.* x *interamericana*, *P.* x *deltoides* and *P. alba*. A total of twenty ramets per clone were measured.

2.2. Phenotypic Traits

For each tree we measured: diameter at breast height – DBH (cm), total height – H (m), height up to the first green branch – He (m), crown diameter – CD (m). We also calculated three transformed variables:

- Crown length: Hc = H - He;
- Crown index: Ic = CD × Hc;
- Mean volume per clone – Vm, calculated using mean values of DBH and H, as described in [19].

Six fully expanded leaves were sampled in the mid-part of the crown. The stomatal density (Sd = number of stomata/mm^2) was calculated for both adaxial and abaxial surface of the leaf. The number of stomata was assessed in three areas of the leaf mid-part with a microscope (x40). The Spearman's coefficient was used for correlations between traits. The significance levels were taken from [18].

List of the hybrid poplar clones which were evaluated at age 15 Table 1

No.	Clone	Gender (reference)
1.	*P.* x *canadensis* 'Sacrau 79'	F [12]
2.	*P.* x *canadensis* 'RO-16'	M [12]
3.	*P.* x *canadensis* 'I-214'	F [15]
4.	*P.* x *canadensis* 'I-45/51'	M [15]
5.	*P.* x *canadensis* 'I-154'	M [15]
6.	*P.* x *canadensis* 'I-488'	F [15]
7.	*P.* x *canadensis* 'Veneziano'	M [17]

Abbreviations: F - female, M - male.

3. Results and Discussions

3.1. Diameter at Breast Height (DBH) and Height (H) at Age 15

On average, the seven clones of hybrid poplars grew to 33.2 cm in diameter and 29.5 m in height in just 15 years, in the Boianu field trial. The best clone in terms of DBH (36.7 cm) and height (32.1 m) was 'I-154' and 'I-214', respectively (Table 2). The intracolonal variability was much higher for the growth in diameter (11.7% - 21.9%) than for the growth in height (3.64% - 6.10%). The difference between the first- and last-performing clone was of 21.9% and 46.6% for the mean growth in diameter and in height, respectively.

The values of mean annual growth in diameter and in height at age 7 [13], 11 [12] and 15 (the present study) are shown in Table 3. Thus, the mean values for diameter at age 15 are lower with 24.8% and 12.3% when compared with the values reported for age 7 and 11, respectively. By contrast, the reduction in mean annual growth in height at age 15, is much smaller: 13.2% and 5.9% relative to age 7 and 11, respectively.

Two clones, 'Sacrau 79' and 'I-214', showed the highest values for the mean annual growth in diameter and height at age 7 and 11. However, the mean annual growth was substantially reduced at age 15, especially for diameter (Table 3). However, clone 'I-154' showed similar values for the annual growth rate in diameter in the last 4 years. Moreover, clone 'Venetiano' had even a higher annual growth rate in height between the last two measurements.

Table 2

Diameter at breast height (DBH), total height (H) and coefficient of variation (s%)

No.	Clone	DBH			H		
		Mean [cm]	cm/year	s%	Mean [m]	m/year	s%
1.	*P. x c.* 'I-154'	36.7	2.45	11.7	30.8	2.05	3.97
2.	*P. x c.* 'RO-16'	34.6	2.31	21.9	24.6	1.64	6.10
3.	*P. x c.* 'Sacrau 79'	34.4	2.29	17.9	30.7	2.04	3.64
4.	*P. x c.* 'Veneziano'	33.3	2.22	19.4	32.0	2.13	5.31
5.	*P. x c.* 'I-45/51'	32.1	2.14	21.6	29.3	1.95	3.69
6.	*P. x c.* 'I-214'	31.0	2.07	14.7	32.1	2.14	4.87
7.	*P. x c.* 'I-488'	30.1	2.01	21.9	26.8	1.46	5.49
	Mean	**33.2**	**2.21**	**18.4**	**29.5**	**1.91**	**4.72**

Dynamics of mean annual growth Table 3

Clone	DBH [cm/yr]			H [m/yr]		
	Mean annual growth at age …					
	7	11	15	7	11	15
'I-154'	2.74	2.47	2.45	2.01	1.98	2.05
'RO-16'	2.84	2.40	2.31	2.08	1.94	1.64
'Sacrau 79'	3.34	2.78	2.29	2.35	2.14	2.04
'Veneziano'	2.91	2.49	2.22	2.17	1.93	2.13
'I-45/51'	2.85	2.49	2.14	2.23	2.09	1.95
'I-214'	3.30	2.83	2.07	2.35	2.10	2.14
'I-488'	2.63	2.18	2.01	2.23	2.03	1.46
Mean	**2.94**	**2.52**	**2.21**	**2.20**	**2.03**	**1.91**

3.2. Tree Volume and Productivity

Clone 'I-154' was the best one in terms of volume, after 15 years of testing in Boianu field trial (Table 4). The ranking of clones changed over 15 years. Thus, two other clones, 'Sacrau 79' and 'I-214', showed the best performance after the first 11 years of testing [12].

Table 4

Tree volume at age 15 (Vm) and productivity (P)

Clone	Vm [m^3]	P [m^3/yr/ha]
'I-154'	1.334	23.6
'Sacrau 79'	1.189	21.1
'Veneziano'	1.108	19.7
'RO-16'	1.048	18.6
'I-45/51'	0.963	17.1
'I-214'	0.951	16.9
'I-488'	0.788	14.0
Mean	**1.054**	**18.7**

One systematic thinning was carried out at age 8, and 1/3 of the poplar trees were removed. The resulted more open stand appeared to favor clones 'I-154', 'Veneziano' and 'Sacrau 79', although other site conditions might have played a role. The clone 'I-154' seemed to better react than clone 'I-214' to the soil-water deficit recorded in the last years in the Danube floodplains [12], [25]. The productivity was relatively higher for clones 'Sacrau 79', 'I-214', 'Veneziano' and 'I-45/51' in Boianu compared with Turcoaia field trial at age 13 [12]. Clone 'RO-16' grew much better in Boianu compared with Turcoaia field trial (18.6 m^3/yr/ha versus 12.4 m^3/yr/ha).

3.3. Natural Pruning and Crown Size

The height up to the first green branch was 20.6% of the tree height averaged for the seven clones (Table 5).

Table 5

Height to the first green branch (He) and crown index (Ic)

Clone	He [%]	I_c = CD x Hc
'Sacrau 79'	21.1	146.3
'I-154'	20.6	133.1
'Veneziano'	17.8	126.0
'I-488'	18.8	102.1
'I-45/51'	20.5	101.2
'RO-16'	28.7	99.4
'I-214'	16.9	97.6
Mean	**20.6**	**115.1**

The highest value (28.7%) was observed in the Romanian reference clone 'RO-16', whereas the lowest value (16.9%) in clone 'I-214'. It is worth mentioning that artificial pruning is recommended for this latter clone [12]. However, the lowest value of parameter *Ic* was calculated for the clone 'I-214' as a result of the lowest

value of its diameter. The most productive clones, 'Sacrau 79' and 'I-154', showed the highest value of this parameter, 146.3 and 133.1, respectively. Larger distances between individuals on rows and between rows would be a better option for the use of these two clones.

3.4. Stomatal Density

It is well known that hybrid poplars show a larger number of stomata on both upper and lower surface of the leaf. However, the stomatal density is much higher on the lower side of the leaf in amphistomatous poplars [2], [4], [23]. Stomatal density, size and conductance, as well as their opening/closing mechanism are correlated with biomass production [1]. These aspects were studied on hybrid poplars grown in Romania [11]. Moreover, there is a positive correlation between stomatal density and resistance to water deficit or floods [21], two important ecological factors for the sylviculture of hybrid poplars. For instance, poplar species which grow in semiarid riparian forest are better adapted to drought due to the smaller size and higher density of stomata [24]. This might be used as a selection criterion for poplar clones in Romania.

The mean value of stomatal density (Table 6) was 250/mm^2 for the seven clones and both surfaces (adaxial and abaxial). However, the highest density was for clone 'Sacrau 79' and 'I-154' which showed 21.1% and 11.0% more stomata per unit of surface area than the overall mean value. Lower values (with 10 to 16%) were observed for three clones 'I-214', 'I-45/51' and 'I-488'. On average, the proportion of stomatal density on the adaxial/abaxial leaf surface is 37/63%. There was an interclonal variability, which seems to be genetically controlled [4 and 22]. Our value (40.4/59.6%) for clone 'I-214' is consistent with that previously reported [8].

Table 6

Stomatal density (Sd) and ratio adaxial / abaxial

Clone	Sd (adaxial + abaxial)	Sd adaxial / Sd abaxial (%)
'Sacrau 79'	304.7	33.3/66.7
'I-154'	279.3	40.0/60.0
'Veneziano'	258.9	33.9/66.1
'RO-16'	256.4	42.9/57.1
'I-214'	226.0	40.4/59.6
'I-45/51'	224.3	30.2/69.8
'I-488'	210.7	38.5/61.5
Mean value	**251.5**	**37.0/63.0**

3.5. Correlations between Phenotypic Traits

DBH and volume are positively correlated with crown diameter and index (Table 7), which supports the large planting scheme for these light-demanding hybrid poplars [27]. The strongest (r_s = 0.928) and significant (α = 0.001) correlation was between the mean volume and the total number of stomata. Moreover, the stomatal density on the lower side of the leaf showed a stronger influence on volume than the density on the upper side of the leaf ($r_{s\ abaxial}$ = 0.857; α = 0.01). A significant linkage between the stomatal density on the lower surface of the leaf and the total biomass volume was reported in other studies on hybrid poplars [2] and [4].

Correlations between phenotypic trails Table 7

Phenotypic traits	Spearman's coefficient of correlation (r_s)	Significance
DBH - CD	0.827	α = 0.02
Vm - CD	0.839	α = 0.02
DBH - Ic	0.619	α 0.10
Vm - Ic	0.809	α = 0.01
DBH - Sd	0.678	α = 0.10
Vm – Sd (adaxial + abaxial)	0.928	α = 0.001
Vm – Sd abaxial	0.857	α = 0.01
Vm – Sd adaxial	0.678	α = 0.10

4. Conclusion

There were differences regarding the biomass production of hybrid poplar clones tested at Boianu experimental plot, in the floodplains of southern Romania. Clone 'Sacrau 79' confirmed its high-growing capacity and relatively constant growing rate. Clones 'I-154' and 'Veneziano' performed well and reacted positively after the systematic thinning. The biomass production of clone 'I-214' was less than the overall average value. However, the observations need to be validated in other field trials. A positive correlation was observed between crown size and stomatal density. The stomatal density on the lower surface of the leaf showed a greater influence on biomass production than the density on the upper surface of the leaf. Our results did confirm the importance of periodical measurements in comparative field trials due to the different temporal dynamics of hybrid poplar clones.

Acknowledgments

We wish to thank to Dr. Mihai Filat for his help in providing us the plan of the comparative trial.

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