There are two factors or independent variables: treatments (NAA solution, Allgrow solution and pure water solution) and clones (OP42 and Bullstofta). On the other hand, several dependent variables were chosen: length of the longest root, root weight, cutting length, leaf area, specific leaf area and root/shoot ratio.

After analysing the data, it was discovered that the data did not comply with the normal distribution. Therefore, the data transformations were made using the best adjustment for each variable. Root length was transformed to square root length (figure 21). Root weight and cutting length were not transformed, because it was not necessary. Leaf area was transformed to logarithm of leaf area (figure 21). Root shoot ratio was transformed to logarithm to base 10 (figure 21). Specific leaf area (SLA, it is relationship between leaf area and leaf weight) and net assimilation rate (NAR, it is biomass assimilation per leaf area in a certain time period) were not transformed.

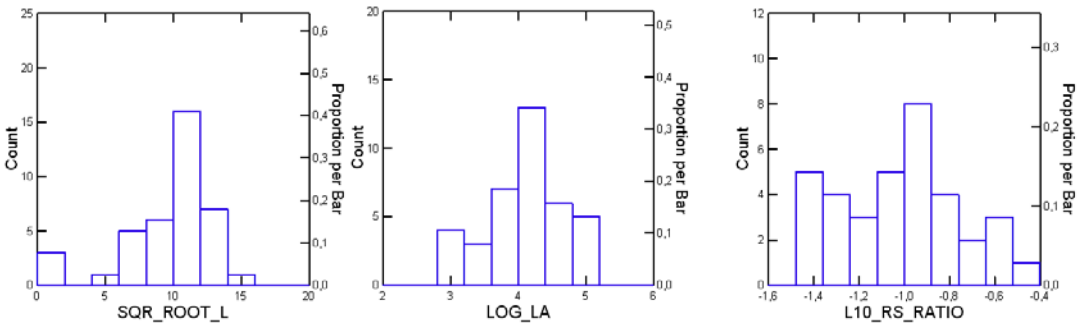

Figure 21. Distribution of dependent variables converted in order to comply with the normal distribution. Left up diagram represents the distribution of square root transformed to root length. Right up diagram represents the distribution of leaf area logarithm transformed to leave area. Down diagram represents the distribution of logarithm to base 10 of root shoot ratio transformed to root shoot ratio.

Results and discussion

The ANOVA results are shown in ANOVA tables for each dependent variable. The analysis of variance for square root length is shown in table 7. There were significant differences between treatments (figure 22, P-value = 0.003 < 0.05). The cuttings pre-treated with NAA had significantly shorter length of the longest root compared to the cuttings pre-treated with Allgrow. A negative effect of NAA on the length of longest root could have been caused by an inadequate concentration. Another option would be that combination of given concentration of NAA and a high concentration of applied “Blomstra” fertiliser caused damages on tissues in cuttings. There were no significant differences in length of the longest root between clones or the clone-treatment interactions. The length of cutting did not have a significant effect on this variable.

Table 7. ANOVA table for the length of the longest root

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
TREATS	138,654	2	69,327	7,264	0,003
CLONES	10,040	1	10,040	1,052	0,313
TREATS*CLONES	3,456	2	1,728	0,181	0,835
CUTTING LENGTH	16,715	1	16,715	1,752	0,195
Error	305,388	32	9,543		

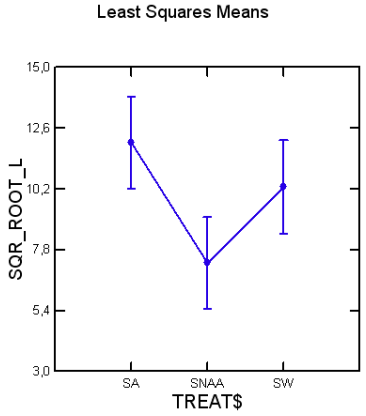

Figure 22. Least squares means for the dependent variable of the length of the longest root. The xlabel includes the three treatments for soaking the cuttings: allgrow solution (SA), solution of NAA (SNAA) and water solution (SW).

Results for root weight are shown in table 8. According to the obtained F-ratios and P-values there were no significant differences between treatments, clones, and clone-treatment interactions. It is though important to conclude that root biomass of clone OP42, but not of clone Bullstofta, was negatively affected by NAA pre-treatment (figure 23).

Table 8. ANOVA table for root weight

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
TREATS	1 931,179	2	965,589	2,699	0,083
CLONES	70,655	1	70,655	0,198	0,660
TREATS*CLONES	1 299,037	2	649,518	1,816	0,179
CUTTING LENGTH	144,191	1	144,191	0,403	0,530
Error	11 447,471	32	357,733		

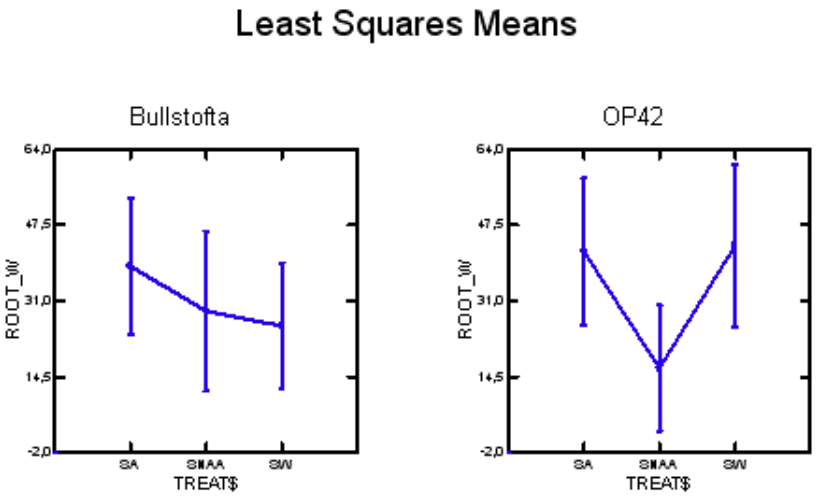

Figure 23. Least squares means for the dependent variable of root weight. The xlabel includes the three solutions for soaking the cuttings: allgrow solution (SA), solution of NAA (SNAA) and water solution (SW). The left figure is for Bullstofta clone and the right is for OP42 clone.

The results for leaf area showed no significant differences between treatments and clones (table 9). The cutting length had significant impact on the obtained F and P values (0.042 < 0.05) for treatment and clones.

Table 9. ANOVA table for leaf area

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
TREATS	0,751	2	0,376	1,417	0,258
CLONES	0,786	1	0,786	2,965	0,095
TREATS*CLONES	0,573	2	0,286	1,080	0,352
CUTTING LENGTH	1,195	1	1,195	4,508	0,042
Error	8,219	31	0,265		

The root/shoot ratio is the relationship between weight of biomass stored in bellow and above-ground plant parts. The weight of cutting is not included in this relationship. In this study there were no significant differences between treatments and clones. A significant clone-treatment effect was related to opposite pattern of response for the two clones to NAA treatment (figure 24).

Table 10. ANOVA table for the root/shoot ratio

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
TREATS	0,042	2	0,021	0,494	0,615
CLONES	0,002	1	0,002	0,053	0,820
TREATS*CLONES	1,074	2	0,537	12,592	0,000
CUTTING LENGTH	0,107	1	0,107	2,515	0,124
Error	1,195	28	0,043		

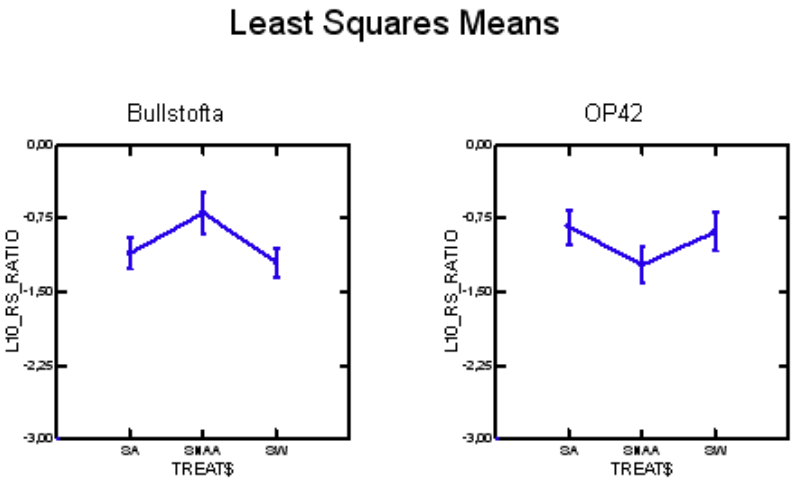

Figure 24. Least squares means for the dependent variable of root/shoot ratio. The xlabel includes the three solutions for soaking the cuttings: allgrow solution (SA), solution of NAA (SNAA) and water solution (SW). The left figure is for Bullstofta clone and the right is for OP42 clone.

The specific leaf area (SLA) is the relationship between leaf area and leaf weight and is often used in growth analysis as an important characteristic of a species or variety. However, this parameter is also affected by different growth conditions, especially available light. Being to a large extent an inherent characteristic, SLA was not affected by treatment or cutting length. The differences in SLA between the two clones are significant, (table11, figure 25).

Table 11. ANOVA table for the specific leaf area

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
TREATS	32,716	2	16,358	1,066	0,357
CLONES	168,518	1	168,518	10,986	0,002
TREATS*CLONES	25,440	2	12,720	0,829	0,446
CUTTING LENGTH	0,608	1	0,608	0,040	0,844
Error	475,509	31	15,339		

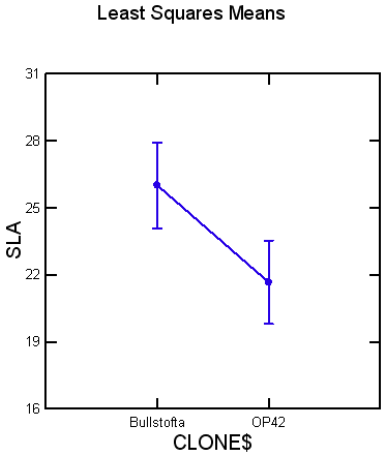

Figure 25. Least squares means for the dependent variable of the specific leaf area. The xlabel represents the two used clones: Bullsofta and OP42.

Net assimilation rate showed no significant differences for any of the treatments. However, a relatively low P-value for clone suggests that also net assimilation rate might be used as a parameter of measuring differences between different poplar varieties (table 12).

Table 12. ANOVA table for the net assimilation rate

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
TREATS	175,547	2	87,773	0,777	0,469
CLONES	348,780	1	348,780	3,086	0,089
TREATS*CLONES	161,932	2	80,966	0,716	0,496
CUTTING LENGTH	7,847	1	7,847	0,069	0,794
Error	3 503,278	31	113,009		

A positive effect of soaking poplar cuttings into NAA solution (or other rooting hormones) is well-known in the literature (Nordine, 1984). In this trial however, no positive effects of pre-treatment with NAA were observed. The pattern of root/shoot ratio in the two clones implies the necessity to test the different concentrations of rooting medium on several clones. This parameter is also important in practical plant propagation as the goal is to produce the plants with larger root/shoot ratio given the desired size of above-ground part of plants.

Conclusions

The success of plantation establishment using poplar cuttings depends mainly on the ability of the cuttings to develop early and vigorous root system.

Normally, pre-soaking stimulates rooting of cuttings of poplar clones increasing the plant survival. In some cases, individual clones do not respond significantly to soaking.

In the greenhouse trial conducted within the frames of this study the results do not support the hypothesis regarding the positive effects of soaking cuttings in NAA.

Another consideration is that the high concentration of added fertilizers might have damaged the roots and caused a negative effect of NAA. According to Hudson & Dale (1975), the application of high concentration of hormones or growth regulators can affect negatively root development.

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ANNEXE 1. Results of the first harvest

Nr	Clone	Treatment	Cutting length mm	Cutting diameter mm	Root no.		Root length mm	Root tip no	Leaf no.	LA cm^2	Shoot length mm	Cutting Weight mg	Root Weight mg	Leaf Weight mg	Shoot Weight mg
					Callus	Cutting									
181	OP42	SNAA	52	11	0	1	76	No data	2	38,7	27	1829	12	198	24
182	Bullstofta	SNAA	54	10	0	0	0	No data	3	36,6	33	1528	24	95	21
183	OP42	SNAA	61	10	0	2	85	No data	2	33,6	21	1519	0	169	25
184	Bullstofta	SNAA	55	10	0	2	36	No data	1	0	8	911	4	0	11
185	OP42	SNAA	53	11	0	0	0	No data	4	23,2	17	1494	0	118	14
186	OP42	SA	57	10	0	2	122	No data	8	84,3	81	2008	30	420	68
187	Bullstofta	SA	47	12	2	4	93	No data	5	56,1	45	1148	22	286	45
188	OP42	SA	56	10	0	5	156	No data	4	59,8	29	1862	42	315	29
189	Bullstofta	SA	55	8	2	5	138	No data	9	73	149	601	39	293	72
190	Bullstofta	SA	59	11	3	6	94	No data	11	74,5	115	1626	41	317	65
191	OP42	SA	49	8	0	4	147	No data	4	22,8	19	886	30	118	19
192	OP42	SA	54	9	1	6	154	No data	5	29,8	38	1217	33	120	22
193	Bullstofta	SA	55	10	0	14	152	No data	12	99,4	161	1437	55	368	94
194	Bullstofta	SA	53	12	0	3	81	No data	12	70,2	118	1724	15	254	58
195	OP42	SA	52	12	1	10	238	No data	11	110,7	151	2339	82	502	108
196	Bullstofta	SNAA	58	10	5	6	139	No data	5	31,9	21	1243	60	211	40
197	OP42	SNAA	60	11	0	4	123	No data	9	76,6	76	1908	18	363	55
198	Bullstofta	SNAA	59	12	0	3	62	No data	5	60,1	46	2166	0	221	38
199	Bullstofta	SNAA	59	10	4	9	137	No data	13	150,7	193	1307	60	607	165
200	OP42	SNAA	58	10	1	4	157	No data	8	66,8	70	1825	38	403	49

201	Bullstofta	SW	57	10	1	9	111	No data	12	134	188	1228	23	451	117
202	Bullstofta	SW	55	10	1	5	47	No data	10	70	109	1225	12	283	55
203	OP42	SW	69	5	0	12	118	No data	10	115,2	184	501	59	508	128
204	Bullstofta	SW	58	10	0	3	143	No data	12	138,7	153	1208	33	504	117
205	OP42	SW	59	9	0	5	126	No data	12	97,5	132	1164	51	436	87
206	Bullstofta	SW	55	10	4	0	33	No data	7	37,3	43	1292	6	137	27
207	OP42	SW	52	7	0	5	144	No data	9	80,4	135	467	43	305	67
208	OP42	SW	54	9	0	5	132	No data	10	52,1	102	1181	46	253	60
209	OP42	SW	56	6	0	4	136	No data	6	37,4	60	584	23	134	21
210	Bullstofta	SW	52	10	2	6	137	No data	6	46,9	77	1209	34	203	60
211	Bullstofta	SW	57	10	0	2	58	No data	5	40	46	1030	9	166	35
212	OP42	SNAA	53	11	0	0	0	No data	2	20	21	1594	0	99	0
213	Bullstofta	SW	56	10	2	8	125	No data	11	98	148	1020	41	325	83
214	Bullstofta	SA	56	11	1	4	160	No data	10	129,5	194	1477	44	507	123
215	Bullstofta	SA	53	9	0	9	138	No data	12	124,4	215	492	48	437	129
216	OP42	SNAA	56	11	2	1	56	No data	8	75,4	99	2076	13	314	58
217	OP42	SNAA	49	11	5	10	89	No data	7	68,1	59	1783	49	379	38
218	OP42	SA	55	8	2	4	129	No data	4	20,6	22	1133	28	96	15
219	Bullstofta	SW	56	9	3	7	129	No data	9	69,1	112	866	48	285	53

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