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THE EFFECTS OF DIFFERENT FACTORS ON PROPAGATION BY HARDWOOD CUTTINGS OF SOME CONIFEROUS ORNAMENTAL PLANTS

UTJECAJ RAZLIČITIH ČIMBENIKA NA RAZMNOŽAVANJE ZRELIM REZNICAMA NEKIH CRNOGORIČNIH UKRASNIH BILJAKA

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SUMMARY

Chamaecyparis lawsoniana 'Ellwoodii', *Cryptomeria japonica* 'Elegans' and *x Cupressocyparis leylandii* have great importance in terms of usage areas as ornamental plant. The overcoming the problem, that may be encountered in generative propagation of these taxa, using vegetative propagation method are very important for producers dealing with park and garden works. It was investigated that the effects of different greenhouse medium, rooting medium and phytohormones on propagation by hardwood cutting of studied taxa. In this study, three greenhouse medium (Greenhouse-1, 2 and 3 medium), two rooting medium (perlite and peat) and four phytohormones (IBA 1000, IBA 5000, NAA 1000 and NAA 5000 ppm) were selected. The first root and callus formation dates, rooting percentage, callus percentage, root length and the number of roots were determined. The results showed that the highest rooting percentages for *C. lawsoniana* 'Ellwoodii' were obtained as 100% in peat rooting medium (IBA 1000 ppm) at Greenhouse-2 medium and Greenhouse-3 medium and perlite rooting medium (control) at Greenhouse-3 medium. On the other hand, the highest rooting percentages for *C. japonica* 'Elegans' were obtained as 100% in IBA 1000, IBA 5000 and NAA 1000 ppm treatments at Greenhouse-1 medium, while this value for *x C. leylandii* occurred in NAA 5000 ppm treatment (73.33%) at Greenhouse-2 medium, in perlite rooting medium for both. The conditions required for the best rooting in cutting propagation vary according to the species studied, and generally, auxin applications, rooting medium temperature 5 °C higher than air temperature and use of perlite rooting medium can be recommended.

KEY WORDS: Cutting propagation, greenhouse medium, rooting medium, auxin, rooting percentage

1. INTRODUCTION
1. UVOD

Belonging to Cupressaceae family, Port-Orford cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) is famous for its great diversity of cultivars which are frequently used in parks and gardens due to the high ornamental qualities (Dirr, 1990; Mamıkoğlu, 2015). Japanese cedar or cryptomeria (*Cryptomeria japonica* D.Don), a coniferous evergreen indigenous to Japan and southern China, is a member of Taxodiaceae family (Maity and Moktan, 2019). The species thrives in rich, deep, acidic, moist soil but will tolerate heavy clay during dry and wet periods (Dirr, 1990). Since Japanese cedar has a lot of cultivars, it has a wide range of ornamental characteristics and usage areas (Jull et al.,1994). Leyland cypress (*x Cupressocyparis leylandii* Dallim. and A. B. Jackson) is an inter-generic hybrid between macrocarpa cypress (*Cupressus macrocarpa* Hartweg) and Nootka cypress (*Chamaecyparis nootkatensis* (D. Don)

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Spach), and was first found in Leighton park in Wales, where these two species are found (Lindstrom et al., 1997). The species is very popular in the United Kingdom and the European continent, therefore, it can frequently have seen as an ornamental tree in parks and gardens as well as in windbreaks (Blythe, 1989). Leyland cypress which can tolerate various habitat conditions, is a rapidly-growing evergreen tree when young, even on poor soils, and, ultimately, reaching 30 m in height (Lindstrom et al., 1997). The existence of the problems (heterozygosity, infertile seeds and etc.) encountered in the generative propagation of these species, which are of high importance as ornamental plants, reveals the necessity to try different production techniques. In addition, since these species are frequently used in landscape works, parks and gardens, the production of these species in the desired form and quality can be achieved by vegetative propagation. Hence, it is necessary to investigate the vegetative propagation methods of these species for sustainable use.

Because the effectiveness of nursery management is seriously affected by delay in germination, alternative planting materials are required (Akinyele, 2010). Vegetative propagation method might be an excellent alternative for plant production, especially for species that have seminal propagation limitations (Oliveira and Ribeiro, 2013), because of the advantages such as planting uniformity, higher productivity, lower costs, and, above all, year-round plantlet production (Wendling et al., 2016). Vegetative propagation of plants by stem cuttings is one of the most common used to produce new plants. Stem cuttings can be classified as four groups to be hardwood, semi-hardwood, softwood and herbaceous (Hartmann et al., 2002). The method is considered one of the most important plant propagation technique since it is economically viable, simple and fast (Stuepp et al., 2018). There are a lot of factors that can affect the rooting potential of stem cuttings. The induction of roots is a process regulated by environmental and endogenous factors such as plant species, maturity, time of year, specific cultivar needs, the source, position, and type of cutting taken, juvenility and condition of stock plant, wounding or leaf removal, bottom heat, temperature, light, plant growth regulators (especially auxin), carbohydrates, mineral salts and other molecules (Hartmann et al., 2002; Gehlot et al., 2014).

Although plants naturally have the necessary substances for root and shoot formation in the vegetative propagation method (Hartmann et al., 2002), most plants require specific chemicals (growth regulators, mineral components, etc.) for the initiation of cell differentiation and root meristem formation (Erst et. al., 2018). Auxins, one of the plant growth regulator, are efficient inducers of adventitious roots in many woody species (De Klerk et al., 1999). They control growth and development including main root formation, lateral and adventitious root initiation (Stoeckle et al., 2018; Guan et al., 2019). IBA (indole-3-butyric acid), IAA (indole-3-acetic acid) and NAA (α-naphthalene acetic acid) can be stated as the widely used sources of auxins for rooting of cuttings (Fogaça and Fett-Neto 2005). Moreover, Singh et al. (2018) reported that IBA and NAA are still the most widely used auxins for rooting stem cuttings. On the other hand, rooting medium is one of the most important factors for rooting status in cutting propagation (Abebe, 2017; Singh and Chauhan, 2020). In addition, Galavi et al. (2013) reported that good growth medium provides a reservoir for plant nutrients, hold plant available water, and provide a means for gas exchange and good anchorage for the plants. In cutting propagation, perlite and peat are the most commonly used rooting medium. Perlite, which is mostly used by growers as rooting substrates, has moisture retention and good aeration characteristics, sterility and light weight (Hartmann et al., 2002). On the other hand, peat is an organic material generally used in greenhouse cultivation, floriculture, seedling production and similar horticultural works all over the world (Çolak and Günay, 2011). The hypothesis of the study is that there are differences in terms of different greenhouse medium, rooting medium and hormones on propagation by hardwood cuttings of *Chamaecyparis lawsoniana* 'Ellwoodii', *Cryptomeria japonica* 'Elegans' and *x Cupressocyparis leylandii*. Thanks to discover the optimum propagation conditions, the study can guide producers in the process of these taxa's production.

2. MATERIAL AND METHOD
2. MATERIJALI I METODE

Hardwood cuttings taken on March 10, 2016 from the last annual shoots of *Chamaecyparis lawsoniana* 'Ellwoodii', *Cryptomeria japonica* 'Elegans' and *x Cupressocyparis leylandii* stock plants located in Karadeniz Technical University (KTU) Kanuni Campus were used as study material in the present study that was conducted in The Research and Application Greenhouse at Faculty of Forestry, KTU. Cutting materials were obtained from single stock plants of 30 years old for each taxon in order to eliminate genetic variation.

This study was carried out in three greenhouse medium with different conditions using perlite and peat rooting medium. These are Greenhouse-1 medium (GM-1; air temperature at 20±2°C, rooting table temperature at 20±2°C), Greenhouse-2 medium (GM-2; air temperature at 20±2°C, rooting table temperature at 25±2°C) with technological systems, where temperatures are adjusted with an automation system, and Greenhouse-3 medium (GM-3) that is nylon tunnel greenhouse medium without temperature adjustment. Since no temperature regulation was made in Greenhouse-3 medium, the temperature measure-

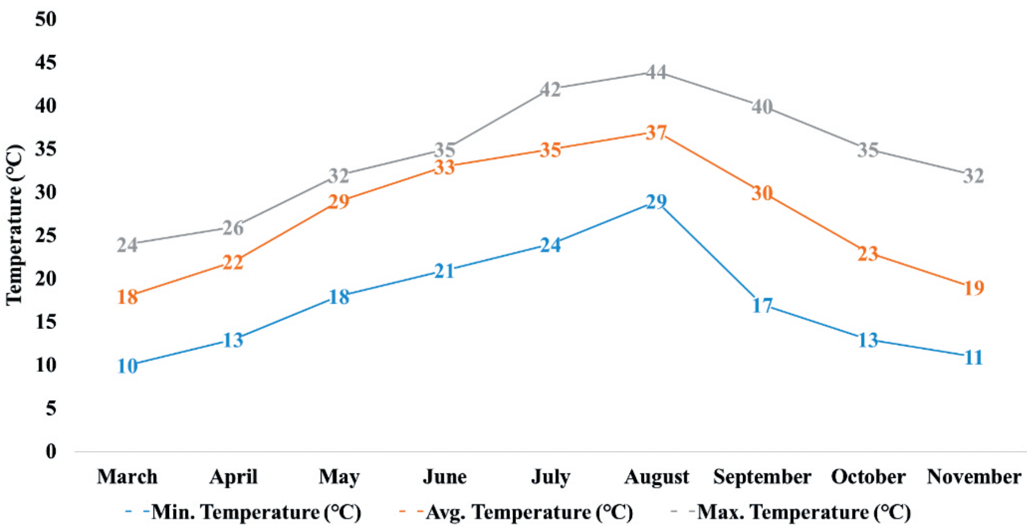

Figure 1. The course of average monthly substrate temperatures in Greenhouse-3 media
Slika 1. Tijek prosječnih mjesečnih temperatura supstrata u Stakleniku-3

ments were taken three times a day (morning, noon and evening) with a thermometer until completion of the study. Monthly temperatures determined in Greenhouse-3 medium are given in Figure 1.

Within the scope of the study, Indole-3-Butyric Acid (IBA) and α-Naphthalene Acetic Acid (NAA) were selected among auxin group hormones in order to encourage the rooting of the cuttings. The phytohormones (PH) prepared in 1000 and 5000 ppm doses were applied to the cuttings in each greenhouse medium (GM) and rooting medium (RM). At this stage, while the cuttings were transferred to the rooting medium, the bottom of the cuttings prepared with a length of 10-12 cm were dipped in powdered hormone prepared in the determined doses. The study was set up to be three replications using "randomised complete block design". For each taxon (*Chamaecyparis lawsoniana* 'Ellwoodii', *Cryptomeria japonica* 'Elegans' and *x Cupressocyparis leylandii*), a total of 900 cuttings were planted to rooting including 720 treatment cuttings (1 taxon x 2 hormones x 2 doses x 3 greenhouse medium x 2 rooting medium x 10 cuttings x 3 replications) and 180 control cuttings (1 taxon x 3 greenhouse medium x 2 rooting medium x 10 cuttings x 3 replications). In addition, on the planted cuttings, the first callus and first root formation dates, rooting percentage (RP), callus percentage (CP), root length (RL) and the number of roots (RN) were determined.

Statistical analysis: Variance analysis and Duncan test were conducted on the obtained data using IBM SPSS 23 statistical program. Analysis of variance (univariate) was used to determine the effects of different greenhouse medium, rooting medium and hormones on measured parameters. Additionally, Duncan test was made to determine the groups that were found in terms of hormones and greenhouse medium for RP, CP, RL and RN.

3. RESULTS
3. REZULTATI

Chamaecyparis lawsoniana 'Ellwoodii' cuttings at the end of 106 days, *Cryptomeria japonica* 'Elegans' cuttings at the end of 109 days and *x Cupressocyparis leylandii* cuttings at the end of 213 days were removed from the whole rooting medium. After 25 days from planting for *C. lawsoniana* 'Ellwoodii', the first callus formations were determined in IBA 1000, IBA 5000, NAA 1000 and NAA 5000 ppm treatments in perlite rooting medium at GM-2, and also in control, NAA 1000 and NAA 5000 ppm treatments in peat rooting medium at GM-2. The first root formations (after 35 days from planting) of *C. lawsoniana* 'Ellwoodii' occurred in IBA 1000, IBA 5000 ppm treatments in peat rooting medium at GM-2. For *C. japonica* 'Elegans', it is determined that the first callus formation occurred at the end of 22 days in IBA 1000, IBA 5000, NAA 1000 and NAA 5000 ppm treatments in perlite rooting medium at GM-2, and the first root formation occurred in IBA 5000 and NAA 5000 ppm treatments after 34 days from planting in the same greenhouse and rooting medium. For *x Cupressocyparis leylandii*, the first callus formation occurred at the end of 29 days in perlite rooting medium at GM-1 (NAA 1000 and NAA 5000 ppm) and GM-2 (IBA 5000 ppm), and in peat rooting medium at GM-3 (NAA 1000 and NAA 5000 ppm). The first root formation occurred at the end of 36 days in NAA 5000 ppm treatment in perlite rooting medium at GM-2. On the rooted cuttings of studied taxa, rooting percentage, callus percentage, root length and the number of roots are given in Table 1 and Table 2 depending on the effects of the different greenhouse medium, rooting medium and hormones.

The highest rooting and callus percentages obtained in different greenhouse, rooting medium and hormones differ depending on the taxa studied. Accordingly, the highest

Table 1. Rooting and callus percentages of studied taxa
Tablica 1. Postotak ukorjenjivanja i kalusa istraživanih svojti

GM (SS)	RM (SU)	PH (F)	*Chamaecyparis lawsoniana* 'Ellwoodii' RP (%) (PZ)	*Chamaecyparis lawsoniana* 'Ellwoodii' CP (%) (PK)	*Cryptomeria japonica* 'Elegans' RP (%) (PZ)	*Cryptomeria japonica* 'Elegans' CP (%) (PK)	*x Cupressocyparis leylandii* RP (%) (PZ)	*x Cupressocyparis leylandii* CP (%) (PK)
Greenhouse-1 Media Supstrat Staklenika-1	Perlite Perlit	Control Kontrola	63.33	23.33	96.67	0.00	26.67	53.33
		IBA 1000	80.00	13.33	100.00	0.00	16.67	63.33
		IBA 5000	90.00	6.67	100.00	0.00	23.33	50.00
		NAA 1000	73.33	16.67	100.00	0.00	16.67	60.00
		NAA 5000	86.67	6.67	96.67	3.33	10.00	50.00
		Average Prosjek	78.67	13.33	98.67	0.67	18.67	55.33
	Peat Treset	Control Kontrola	83.33	13.33	43.33	46.67	20.00	40.00
		IBA 1000	96.67	6.67	53.33	36.67	30.00	36.67
		IBA 5000	93.33	0.00	63.33	26.67	3.33	20.00
		NAA 1000	93.33	3.33	70.00	26.67	26.67	23.33
		NAA 5000	93.33	3.33	60.00	30.00	13.33	43.33
		Average Prosjek	92.00	5.33	58.00	33.34	18.67	32.67
Greenhouse-2 Media Supstrat Staklenika-2	Perlite Perlit	Control Kontrola	53.33	46.67	80.00	6.67	43.33	43.33
		IBA 1000	90.00	10.00	60.00	13.33	40.00	40.00
		IBA 5000	83.33	16.67	83.33	6.67	53.33	30.00
		NAA 1000	93.33	6.67	80.00	10.00	63.33	23.33
		NAA 5000	90.00	10.00	70.00	13.33	73.33	20.00
		Average Prosjek	82.00	18.00	74.67	10.00	54.66	31.33
	Peat Treset	Control Kontrola	90.00	3.33	50.00	20.00	33.33	23.33
		IBA 1000	100.00	0.00	46.67	33.33	50.00	16.67
		IBA 5000	96.67	0.00	63.33	30.00	40.00	33.33
		NAA 1000	90.00	10.00	46.67	30.00	43.33	23.33
		NAA 5000	93.33	6.67	70.00	13.33	30.00	13.33
		Average Prosjek	94.00	4.00	55.33	25.33	39.33	22.00
Greenhouse-3 Media Supstrat Staklenika-3	Perlite Perlit	Control Kontrola	100.00	0.00	53.33	20.00	23.33	53.33
		IBA 1000	63.33	30.00	60.00	6.67	16.67	66.67
		IBA 5000	56.67	40.00	83.33	6.67	23.33	53.33
		NAA 1000	63.33	36.67	70.00	16.67	23.33	60.00
		NAA 5000	53.33	46.67	80.00	3.33	6.67	73.33
		Average Prosjek	67.33	30.67	69.33	10.67	18.67	61.33
	Peat Treset	Control Kontrola	93.33	3.33	83.33	6.67	50.00	30.00
		IBA 1000	100.00	0.00	46.67	6.67	33.33	23.33
		IBA 5000	96.67	3.33	50.00	23.33	30.00	36.67
		NAA 1000	100.00	0.00	63.33	33.33	60.00	26.67
		NAA 5000	90.00	10.00	56.67	10.00	66.67	20.00
		Average Prosjek	96.00	3.33	60.00	16.00	48.00	27.33

Table 2. Root length and the number of roots of studied taxa
Tablica 2. Duljina korjena i broj korjena proučavanih svojti

GM (SS)	RM (SU)	PH (F)	*Chamaecyparis lawsoniana* 'Ellwoodii' RL (cm) (DK)	*Chamaecyparis lawsoniana* 'Ellwoodii' RN (pcs) (BK)	*Cryptomeria japonica* 'Elegans' RL (cm) (DK)	*Cryptomeria japonica* 'Elegans' RN (pcs) (BK)	*x Cupressocyparis leylandii* RL (cm) (DK)	*x Cupressocyparis leylandii* RN (pcs) (BK)
Greenhouse-1 Media Supstrat Staklenika-1	Perlite Perlit	Control Kontrola	6.00	8.17	10.52	4.45	15.65	2.63
		IBA 1000	7.73	8.09	11.01	4.43	11.18	2.20
		IBA 5000	6.08	8.00	10.48	4.40	10.71	3.29
		NAA 1000	7.04	8.00	10.66	4.97	9.90	1.80
		NAA 5000	8.54	9.38	10.59	5.07	13.97	1.00
		Average Prosjek	7.14	8.38	10.65	4.66	12.41	2.39
	Peat Treset	Control Kontrola	7.65	10.08	8.43	4.25	6.17	3.17
		IBA 1000	9.13	9.38	8.34	4.50	7.16	2.63
		IBA 5000	11.64	11.14	7.77	4.36	16.20	2.00
		NAA 1000	11.05	9.39	10.91	4.83	6.28	2.63
		NAA 5000	11.08	9.56	10.93	4.19	9.53	3.00
		Average Prosjek	10.16	9.90	9.48	4.46	7.37	2.77
Greenhouse-2 Media Supstrat Staklenika-2	Perlite Perlit	Control Kontrola	5.28	7.60	8.28	4.70	20.91	3.62
		IBA 1000	7.22	6.96	9.99	4.62	14.70	1.83
		IBA 5000	8.39	9.48	11.69	5.22	14.49	3.00
		NAA 1000	8.10	8.59	9.02	3.91	16.80	3.84
		NAA 5000	9.67	13.62	10.36	4.65	14.78	3.27
		Average Prosjek	7.94	9.39	9.88	4.62	16.15	3.20
	Peat Treset	Control Kontrola	7.16	7.00	12.89	4.45	8.47	2.80
		IBA 1000	9.65	10.50	11.05	4.13	9.47	2.60
		IBA 5000	10.25	7.34	13.41	5.00	9.93	3.17
		NAA 1000	10.89	9.93	12.28	3.45	11.62	2.46
		NAA 5000	9.69	9.61	13.54	5.47	8.49	2.00
		Average Prosjek	9.58	8.92	12.83	4.69	9.74	2.64
Greenhouse-3 Media Supstrat Staklenika-3	Perlite Perlit	Control Kontrola	7.79	17.03	7.49	3.60	11.83	1.83
		IBA 1000	6.38	11.53	9.14	4.44	11.70	3.00
		IBA 5000	4.95	8.40	10.80	4.52	12.06	1.40
		NAA 1000	6.13	8.94	8.78	5.53	17.43	2.29
		NAA 5000	5.87	6.46	10.46	6.00	13.95	3.00
		Average Prosjek	6.47	11.62	9.51	4.87	13.67	2.17
	Peat Treset	Control Kontrola	9.38	12.18	8.29	4.76	7.81	2.07
		IBA 1000	10.61	14.77	9.89	5.62	10.08	2.44
		IBA 5000	8.46	13.00	7.94	4.30	10.03	2.78
		NAA 1000	11.38	13.60	8.72	4.80	8.43	3.67
		NAA 5000	9.61	11.67	8.34	5.93	13.72	3.95
		Average Prosjek	9.92	13.08	8.59	5.08	10.23	3.16

Table 3. Variance analysis (univariate) results related to RP, CP, RL and RN
Tablica 3. Retultati univarijantne analize varijace za povezani s PZ, PK, DK i BK

		Chamaecyparis lawsoniana 'Ellwoodii'		*Cryptomeria japonica* 'Elegans'		*x Cupressocyparis leylandii*	
		F	p	F	p	F	p
RP (PZ)	GM (SS)	87.489	0.000**	506.482	0.000**	1505.587	0.000**
	RM (SU)	2103.040	0.000**	3338.336	0.000**	122.500	0.000**
	PH (F)	42.494	0.000**	130.686	0.000**	62.234	0.000**
	GMxRM	185.595	0.000**	533.813	0.000**	965.832	0.000**
	GMxPH	176.844	0.000**	43.881	0.000**	58.280	0.000**
	RMxPH	5.938	0.000**	27.306	0.000**	79.414	0.000**
	GMxRMxPH	145.146	0.000**	163.651	0.000**	142.576	0.000**
CP (PK)	GM (SS)	152.427	0.000**	47.099	0.000**	765.922	0.000**
	RM (SU)	1901.903	0.000**	2051.333	0.000**	2722.335	0.000**
	PH (F)	23.080	0.000**	34.804	0.000**	24.311	0.000**
	GMxRM	229.531	0.000**	413.932	0.000**	285.772	0.000**
	GMxPH	171.526	0.000**	63.118	0.000**	50.550	0.000**
	RMxPH	6.428	0.000**	26.423	0.000**	42.642	0.000**
	GMxRMxPH	147.068	0.000**	57.196	0.000**	74.725	0.000**
RL (DK)	GM (SS)	3.236	0.040*	14.003	0.000**	2.063	0.129
	RM (SU)	195.637	0.000**	0.452	0.502	20.278	0.000**
	PH (F)	11.144	0.000**	1.796	0.128	0.368	0.831
	GMxRM	7.384	0.001**	13.690	0.000**	1.922	0.148
	GMxPH	7.014	0.000**	1.365	0.209	1.087	0.373
	RMxPH	4.669	0.001**	1.863	0.116	1.980	0.098
	GMxRMxPH	2.548	0.010*	1.070	0.382	0.883	0.531
RN (BK)	GM (SS)	30.814	0.000**	1.785	0.169	0.754	0.471
	RM (SU)	16.090	0.000**	0.024	0.876	0.565	0.453
	PH (F)	0.845	0.497	2.230	0.065	0.183	0.947
	GMxRM	7.645	0.001**	0.590	0.555	2.264	0.106
	GMxPH	9.107	0.000**	2.109	0.033*	1.099	0.364
	RMxPH	5.194	0.000**	0.420	0.794	0.101	0.982
	GMxRMxPH	6.817	0.000**	0.815	0.589	1.074	0.382

* $p < 0.05$ and ** $p < 0.01$ (There is statistically significant difference.)

rooting percentages for *C. lawsoniana* 'Ellwoodii' were obtained as 100% in peat rooting medium at GM-2 (IBA 1000 ppm) and GM-3 (IBA 1000 and NAA 1000 ppm) and perlite rooting medium (control) at GM-3. On the other hand, the highest rooting percentages for *C. japonica* 'Elegans' were obtained as 100% in IBA 1000, IBA 5000 and NAA 1000 ppm treatments in perlite rooting medium at GM-1, while this value for *x C. leylandii* occurred in NAA 5000 ppm treatment (73.33%) in perlite rooting medium at GM-2. When the callus percentages were examined, the highest callus percentages for *C. lawsoniana* 'Ellwoodii' were obtained as 46.67% in perlite rooting medium at GM-2 (control) and GM-3 (NAA 5000 ppm). For *C. japonica* 'Elegans', the highest callus percentage occurring in the control cuttings in peat rooting medium at GM-1 with 46.67%, occurred as 73.33% in NAA 5000 ppm treatment in perlite rooting medium at GM-3 for *x C. leylandii*.

In terms of the longest root length and the highest number of roots, there is again difference depending on greenhouse, rooting medium and hormones. The longest root length for *C. lawsoniana* 'Ellwoodii' were obtained in IBA 5000 ppm (11.64 cm) in peat rooting medium at GM-1. Although the highest number of roots for this taxon was obtained as 17.03 roots in the control cuttings in perlite rooting medium at GM-3, 14.77 roots obtained in the IBA 1000 ppm treatment in the same greenhouse medium were found to be close to this value. For *C. japonica* 'Elegans', the longest root length and the highest number of roots were obtained as 13.54 cm and 6.00 roots in NAA 5000 ppm tre-

Table 4. Duncan test results related to RP, CP, RL and RN
Tablica 4. Rezultati Duncanovog testa za PZ, PK, DK i BK

			RP (%) (PZ)	CP (%) (PK)	RL (cm) (DK)	RN (pcs) (BK)
Chamaecyparis lawsoniana 'Ellwoodii'	GM (SS)	GM-1 (SS-1)	85.33 **b**	9.33 **c**	8.79 **a**	9.22 **b**
		GM-2 (SS-2)	88.00 **a**	11.00 **b**	8.81 **a**	9.14 **b**
		GM-3 (SS-3)	81.67 **c**	17.00 **a**	8.53 **a**	12.50 **a**
	PH (F)	Control (Kontrola)	80.55 **d**	15.00 **a**	7.46 **c**	10.93 **a**
		IBA 1000	88.33 **a**	10.00 **c**	8.66 **b**	10.31 **ab**
		IBA 5000	86.11 **b**	11.11 **bc**	8.62 **b**	9.72 **b**
		NAA 1000	85.55 **bc**	12.22 **b**	9.41 **a**	9.95 **ab**
		NAA 5000	84.44 **c**	13.89 **a**	9.35 **a**	10.37 **ab**
Cryptomeria japonica 'Elegans'	GM (SS)	GM-1 (SS-1)	78.33 **a**	17.00 **a**	10.24 **b**	4.60 **a**
		GM-2 (SS-2)	65.00 **b**	17.67 **a**	11.09 **a**	4.64 **a**
		GM-3 (SS-3)	64.67 **b**	13.33 **b**	9.08 **c**	4.96 **a**
	PH (F)	Control (Kontrola)	67.78 **c**	16.67 **b**	9.27 **b**	4.43 **b**
		IBA 1000	61.11 **d**	16.11 **b**	9.98 **ab**	4.61 **ab**
		IBA 5000	73.89 **a**	15.56 **b**	10.60 **a**	4.66 **ab**
		NAA 1000	71.67 **b**	19.45 **a**	9.97 **ab**	4.63 **ab**
		NAA 5000	72.22 **b**	12.22 **c**	10.78 **a**	5.23 **a**
x Cupressocyparis leylandii	GM (SS)	GM-1 (SS-1)	18.67 **c**	44.00 **a**	10.08 **b**	2.57 **a**
		GM-2 (SS-2)	47.00 **a**	26.67 **b**	13.50 **a**	2.96 **a**
		GM-3 (SS-3)	33.33 **b**	44.33 **a**	11.11 **b**	2.90 **a**
	PH (F)	Control (Kontrola)	32.78 **b**	40.55 **a**	12.26 **a**	2.72 **a**
		IBA 1000	31.11 **c**	41.11 **a**	10.74 **a**	2.40 **a**
		IBA 5000	28.89 **d**	37.22 **b**	11.86 **a**	2.86 **a**
		NAA 1000	38.89 **a**	36.11 **b**	12.22 **a**	3.10 **a**
		NAA 5000	33.33 **b**	36.67 **b**	13.20 **a**	3.19 **a**

atments in peat rooting medium at GM-2 and in perlite rooting medium at GM-3, respectively. The longest root length determined in control cuttings (20.91 cm) in perlite rooting medium at GM-2 for *x C. leylandii* was followed by NAA 1000 ppm treatment (16.80 cm) in the same greenhouse and rooting medium. In addition, the highest number of roots related to this taxon was obtained as 3.95 roots in NAA 5000 ppm treatment in peat rooting medium at GM-3. The results of variance analysis (univariate) of GM, RM, H and the interactions of GM x RM, GM x PH, RM x PH and GM x RM x PH in terms of RP, CP, RL and RN regarding the studied taxa are given in Table 3.

When the variance analysis results are examined, there are statistically significant differences ($p<0.01$) in GM, RM, PH and GM x RM, GM x PH, RM x PH and GM x RM x PH interactions of the studied taxa in terms of rooting and callus percentages. As a result of the variance analysis of root length data obtained for *C. lawsoniana* 'Ellwoodii', statistical differences at 99% confidence level emerged in terms of RM, PH and GM x RM, GM x PH, RM x PH interactions, and at 95% confidence level emerged in terms of GM and GM x RM x PH interaction. There were statistically significant differences ($p<0.01$) with regard to the number of roots of this taxon in terms of all factors and interactions except H. For *C. japonica* 'Elegans', statistical differences were found in GM and GM x RM interaction ($p<0.01$) in terms of root length, and only in GM x PH interaction ($p<0.05$) in terms of root number. While no statistical difference occurred in terms of root number for *x C. leylandii*, there was a statistical difference in terms of root length only in RM at 99% confidence level. The Duncan test results for the groups formed as a result of the statistical differences obtained in terms of RP, CP, RL and RN regarding the taxa studied and the graphs of the relationship between the greenhouse medium, rooting medium and hormones in terms of rooting percentages are given in Table 4 and Figure 2, respectively. The resulting groups have emerged as a result of the combination of the results obtained in perlite and peat rooting medium depending on the greenhouse medium and hormones.

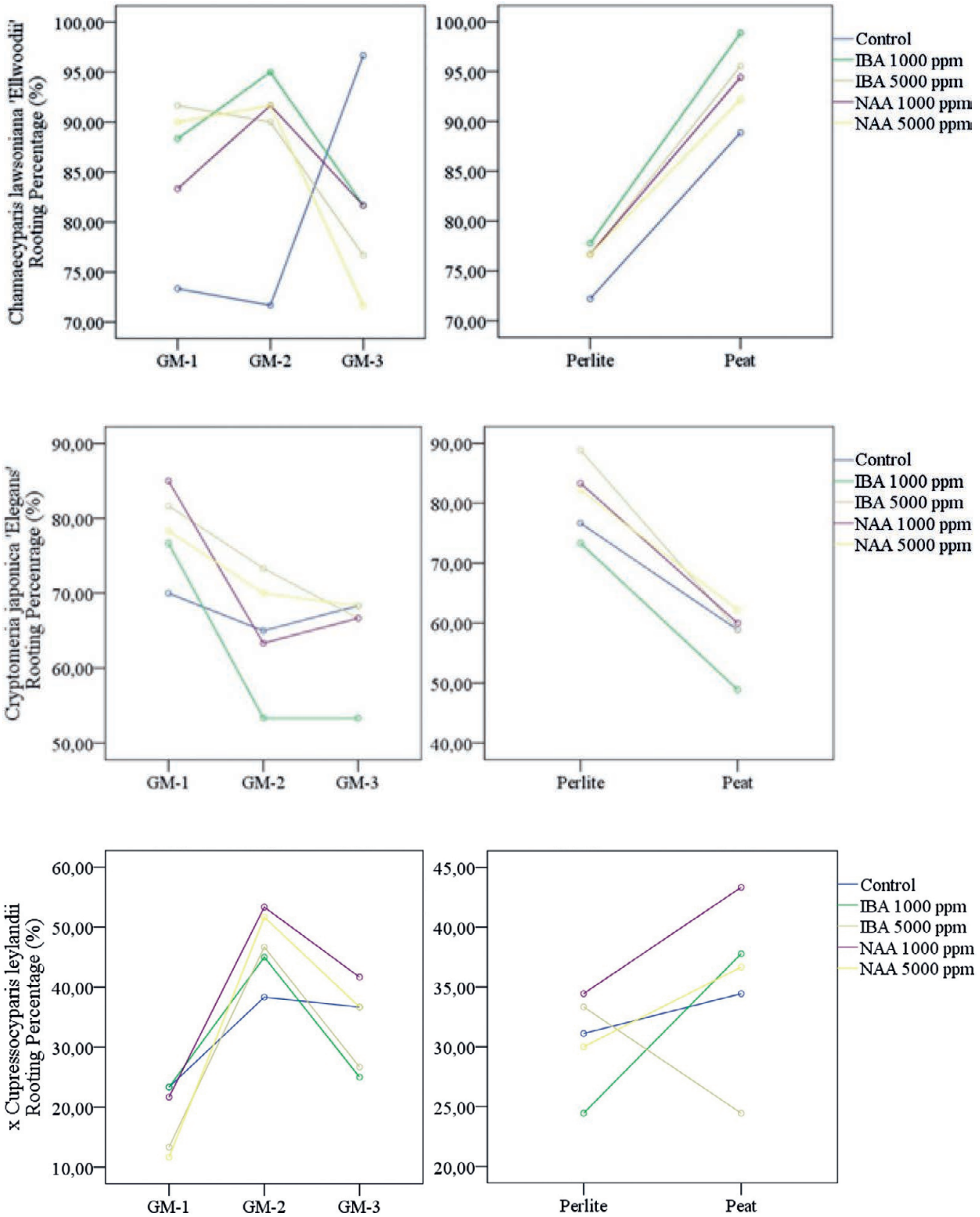

Figure 2. The relationships between the greenhouse media, rooting media and hormones in terms of rooting percentages related to studied taxa
Slika 2. Odnosi između stakleničkih uvjeta, supstrata za ukorjenjivanje i fitohormona u smislu postotka ukorjenjivanja povezanih s istraživanim svojtam

For *C. lawsoniana* 'Ellwoodii', there were three different groups in greenhouse medium in terms of RP, while GM-2 formed the first group with the highest value. On the other hand, five different groups occurred in hormones, and while IBA 1000 ppm treatment formed the first group, the control treatment formed the last group. For *C. japonica* 'Elegans', two different groups emerged in terms of RP, GM-1 alone formed the first group, GM-2 and GM-3 together formed the second group. In terms of hormones, IBA 5000 ppm treatment formed the first group. For *x C. leylandii*, all three greenhouse medium were in different groups in terms of RP, and GM-2 constituted the first group. Four different groups occurred in hormones. Accordingly, while NAA 1000 ppm treatment formed the first group, IBA 5000 ppm treatment formed the last group.

4. DISCUSSION
4. RASPRAVA

As a result of the study investigating the effects of the greenhouse medium, rooting medium and hormones on the propagation by hardwood cuttings of *Chamaecyparis lawsoniana* 'Ellwoodii', *Cryptomeria japonica* 'Elegans' and *x Cupressocyparis leylandii*, a well-known fact was once again determined. Accordingly, each taxon has different responses to the applied factors. The first root formations (after 35 days from planting) of *C. lawsoniana* 'Ellwoodii' occurred in IBA 1000, IBA 5000 ppm treatments in peat rooting medium at GM-2. For this taxon, the highest rooting percentages occurred as 100% in peat rooting medium at GM-2 (IBA 1000 ppm) and GM-3 (IBA 1000 and NAA 1000 ppm) and perlite rooting medium (control) at GM-3. In addition, the highest callus percentage with 46.67% was formed in perlite rooting medium in GM-2 (control) and GM-3 (NAA 5000 ppm). On the one hand, for *C. lawsoniana* 'Ellwoodii', the longest root length was obtained in IBA 5000 ppm (11.64 cm) in peat rooting medium at GM-1, on the other hand, the highest number of roots for this taxon was obtained as 17.03 roots in the control cuttings in perlite rooting medium at GM-3. In a research conducted by Stumpf et al. (1999) on cutting propagation of *Chamaecyparis lawsoniana* reported that the highest results were obtained in cuttings treated with the solution of IBA 10000 ppm in vermiculite medium in terms of rooting percentage (99%), the number of roots (14.9 roots) and root length (12.03 cm). In another study conducted on this species, the highest rooting percentage and the highest number of roots were achieved in vermiculite medium as 84% and 3.6 roots, respectively (Stumpf et al., 2001). In a study conducted by Iliev et al. in 2010 on the cutting propagation of 'Columnaris', 'Potentii', and 'Golden Wonder' cultivars of *Chamaecyparis lawsoniana*, the highest rooting percentages were obtained in the cuttings taken from 'Columnaris' cultivar in March and treated with 0.5% and 0.8% IBA (95%), in the cuttings taken from 'Potentii' cultivar in November and treated with 0.8% IBA (95%), in the cuttings taken from 'Golden Wonder' cultivar in March and treated with 0.8% IBA (60%). When compared with this study, similar results were obtained in terms of rooting percentage and differences were observed in terms of root length and the number of roots. In addition, in case of propagation by hardwood cuttings, when the propagation conditions determined by this study are met, root formation has occurred at the end of about one month, which shows that it is possible to produce taxon quickly with this method.

For *Cryptomeria japonica* 'Elegans', it is determined that the first root formation occurred in IBA 5000 and NAA 5000 ppm treatments after 34 days from planting in perlite rooting medium at GM-2. While the highest rooting percentages for this taxon were obtained as 100% in IBA 1000, IBA 5000 and NAA 1000 ppm treatments at GM-1, the highest callus percentage occurred in the control cuttings in peat rooting medium at GM-1 with 46.67%. Additionally, the longest root length (13.54 cm) and the highest number of roots (6.00 roots) were obtained in NAA 5000 ppm treatments in peat rooting medium at GM-2 and in perlite rooting medium at GM-3, respectively. Jull et al. (1994) found that the highest rooting percentage occurred in hardwood and semi-hardwood cuttings with 87% and 78%, respectively. They also stated that while IBA had no effect on softwood cuttings, it influenced rooting percentage, the number of roots, total root length, root area, and root dry weight of semi-hardwood, hardwood, and pre-budbreak cuttings, except for root dry weight of semi-hardwood cuttings. The obtained in IBA 1000, IBA 5000 and NAA 1000 ppm treatments in perlite rooting medium at GM-1 in the present study, 100% rooting percentage shows the effectiveness of the auxin hormones used.

The first root formation obtained for *x Cupressocyparis leylandii* was determined at the end of 36 days in NAA 5000 ppm treatment in perlite rooting medium at GM-2. The highest rooting percentage for this taxon was obtained as 73.33% in NAA 5000 ppm treatment in perlite rooting medium at GM-2. For *x C. leylandii*, the longest root length determined in control cuttings (20.91 cm) in perlite rooting medium at GM-2 was followed by NAA 1000 ppm treatment (16.80 cm) in the same greenhouse and rooting medium. Moreover, the highest number of roots was obtained as 3.95 roots in NAA 5000 ppm treatment in peat rooting medium at GM-3. In the study on this taxon, Silva et al. (2005) obtained the highest rooting percentage as 63.9% in cuttings applied with double wounding and IBA 10000 ppm. They also found that cuttings (4.5 roots) treated with IBA 10000 ppm formed significantly more roots than untreated (2.6 roots). In another study investigating the effects of indole butyric acid and wounding on the vegetative propagation of Leyland cypress, the highest values in the measurement performed at the end of 4 months were obtained with wounding and IBA 13000 ppm with a rooting rate of 27%, 0.17 average roots and 14.3 mm average length of the main root per rooted cutting (Collado et al., 2010). In our study, compared to the studies conducted on this taxon, with low doses of hormone applications, much higher rooting percentage and higher quality individuals in terms of morphological characteristics were obtained. There are a lot of studies, including researches conducted by Vakouftsis et al. (2009) on *Cupressus macrocarpa* 'Goldcrest', Bayraktar et al. (2018a) on *Taxus baccata*, Ion (2011) on *Spiraea salicifolia*, Ciriello and Mori (2015) on *Calophyllum brasiliense*, Bayraktar et al. (2018b) on *Elaeagnus umbellata*, Swarts et al. (2018) on *Lobostemon fruticosus*, Erken and Özzambak (2020) on *Chamaecytisus hirsutus* and Yildirim et al. (2020) on *Salix* *anatolica*, investigating the effects of different factors on the vegetative propagation of coniferous and deciduous. What all these studies have in common is that the use of auxin increases rooting status in all of them.

5. CONCLUSION
5. ZAKLJUČAK

As a result of the present study, while the highest rooting percentage for *Chamaecyparis lawsoniana* 'Ellwoodii' and *x Cupressocyparis leylandii* was obtained in GM-2 where the rooting table temperature was five degrees higher than the air temperature, the highest rooting percentage for *Cryptomeria japonica* 'Elegans' was obtained in GM-1 where rooting table temperature and air temperature were the same. Since the studied taxa show very different rooting characteristics against different rooting factors, each taxon should be evaluated within itself. In addition, other factors that may affect rooting status, for example, different rooting table temperatures, different active substance and phytohormones doses, different rooting medium or their mixtures are investigation material for future studies. This study, in which the best production conditions are investigated for *Chamaecyparis lawsoniana* 'Ellwoodii', *Cryptomeria japonica* 'Elegans' and *x Cupressocyparis leylandii*, is a guiding feature for the producers in order to ensure the sustainable utilization of these taxa widely used in especially parks and gardens due to their beautiful appearance.

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SAŽETAK

Chamaecyparis lawsoniana 'Ellwoodii', *Cryptomeria japonica* 'Elegans' i *x Cupressocyparis leylandii* od velike su važnosti s obzirom na njihovo područje uporabe kao ukrasnog bilja. Prevladavanje problema s kojim se može susresti u generativnoj reprodukciji ovih svojti vegetativnim načinom razmnožavanja vrlo je važno za proizvođače koji se bave parkovnim i vrtnim radovima. Istražen je utjecaj različitih stakleničkih supstrata (SS), supstrata za ukorjenjivanje (SU) i fitohormona (F) na razmnožavanje reznicama proučavanih svojti. U ovom istraživanju odabrana tri staklenička medija (Staklenik-1, 2 i 3), ????dva supstrata za ukorjenjivanje (perlit i treset) i dvije aktivne tvati fitohormona (IBA i NAA) s dvije koncentracije ppm (1000 i 5000 ppm). Određeni su datumi nastanka prvog korijena i kalusa, postotak zakorjenjivanja (PZ), postotak kalusiranja (PK), ukupna duljina korijena (DK) i broj korijena (BK). Rezultati su pokazali da su najviši postoci (100%) ukorjenjivanja zabilježeni kod *C. lawsoniana* 'Ellwoodii' u supstratu od treseta (IBA 1000 ppm) na podlogama staklenika-2 i podlogama staklenika-3 i podlogu za ukorjenjivanje perlita (kontrola) na stakleniku-3 mediji. S druge strane, najveći postotak ukorjenjivanja za *C. japonica* 'Elegans' dobiven je kao 100% u tretmanima IBA 1000, IBA 5000 i NAA 1000 ppm na podlogama SS-1, dok se ova vrijednost za *x C. leylandii* dogodila u tretmanu NAA 5000 ppm (73.33%) na podlogama SS-2, u medijima za ukorjenjivanje perlita za oba. Uvjeti potrebni za najbolje ukorjenjivanje u razmnožavanju zrelim reznicama razlikuju se ovisno o istraživanim svojstama, a općenito se mogu preporučiti primjena auksina, temperatura supstrata za ukorjenjivanje 5 °C viša od temperature zraka i uporaba perlita za ukorjenjivanje.

KLJUČNE RIJEČI: Razmnožavanje reznicama, supstrati za staklenike, supstrat za ukorjenjivanje, auksin, postotak ukorjenjivanja