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IBA Treatment of Poplar Cuttings and Soil Composition Amendment for Improved Adaptability and Survival

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Abstract

Poplar trees from the *Salicaceae* family over the years have been utilized for various reasons which include prevention of deforestation as well as phytoremediation. This study aims to determine the optimal pre-treatment and soil conditions required for propagation of poplar cuttings for increased initial adaptability and survival rate. Five poplar clones (Hanan, 110, 107, DN-34, 52-225) were selected for IBA, soil composition treatments on propagation. IBA pre-treatment of cuttings were utilized 0, 10, and 100 mg l^{-1} concentrations. Soil compositions were amended with TKS-2+perlite 2:1 (v:v) and sandy clay loam mixed with artificial soil. According to the greenhouse results 10 mg l^{-1} of IBA showed a significant increase in plant height whereas 100 mg l^{-1} inhibited plant growth except in clone 110. Soil composition severely affected root growth and hence overall growth of the clones. Sandy clay loam soil had poor to stunted growth compared to TKS-2+perlite.

Key Words: hybrid poplar, soil composition, indolebutyric acid, PGR, pre-treatment

Introduction

Populus, a deciduous tree species belonging to the *Salicaceae* family includes poplar, aspen and cottonwood. These tree species stand out from others due to their fast growing ability. Poplar is mostly native to the Northern Hemisphere however 74 species are distributed around the world especially in temperate and cold regions (Riemenschneider et al. 2001). Due to rapid growth and adaptability poplars are being utilized for preventing desertification as well as phytoremediation purposes (Robinson et al. 2000).

Cutting propagations are commonly used for mass proliferation of poplars. Cutting refers to growing the tree as a complete object by planting in soil the cutting of a particular portion of the tree such as branch, root, bud or leaves. For propagation purposes these trees can be grown in large quantities with the same genetics as the mother tree. This can be achieved in a short period of time with less economic and technological burden hence; poplar is being evaluated as an optimal species for preventing desertification especially in terms of costs and efficiency (Lilley and Walker 1974). China and Mongolia are using poplar as the main tree species for preventing desertification, and JICA (Japan International Cooperation Agency) has reported the achievement of planting poplar in dried desert areas of China (Ichikumi 1994).

Various studies have been conducted on soil types and PGR pre-treatment on cutting propagations (Hodge 2004;

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Harfouche et al. 2007). Genetic variations in the rooting ability of cuttings of different *Populus* species, families and clones have been studied for over half a century worldwide (Polle et al. 2013). Rooting of the cuttings is a complex process regulated by multiple hormones (Achard et al. 2006) and various genetic studies have provided ample evidence to support the role of plant growth regulators in root development (Saini et al. 2013). The most important regulators are auxin and cytokinins (Hausman et al. 1997). The main auxins that influence rooting of poplar cuttings include indole acetic acid (IAA) and indole butyric acid (IBA). IBA is more stable than IAA, and more importantly, IBA can convert to IAA via a mechanism that is similar to fatty acid β-oxidation (Rogg et al. 2001). Hence, the need to study optimal IBA pre-treatment requirements for the various clones under consideration in this study. Alongside pre-treatment conditions, soil composition also plays a crucial role when studying propagation. The two major soil types utilized in this study were sandy clay loam and TKS 2+perlite 2:1 (v:v).

The purpose of this study was to investigate the optimal conditions for pre-treatment and soil composition for propagation of poplar cuttings in order to increase the initial adaptability and overall survival rate of the clones.

Materials and Methods

Experiment materials

Five poplar clones (Hanan, 110, 107, DN-34, 52-225) were selected for examining the influence of IBA pre-treatment and soil type on cutting propagation. The poplar cuttings were taken from the nursery at Dongguk University, Seoul, South Korea, and gotten targeting thick branches of poplar clones with 1-1.5 cm among the shoot from the previous year which was being managed after being introduced to Korea. The length of the cuttings were 15 cm with a 120 cuttings prepared for each clone. Initial planting and experiments were conducted in the greenhouse (elevation 168 m) located in Gaeryu-ri, Pochun-si, Gyeonggi-do.

IBA pre-treatment and soil composition growth characteristics

Collection and preparation of cuttings were made a day before the cuttings, and in order to examine changes in growth according to pre-treatment, the cuttings were dipped in three different concentrations of IBA 0, 10, 100 mg l^{-1} solution for 12 hours after preparation. In order to examine the changes in growth according to soil composition, artificial soil was mixed with TKS-2 (FloraGard Ltd., Oldenvurg, Germany)+Perlite 2:1 (v:v) and sandy clay loam which were filled into seedling boxes (W:H:L 25×60×20 cm). For each treatment condition 20 cuttings (5×4 repeated) were prepared. TKS-2 soil was used because it is a soil conditioner of German FloraGard with excellent moisture and organic matter content, and sandy clay loam .

The growth characteristics of the cuttings for each condition were measured based on plant height, number of leaves, leaf length, leaf width, root length, rhizomes, weight, dry weight of above and underground parts. To measure dry weight, harvested leaves, stems and roots were placed in paper bags and dried for 48 hours at 70°C in a dry-oven and the change in measurements were recorded. T/R ratio was calculated by dividing the dry weight of the above ground parts by the dry weight of the roots.

Chlorophyll fluorescent reactions according to IBA pre-treatment and soil composition

Chlorophyll fluorescent reactions were measured for comparing the physiological characteristics according to the IBA pre-treatment and soil composition. The poplar cuttings were pre-treated with the concentrations of IBA 10 mg l^{-1} solution for 12 hours after preparation and compared fluorescence response values according to soil compositions. The fluorescent reaction values of healthy plants growing in the nursery were used as a control group. For measurement, a continuous source chlorophyll fluorometer, OS 30P, ADC BioScientific Ltd., UK was used, and the measurements was taken by attaching the sample clip that blocks light before measurement against the leaf and after adapting to the dark condition for 20 minutes (Kim et al. 2011). During measurement, 3,000 μmol $m^{-2}s^{-1}$ PAR light was examined. A comparison analysis was made by measuring the variables of initial fluorescent reaction (Fo), maximum fluorescent reaction (Fm), maximum changing value of fluorescent reaction (Fv=Fm−Fo) and photochemical reaction efficiency (Fv/Fm).

Statistical analysis

The data from this experiment are presented as means ± standard deviation obtained from three or more repetitions. One-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test using SPSS Version 21 (IBM Corp., USA) was performed with statistical significance accepted at $p<0.05$.

Results

IBA pre-treatment and growth

Growth characteristics of poplar cuttings according to IBA pre-treatment had shown various values for each measurement feature and each poplar clone (Table 1-5). Especially, plant height increase has shown significantly higher values for all poplar clones in 10 mg l^{-1} IBA treatment groups, and in other clones excluding 110 clones, 100 mg l^{-1} treatment was found to inhibit plant height growth of poplar clones. When IBA is used to promote rooting for initial survival of poplar cuttings, it is determined that it should be dipped for 24 hours in 10 mg l^{-1} to be most effective.

Soil composition and growth

Growth of each poplar clone based on soil composition was distinguishable. In sandy clay loam soil, the growth of all clones had shown poor growth status compared to

Table 1. Effects of soil types and IBA treatment on the cutting growth of Hanan poplar clone

Treatment			Plant height (cm)***	No. of leaves per plant*	Leaf length (cm)***	Leaf width (cm)***	Root length (cm)***	No. of roots per plant***	Root diameter (cm)**
Clone	Soil type	IBA (mg l^{-1})							
Hanan	T+P	0	44.93±6.38[b]	33.33±5.86[a]	7.27±0.15[b]	7.57±0.35[b]	25.40±8.12[abc]	20.67±0.58[b]	2.32±0.89[a]
		10	66.10±3.08[a]	29.33±7.37[ab]	9.73±0.55[a]	9.53±0.67[a]	28.47±7.63[ab]	28.03±2.05[a]	2.27±0.41[a]
		100	44.07±6.90[b]	23.33±9.61[abc]	8.30±0.96[ab]	8.43±1.16[ab]	34.93±5.53[a]	10.33±3.51[d]	2.30±0.36[a]
	SCL	0	12.10±6.42[c]	21.00±4.08[bc]	5.23±1.91[c]	5.15±1.23[c]	17.00±4.35[b]	14.50±4.04[cd]	0.99±0.33[b]
		10	16.30±6.43[c]	21.50±5.45[bc]	4.40±0.76[c]	4.88±0.36[c]	21.03±5.58[bc]	14.00±2.45[cd]	0.71±0.21[b]
		100	9.70±3.14[c]	17.25±3.77[c]	4.58±0.68[c]	4.43±0.64[c]	17.63±3.55[c]	16.25±2.99[bc]	0.71±0.19[b]

Values are means±standard deviation. Means within columns followed by the sameletters are not significantly different level by Duncan's multiple range test.
T+P, TKS-2+Perlite (2:1,v:v); SCL, sandy clay loam.
*Significant at the 5% level. **Significant at the 1% level. ***Significant at the 0.1% level.

Table 2. Effects of soil types and IBA treatment on the cutting growth of 110 poplar clone

Treatment			Plant height (cm)***	No. of leaves per plant*	Leaf length (cm)**	Leaf width (cm)**	Root length (cm)**	No. of roots per plant[ns]	Root diameter (cm)**
Clone	Soil type	IBA (mg l^{-1})							
110	T+P	0	30.87±2.93[c]	28.33±3.51[b]	7.97±1.17[b]	7.43±0.35[b]	40.83±12.10[a]	20.00±6.08	2.30±0.95[a]
		10	55.43±5.38[a]	42.67±8.02[a]	9.37±1.40[b]	8.87±1.98a[b]	42.37±6.14[a]	25.33±3.51	2.49±0.65[a]
		100	43.10±6.06[b]	28.00±8.54[b]	10.90±1.13[a]	10.10±1.65[a]	37.07±1.89[a]	25.67±10.12	2.26±0.24[a]
	SCL	0	15.88±3.88[e]	26.00±5.29[b]	4.98±0.83[c]	4.68±0.91[c]	19.95±5.85[b]	21.00±8.29	1.18±0.33[b]
		10	21.38±5.58[d]	37.75±5.12[ab]	4.95±0.59[c]	4.23±0.32[c]	20.98±2.87[b]	18.50±5.26	1.30±0.15[b]
		100	17.35±5.80[de]	23.75±7.18[b]	5.28±0.30[c]	4.98±0.69[c]	16.63±1.86[b]	13.50±7.77	0.69±0.25[b]

Values are means±standard deviation. Means within columns followed by the same letters are not significantly different level by Duncan's multiple range test.
T+P, TKS-2+Perlite (2:1,v:v); SCL, sandy clay loam; ns, non significant.
*Significant at the 5% level. **Significant at the 1% level.***Significant at the 0.1% level.

Table 3. Effects of soil types and IBA treatment on the cutting growth of 107 poplar clone

Treatment			Plant height (cm)***	No. of leaves per plant[ns]	Leaf length (cm)***	Leaf width (cm)***	Root length (cm)***	No. of roots per plant**	Root diameter (cm)***
Clone	Soil type	IBA ($mg\ l^{-1}$)							
107	T+P	0	70.40±13.18[a]	25.33±6.66	9.93±0.64[a]	9.50±0.10[b]	48.90±5.12[a]	20.33±5.86[ab]	2.56±0.51[a]
		10	59.10±7.13[a]	33.33±8.39	10.47±1.00[a]	9.73±0.67[b]	31.70±7.53[b]	25.00±6.24[a]	2.91±0.45[a]
		100	41.40±9.26[b]	13.67±5.51	11.07±1.36[a]	11.37±0.55[a]	22.30±1.71[c]	16.67±4.73[abc]	1.76±0.47[b]
	SCL	0	14.18±0.31[c]	20.25±6.95	5.85±1.26[b]	5.50±1.75[c]	16.18±2.05[cd]	8.75±4.19[c]	1.15±0.36[bc]
		10	21.00±1.90[c]	26.50±8.23	6.25±0.98[b]	6.13±1.04[c]	18.90±5.34[cd]	15.50±4.80[bc]	0.81±0.38[bc]
		100	15.63±5.94[c]	21.50±11.12	6.05±0.44[b]	5.70±0.24[c]	12.90±3.13[c]	10.50±5.26[b]	1.00±0.51[bc]

Values are means±standard deviation. Means within columns followed by the same letters are not significantly different level by Duncan's multiple range test.
T+P, TKS-2+Perlite (2:1,v:v); SCL, sandy clay loam; ns, non significant.
**Significant at the 1% level. ***Significant at the 0.1% level.

Table 4. Effects of soil types and IBA treatment on the cutting growth of DN-34 poplar clone

Treatment			Plant height (cm)***	No. of leaves per plant*	Leaf length (cm)***	Leaf width (cm)***	Root length (cm)*	No. of roots per plant[ns]	Root diameter (cm)***
Clone	Soil type	IBA ($mg\ l^{-1}$)							
DN-34	T+P	0	55.90±2.69[b]	34.67±8.08[ab]	8.20±0.89[a]	7.20±0.66[b]	23.60±4.92[a]	26.00±2.00	1.64±0.30[a]
		10	67.97±3.12[a]	32.00±11.53[ab]	9.13±0.85[a]	8.03±0.81[ab]	20.67±0.72[ab]	26.00±6.24	1.61±0.09[a]
		100	52.87±8.92[b]	39.33±7.77[a]	9.10±1.93[a]	9.30±2.50[a]	24.73±10.28[a]	21.67±6.03	1.93±0.18[a]
	SCL	0	20.73±6.02[c]	24.25±4.99[bc]	4.78±0.97[b]	4.35±0.74[c]	18.58±3.96[ab]	17.50±5.26	0.71±0.24[b]
		10	26.23±5.51[c]	32.75±4.99[ab]	5.15±0.87[b]	4.68±0.92[c]	13.10±1.78[b]	22.50±10.66	0.54±0.15[b]
		100	28.70±2.53[c]	19.75±5.12[c]	5.43±0.79[b]	4.75±0.57[c]	12.78±2.10[b]	18.75±1.71	0.72±0.11[b]

Values are means ±standard deviation. Means within columns followed by the same letters are not significantly different level by Duncan's multiple range test.
T+P, TKS-2+Perlite (2:1,v:v); SCL, sandy clay loam; ns, non significant.
*Significant at the 5% level. ***Significant at the 0.1% level.

TKS-2+Perlite conditions. In 100 mg l^{-1} IBA treatment for clone 52-225 all cuttings in sandy clay loam were found dead (Table 5).

Growth characteristics of poplar clones

Among the items measured from IBA pre-treatment conditions, growth status of each poplar clone was compared based on plant height which has shown significant differences throughout the poplar clones. Hanan had excellent growth with plant height of 66.1 cm in IBA 10 mg l^{-1} and TKS-2+Perlite soil treatment group (Table 1). For clone 110, IBA pre-treatment had positively influenced growth and had an excellent height of 55.43 cm in 10 mg l^{-1} treatment group (Table 2). Clone 107 had shown the longest shoot growth of 70.4 cm in the control group. Clone 107 also showed significant resulting values along with the control group in IBA 10 mg l^{-1} treatment group whereas in 100 mg l^{-1} treatment group, overall growth was poor (Table 3). Clone DN-34 had shown a significant difference in IBA 10 mg l^{-1} and TKS-2+Perlite soil treatment group with the plant height value of 67.97 cm (Table 4). Clone 52-225 had shown growth of 45.33 cm in IBA 10 mg l^{-1} and TKS-2+Perlite soil treatment group but had poor shoot growth of 23.3 cm in 100 mg l^{-1} IBA treatment (Table 5).

Table 5. Effects of soil types and IBA treatment on the cutting growth of 52-225 poplar clone

Treatment			Plant height (cm)***	No. of leaves per plant[ns]	Leaf length (cm)**	Leaf width (cm)**	Root length (cm)**	No. of roots per plant	Root diameter (cm)
Clone	Soil type	IBA (mg l^{-1})							
52-225	T+P	0	42.07±13.17[a]	15.67±4.16	11.27±0.67[ab]	9.70±0.50[a]	31.90±3.06[ab]	14.67±0.58[ab]	1.79±0.13[b]
		10	45.33±3.86[a]	18.00±5.57	12.57±2.11[a]	10.17±0.96[a]	39.90±8.31[a]	18.67±4.73[ab]	2.60±0.48[a]
		100	23.20±5.41[b]	18.33±1.53	9.23±0.55[bc]	8.07±0.47[bc]	26.80±6.91[bc]	13.00±2.65[ab]	2.06±0.38[b]
	SCL	0	6.78±2.70[c]	13.25±3.59	6.45±1.91[c]	5.88±1.26[c]	14.45±3.88[d]	10.50±4.80[b]	0.44±0.18[c]
		10	6.00±3.43[c]	13.00±2.94	7.10±2.41[c]	7.00±2.34[c]	17.53±7.21[cd]	22.00±8.68[a]	0.82±0.27[c]
		100	-	-	-	-	-	-	-

Values are means±standard deviation. Means within columns followed by the same letters are not significantly different level by Duncan's multiple range test.
T+P, TKS-2+Perlite (2:1,v:v), SCL, sandy clay loam; ns, non significant.
*Significant at the 5% level. **Significant at the 1% level. ***Significant at the 0.1% level.

Table 6. Effect of soil types and IBA treatment on dry weight and T/R ratio for the sum of all poplar clones

Treatment		Dry weight (g)		T/R Ratio[ns] (%)
Soil type	IBA (mg l^{-1})	Above Ground*	Below Ground*	
T+P	0	1.79±0.45[b]	6.85±3.24[b]	3.80±0.87
	10	2.42±0.62[a]	11.28±1.15[a]	5.16±1.22
	100	1.34±0.58[b]	5.24±1.80[b]	4.63±0.64
SLC	0	2.06±0.62[a]	7.76±3.13[b]	4.39±3.17
	10	3.47±2.58[a]	10.70±4.41[ab]	3.98±1.46
	100	1.36±0.77[b]	6.03±2.62[b]	3.58±2.08

Values are means±standard deviation. Means within columns followed by the same letters are not significantly different level by Duncan's multiple range test.
T+P, TKS-2+Perlite (2:1,v:v); SCL, sandy clay loam; ns, non significant.
*Significant at the 5% level.

Dry weight analysis

Although changes in the root length, weight and rhizome according to IBA pre-treatment were expected, no clear significant differences were found in the aboveground and underground dry weights comparison. In addition, it was difficult to confirm the significant influence of IBA pre-treatment on rooting through T/R ratio. This is because when rooting is active, the upper shoot growth is also vigorous. However, in comparison the dry weight sum of all poplar clones in 10 mg l^{-1} IBA pre-treatment had highest dry weight which indicated that 10 mg l^{-1} IBA pre-treatment was effective in increasing the dry weight without the differences in soil composition and clones. Table 6 shows the dry weight and T/R ratio for the sum of all poplar clones in each treatment.

Physiological characteristics according to IBA pre-treatment of the soil composition

After the cuttings, Fo value had increased and Fm value had decreased thus conclusively, it was observed that the Fv/Fm value was either similar or had decreased when compared to the control group. This meant that the cuttings itself act as a stress factor to the plants before adapting after rooting, and like the sandy clay loam, soil lacking the nutrition with high sand content and uneven drainage was thought to strengthen its degree. When examining the characteristics of each clone, Hanan, 110, 107 and DN-34 clones have shown similar values as the control group in TKS-2+Perlite soil. In sandy clay loam, a lower value was observed indicating that the clones were exposed to stress. In the case of clone 52-225, the control group was 0.81 but the measurement value after the cuttings had shown poor values of 0.74 for both TKS-2+Perlite soil and sandy clay loam (Table 7).

Table 7. Effects of soil type and IBA 10 ppm treatment on the Chlorophyll fluorescence of poplar clones

Clone	Soil type	IBA ($mg\ l^{-1}$)	Chlorophyll fluorescence		
			F_o^{ns}	F_m^{ns}	F_v/F_m*
Hanan	Control	0	81.75±5.50	433.00±21.60	0.81±0.02[a]
	T+P	10	74.00±5.70	398.00±43.12	0.81±0.01[a]
	SLC	10	97.25±6.24	399.50±21.61	0.76±0.03[b]
110	Control	0	103.40±6.99	451.20±59.92	0.77±0.02[ab]
	T+P	10	84.60±8.99	389.60±33.85	0.78±0.01[a]
	SLC	10	98.80±16.30	360.20±46.05	0.73±0.03[b]
107	Control	0	74.60±7.37	408.20±33.06	0.82±0.01[a]
	T+P	10	76.80±12.68	334.80±20.58	0.77±0.04[a]
	SLC	10	94.40±4.56	313.60±44.60	0.69±0.05[b]
DN-34	Control	0	98.00±9.54	462.33±24.42	0.79±0.02[a]
	T+P	10	73.80±9.01	363.20±33.81	0.80±0.01[a]
	SLC	10	93.60±7.02	415.60±36.74	0.77±0.02[a]
52-225	Control	0	82.00±4.53	445.40±44.42	0.81±0.03[a]
	T+P	10	94.00±13.02	359.40±35.75	0.74±0.04[b]
	SLC	10	89.80±6.72	348.20±50.93	0.74±0.03[b]

Values are means±standard deviation. Means within columns followed by the same letters are not significantly different level by Duncan's multiple range test.
Control: Nursery T+P, TKS-2+Perlite (2:1,v:v); SCL, sandy clay loam; ns, non significant.
*Significant at the 5% level.

Discussion

Poplar cuttings and rooting promotion

Soil temperature suitable for root cuttings have been determined to be between 10-15°C (Dumant 1979; Hansen 1986), and through this research, the dH_2O dipping treatment during the cutting pre-treatment was found to be effective for generating the potential root vitality of poplar cuttings (Petersen and Phipps 1976; Hansen et al. 1993; Riemenschneider 1997). During the cutting propagation, auxins such as IBA (indole-3butyric acid) and NAA (α-naphthalenneacetic acid) are commonly used to facilitate rooting (Kwak and Jung 1980). However, in the case of poplar, since asexual breeding is more convenient and economical, a study on the treatment of growth regulation is insufficient. Although there are studies which investigated the best optimal conditions for rooting environment by compositely applying the length of cuttings of 4 crossbreed poplar clones with the pre-treatment and methods of various growth regulators (DesRochers and Thomas 2003), a study which was artificially conducted in the environment similar to dry and semi-dry areas with an expectation of low growth is considered insufficient.

PGR effects on cutting propagation

The auxin pre-treatment method consists of dipping process and dressing method. In the dipping process, a variety of results can be seen depending on the relationship between the concentration and dipping time. Generally, cuttings are dipped for a longer period in 100-200 $mg\ l^{-1}$ in concentrations, however in high concentrations of 1,000-2,000 $mg\ l^{-1}$, it was necessary to be effective even with a second of dipping (Cooper 1944). Depending on the species, instant dipping treatment in a high concentration was reported to be effective for improving the rooting ratio (Shim et al. 1993; Cheong 2018), and for poplar cuttings, a need for additional future studies are being raised.

During the cutting propagation, there could be a difference in the growth of plant roots depending on the soil configuration. Especially, the growth of roots is known to be influenced by the physical attributes and physicochemical properties of soil (Yoshida et al. 1992; Kang 1998). Soil porosity and permeability have a positive correlation, and the amount of air existing in soil pores affect the respiration of roots and this was found to influence the overall growth of plants (Choi et al. 2000). In this study, the sandy clay loam soil having relatively small pores and permeability was detrimental to the growth of poplar cuttings.

Soil composition and effects on clone growth

As a result of examining the influence of soil composition on the growth changes of poplar clones' roots, in TKS-2+Perlite cuttings, root length and weight had all shown significant values. Especially the growth values of rhizomes showed high significant differences in all clones. An influence of IBA pre-treatment on the growth changes of poplar clone roots was not as large as the difference in growth according to soil composition.

When examining the above results, cuttings with TKS-2+Perlite soil and IBA 10 ppm pre-treatment were excellent for growth, thus it is thought that efficient poplar clone proliferation having rich biomass can be possible. Cutting treatment with IBA 10 mg l^{-1} for 24 hours had shown some degree of difference depending on the soil composition but it was observed to have a significant effect on the growth of poplar clones. Unstable growth was observed in sandy clay loam.

Fluorescence as a measurement of environmental stress

Fo (Minimum Fluorescence) refers to the minimum fluorescence among the fluorescent reaction generated by elevated chlorophyll molecules of photosystem II antenna before moving to the centre of photosystem II: PS II reaction, and Fm (Maximum Fluorescence) refers to the maximum fluorescence induced by irradiation of saturated light which can completely reduce the amount of light (U et al. 1994; Won et al. 2008). Fv/Fm represents the maximum photochemical efficiency of Photosystem II (Parkhill et al. 2001). Fo, Fm and Fv/Fm can identify the degree of stress on the plant and can be utilized as the measurement standard of physiological seedling quality for each seedling condition, and when the plant undergoes stress, Fo will increase but Fm will decrease (U et al. 1994). The results of Fv/Fm in this study showed significantly lower values in sandy clay loam.

Conclusion

In order to explore the optimal conditions for mass propagation of cuttings, a cutting propagation experiment was conducted by differentiating the growth regulator pre-treatment and soil composition of cuttings. For mass propagation of poplar cuttings, the optimal conditions from this study were concluded as TKS-2+Perlite soil and 10 mg l^{-1} IBA pre-treatment for 24 hours. Even these conditions seems conclusive for now, further pre-treatment studies are required to show the most appropriate pre-treatment and soil conditions for mass propagation of poplar cuttings.

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