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Vegetative propagation of *Ulmus villosa* Brandis and *Ulmus wallichiana* Planchon: optimizing plant growth regulators and growing media on root formation in hardwood stem cuttings

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***Ulmus villosa* and *Ulmus wallichiana* are agroforestry tree species of the Kashmir valley, India. Low viability and less longevity of the seeds limit their propagation. The hardwood stem cuttings of both species were propagated in growing medium (soil, sand and a mixture of cocopeat : vermiculite : perlite) and treated with different indole-butyric acid (IBA) concentrations. The results showed maximum sprouting, rooting, survival, shoot length, root length, and leaf area at 2500 and 2000 ppm IBA for *U. villosa* and *U. wallichiana* respectively. Moreover, with cocopeat : vermiculite : perlite 2 : 1 : 1, significant results were observed in both the species. The interaction between planting media and IBA concentration showed significant variance.**

Keywords: Growing media, indole-butyric acid, stem cuttings, *Ulmus villosa*, *Ulmus wallichiana*, vegetation propagation.

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ELMS are common worldwide, generally distributed in the temperate regions of the Northern Hemisphere, subtropics of Central America and Southeast Asia[1]. A total of 35 species are distributed throughout the world, but only 5 are reported in the Indian subcontinent, viz. *Ulmus wallichiana*, *Ulmus villosa*, *Ulmus pumila*, *Ulmus chumlia* and *Ulmus lanceifolia*. Two species, namely *U. wallichiana* and *U. villosa* have been reported from the Kashmir valley, India, but show low regeneration in the forests due to rare seed availability[2].

Ulmus villosa Brandis is a deciduous tree popularly called marinoo in India[3]. The tree shows scattered distribution in Northwestern Himalayas and grows up to 20–30 m in height at an altitude ranging from 1200 to 2500 m amsl (ref. 4). It is considered an important agroforestry tree species, but irrespective of its multi-purpose advantages meagre research thrust has been given on the quantitative or qualitative development and mass production of the species[5].

Ulmus wallichiana Planchon, famous as Kashmiri elm, Bhutan elm or Himalayan elm, is found at elevations ranging from 800 to 3000 m amsl, distributed from Nuristan in Afghanistan, northern Pakistan and India to western Nepal. The species is widely distributed in Kashmir, especially found in Dachigam, Tangmarg, Babareshi, Pahalgam, Chandanwari and Verinag[3]. The Himalayan elm can reach up to a height of 30 m with distinct greyish-brown trunk furrowed longitudinally, broad crown region and branches grow in ascending fashion[3]. Naturally the elm tree shows sexual mode of propagation through seeds, but the seeds of *U. wallichiana* are either empty or exhibit less longevity, which results in low availability for afforestation. Like *U. villosa*, *U. wallichiana* is source of fuel, timber and is reported to have the potential to prevent and treat osteoporosis[6].

In order to overcome the propagation barrier through seed multiplication, vegetative propagation has been a thrust area in the recent past. Vegetative propagation through stem cuttings can be used to select superior varieties of *U. villosa* and *U. wallichiana* for planting. One of the critical aspects for propagation by stem cuttings is the root development process which is influenced by the plant growth regulators, especially by the root-stimulating agents. They play a crucial role in root development in difficult-to-root plants, improving rooting percentage in cuttings and decreasing rooting time[7].

The choice of rooting medium is one of the most important factors for achieving optimum rooting in the shortest time. It is important to choose the correct rooting medium to get optimum rooting in the shortest time. Peat moss is the most commonly used peat in horticulture[8]. It is reported that peat moss improves the physical characteristics of the soil, such as porosity and water-holding capacity[9].

The aim of this study was to analyse the impact of growth regulators and growing media on the rooting of *U. villosa* and *U. wallichiana* hardwood stem cuttings.

The study was carried out at the Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-Kashmir) located at Benhama, Ganderbal, to examine the effect of planting medium and indole-butyric acid (IBA) concentration on the rooting ability of stem cuttings of *U. villosa* and *U. wallichiana*. These cuttings were collected in February from young trees of 9 inches length and pencil size diameter[10]. The 5 cm leaf basal portion of each cutting was removed and treated with fungicide (1% captan) and 1% sucrose followed by growth hormone treatment, viz. 0, 500, 1000, 1500, 2000 and 2500 ppm concentration of IBA solution to a depth of 2 cm (quick deep 1 min) using the methodology of Blazich[11]. The treated cuttings were cultivated into a 780 cm^3 polyethylene propagating container filled with four media, viz. soil, sand, mixture of cocopeat : vermiculite : perlite (1 : 1 : 1 by vol.) and mixture of cocopeat : vermiculite : perlite (2 : 1 : 1 by vol.). The experimental design used was a complete block design with ten cuttings for each of the four replications. Thirteen weeks after the experiment was initiated, the cuttings were harvested and observations were recorded for rooting percentage, survival percentage, root length (cm), shoot length (cm) and leaf area (cm^2) (Figure 1). The statistical analysis and means comparison was done using SPSS software.

Tables 1 and 2 and Figures 2 and 3 reveal that IBA concentration and growing media had a significant influence on sprouting, rooting and survival percentage in the hardwood cuttings of *U. villosa*. The maximum sprouting, rooting and survival percentage were observed in T_5 (2500 ppm IBA) and propagated in cocopeat + vermiculite + perlite (2 : 1 : 1). While minimum was observed in soil and T_6 (control).

Based on the analysis of variance (Table 2) highest shoot length, root length and leaf area were observed in cuttings treated with T_5 (2500 ppm IBA) and grown in cocopeat + vermiculite + perlite (2 : 1 : 1). However, least was observed in T_6 (control) and soil. Data generated on interaction effects of IBA concentration and growing media on rooting percentage, shoot length, root length and leaf area showed a significant effect, while sprouting showed non-significant interactions of *U. villosa*. Hardwood stem cuttings of *U. wallichiana* treated with 2000 ppm IBA concentration and propagated in mixture of cocopeat + vermiculite + perlite (2 : 1 : 1) recorded significantly highest mean number of cuttings that developed roots, sprouted shoots and survived shoots compared to those treated with 0% IBA (control) and propagated in the soil (Table 2).

The length of roots, shoots and leaf area per sprouted stem cutting of *U. wallichiana* were significantly influenced ($P < 0.001$) by rooting media and IBA concentration (Table 3). The maximum root length, shoot length and leaf area per sprouted stem cutting were observed in 2000 ppm IBA concentration when propagated in cocopeat + vermiculite + perlite (2 : 1 : 1). In contrast, minimum was recorded in control when propagated in the soil. In addition, significant influence on sprouting, rooting, survival, shoot length, root length and leaf area was noted during the interaction of IBA and different growing media combinations (Table 4).

It was reported that stem cuttings of *Warburgia ugandensis* treated with 0.8% w/w IBA hormone concentration and propagated in milled pine bark yielded the highest mean number of cuttings that formed callus, developed roots and sprouted shoots[12]. The highest number of shoot leaf and shoot dry weight of *Ligustrum ovalifolium* cutting was recorded when propagated in a mixture of sand : loamy soil : peat moss and treated with IBA concentration of 3000 mg l^{-1} (ref. 13). Similar results were reported in an experiment on *Massularia acuminata* with highest number of roots, rooting, shoot length and root length in level 2 IBA/coconut water (500 ppm/25%). While the highest number of roots and maximum root length were recorded at hormone concentrations NAA 1500 ppm and IBA in 1000 ppm (ref. 14). Also, IBA has been found to be the best rooting hormone in case of many other tree species[15–18]. The reason being that the auxins have been reported to influence rooting through the translocation of carbohydrates and many other nutrients to the rooting zone required for root growth and development[19]. Moreover, emergence of adventitious roots through cell division, multiplication, elongation and specialization is also governed by the plant growth substances, particularly auxins[20]. This clearly indicates that treating stem cuttings with auxins can increase the percentage of rooting, root initiation and number of roots, and length of roots. Application of optimal hormone concentration is important for successful rooting of the cuttings[21]. In *U. wallichiana*, the decline in rooting percentage with IBA concentration greater than 2000 ppm is also a clear indication that some hormone concentrations are inhibitory to root initiation[22]. All characters increased when cuttings of both the species were propagated in cocopeat + vermiculite + perlite (2 : 1 : 1). This could be due to the high

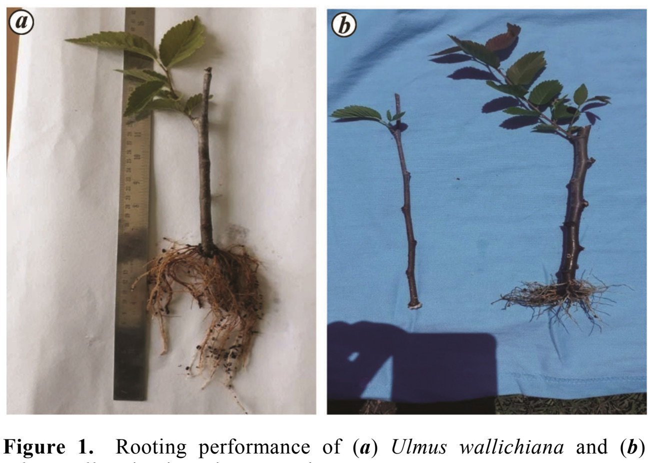

Figure 1. Rooting performance of (***a***) *Ulmus wallichiana* and (***b***) *Ulmus villosa* hardwood stem cuttings.

Table 1. Effect of indole-butyric acid (IBA) concentration and growing media on sprouting, rooting and survival per cent of hardwood stem cuttings of *Ulmus villosa*

Characters	IBA concentration	Growing media (GM)				IBA effect
		Soil	Sand	Cocopeat + vermiculite + perlite (1 : 1 : 1)	Cocopeat + vermiculite + perlite (2 : 1 : 1)	
Sprouting (%)	T_1 (500 ppm)	65.00	68.25	72.50	74.25	70.00
	T_2 (1000 ppm)	68.25	71.00	77.63	80.75	74.41
	T_3 (1500 ppm)	75.00	76.75	81.50	86.25	79.88
	T_4 (2000 ppm)	86.25	85.50	91.75	93.25	89.19
	T_5 (2500 ppm)	88.75	94.75	96.75	98.25	94.63
	T_6 (control)	55.50	59.00	60.50	67.00	49.00
	GM effect	70.79	74.38	78.44	81.13	
Rooting (%)	T_1 (500 ppm)	63.00	66.75	68.75	71.75	67.56
	T_2 (1000 ppm)	65.50	70.25	72.75	77.50	71.50
	T_3 (1500 ppm)	74.00	75.75	80.50	85.75	79.00
	T_4 (2000 ppm)	83.75	85.00	90.75	92.50	88.00
	T_5 (2500 ppm)	86.00	89.50	91.50	96.50	90.88
	T_6 (control)	41.05	50.25	51.00	54.00	49.00
	GM effect	68.88	72.92	75.88	79.67	
Survival (%)	T_1 (500 ppm)	62.00	66.00	68.25	71.25	66.88
	T_2 (1000 ppm)	65.50	69.75	72.50	77.50	71.31
	T_3 (1500 ppm)	72.25	75.25	80.05	82.75	77.58
	T_4 (2000 ppm)	83.63	85.00	90.25	90.25	87.28
	T_5 (2500 ppm)	86.00	87.50	91.50	95.65	90.16
	T_6 (control)	41.05	46.50	50.00	54.00	47.89
	GM effect	67.88	71.67	75.43	78.57	
CD ($P \leq 0.05$)						
GM		1.76	1.81	2.14		
IBA concentration		1.44	1.48	1.74		
GM × IBA		N.S	3.63	N.S		

Table 2. Effect of IBA concentration and growing media on shoot length, root length and leaf area success of hardwood stem cuttings of *U. villosa*

Characters	IBA concentration	Growing media (GM)				IBA effect
		Soil	Sand	Cocopeat + vermiculite + perlite (1 : 1 : 1)	Cocopeat + vermiculite + perlite (2 : 1 : 1)	
Shoot length (cm)	T_1 (500 ppm)	18.08	20.43	57.15	55.78	37.86
	T_2 (1000 ppm)	18.38	20.65	58.08	59.78	39.22
	T_3 (1500 ppm)	24.68	31.78	63.29	65.67	46.35
	T_4 (2000 ppm)	41.75	56.68	75.73	75.98	62.53
	T_5 (2500 ppm)	47.63	60.78	76.68	80.10	66.29
	T_6 (control)	14.00	16.50	38.00	45.50	28.55
	GM effect	26.25	35.13	59.32	60.63	
Root length (cm)	T_1 (500 ppm)	7.75	16.98	19.63	21.38	16.43
	T_2 (1000 ppm)	8.25	16.63	19.38	23.50	16.94
	T_3 (1500 ppm)	10.63	21.63	20.98	23.76	19.25
	T_4 (2000 ppm)	15.85	21.78	22.31	25.88	21.45
	T_5 (2500 ppm)	16.75	22.73	25.13	27.23	22.96
	T_6 (control)	3.50	7.00	9.25	10.55	8.08
	GM effect	11.12	17.95	19.28	22.71	
Leaf area (cm^2)	T_1 (500 ppm)	29.93	29.93	30.30	30.18	30.08
	T_2 (1000 ppm)	30.18	30.30	32.90	31.05	31.11
	T_3 (1500 ppm)	31.05	32.90	32.90	32.90	32.44
	T_4 (2000 ppm)	32.90	33.65	33.65	34.90	33.78
	T_5 (2500 ppm)	33.65	34.65	36.65	40.10	36.26
	T_6 (control)	20.25	21.98	22.05	23.10	21.84
	GM effect	29.66	30.57	31.41	32.04	
CD ($P \leq 0.05$)						
GM		2.09	1.34	0.98		
IBA concentration		1.71	1.09	0.80		
GM × IBA		4.19	2.68	1.96		

Table 3. Effect of IBA concentration and growing media on sprouting, rooting and survival per cent of hardwood stem cuttings of *Ulmus wallichiana*

Characters	IBA concentration	Growing media (GM) Soil	Sand	Cocopeat + vermiculite + perlite (1 : 1 : 1)	Cocopeat + vermiculite + perlite (2 : 1 : 1)	IBA effect
Sprouting (%)	T_1 (500 ppm)	14.00	16.88	37.50	40.75	27.28
	T_2 (1000 ppm)	14.75	18.88	40.25	40.75	28.66
	T_3 (1500 ppm)	19.75	19.38	44.00	46.00	32.28
	T_4 (2000 ppm)	22.75	25.13	51.75	60.00	39.91
	T_5 (2500 ppm)	20.25	22.25	50.25	52.00	36.19
	T_6 (control)	10.50	13.75	20.00	25.50	4.44
	GM effect	16.56	17.63	37.75	40.88	
Rooting (%)	T_1 (500 ppm)	13.13	15.63	17.03	15.25	15.26
	T_2 (1000 ppm)	13.23	16.68	17.89	17.00	16.20
	T_3 (1500 ppm)	18.50	18.13	18.38	18.75	18.44
	T_4 (2000 ppm)	20.75	21.50	21.75	52.50	31.92
	T_5 (2500 ppm)	19.00	19.75	20.00	24.00	20.69
	T_6 (control)	2.50	2.50	4.00	5.25	3.25
	GM effect	15.50	16.41	16.14	24.03	
Survival (%)	T_1 (500 ppm)	12.75	15.13	16.23	15.75	14.96
	T_2 (1000 ppm)	13.75	17.93	16.78	16.00	16.11
	T_3 (1500 ppm)	18.00	15.50	18.03	18.50	17.51
	T_4 (2000 ppm)	21.00	20.75	19.25	47.55	27.14
	T_5 (2500 ppm)	19.00	19.50	19.00	24.00	20.38
	T_6 (control)	2.50	2.50	3.50	4.25	3.18
	GM effect	15.55	15.02	16.88	21.51	
CD ($P \leq 0.05$)						
GM		1.65	0.79	8.94		
IBA concentration		2.82	0.97	1.15		
GM × IBA		4.85	1.95	2.31		

Table 4. Effect of IBA concentration and growing media on shoot length, root length and leaf area success of hardwood stem cuttings of *U. wallichiana*

Characters	IBA concentration	Growing media (GM) Soil	Sand	Cocopeat + vermiculite + perlite (1 : 1 : 1)	Cocopeat + vermiculite + perlite (2 : 1 : 1)	IBA effect
Shoot length (cm)	T_1 (500 ppm)	6.00	12.63	15.00	15.75	11.21
	T_2 (1000 ppm)	6.63	12.38	14.63	16.28	12.48
	T_3 (1500 ppm)	6.25	14.35	14.85	14.85	12.58
	T_4 (2000 ppm)	8.13	21.25	22.30	23.00	18.67
	T_5 (2500 ppm)	7.65	19.18	20.66	21.93	17.35
	T_6 (control)	4.20	8.00	12.00	13.75	9.48
	GM effect	6.47	14.46	16.44	17.59	
Root length (cm)	T_1 (500 ppm)	8.10	9.90	10.23	11.75	9.99
	T_2 (1000 ppm)	8.25	9.73	9.95	13.13	10.26
	T_3 (1500 ppm)	8.50	10.38	11.63	12.00	10.63
	T_4 (2000 ppm)	10.63	12.50	13.50	14.08	12.68
	T_5 (2500 ppm)	9.88	10.68	12.25	12.88	11.42
	T_6 (control)	2.25	3.25	5.55	9.55	4.55
	GM effect	7.68	10.00	10.70	13.22	
Leaf area (cm^2)	T_1 (500 ppm)	40.10	40.55	41.93	42.18	41.19
	T_2 (1000 ppm)	40.55	42.18	44.05	44.05	42.71
	T_3 (1500 ppm)	42.18	44.05	45.28	45.28	44.19
	T_4 (2000 ppm)	45.28	47.20	48.05	50.60	47.78
	T_5 (2500 ppm)	44.05	45.28	47.20	47.20	45.93
	T_6 (control)	32.90	33.65	34.90	36.65	34.53
	GM effect	40.84	42.15	43.57	44.33	
CD ($P \leq 0.05$)						
GM		0.82	0.98	0.53		
IBA concentration		0.66	0.80	0.43		
GM × IBA		1.64	1.97	1.06		

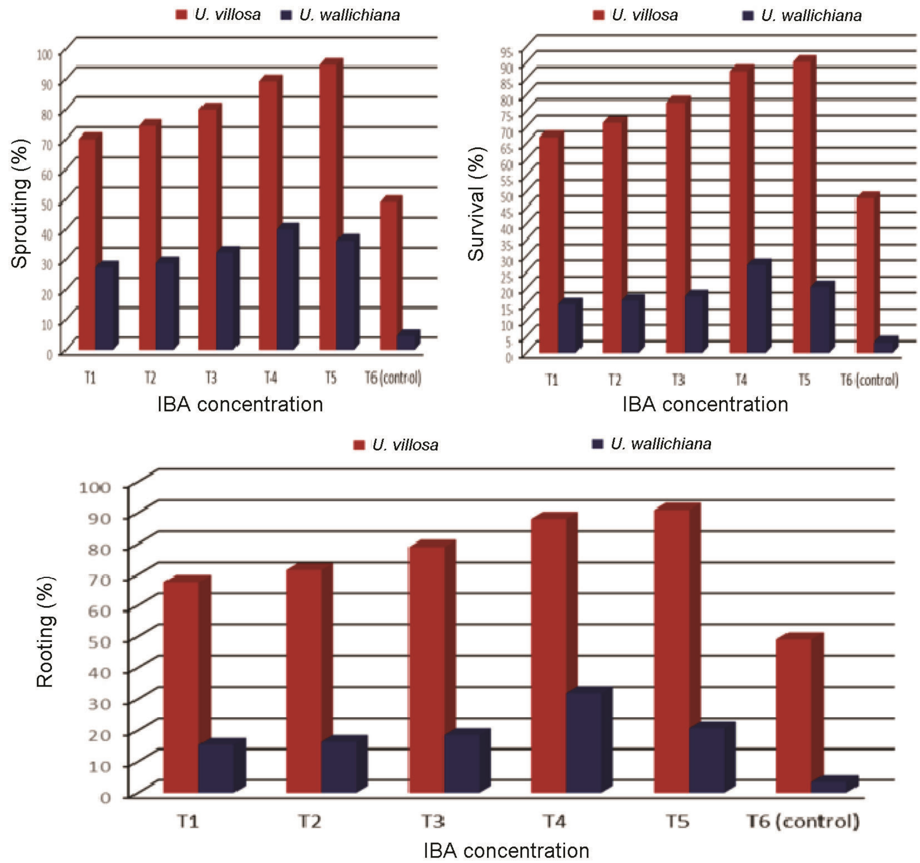

Figure 2. Mean percentage of *U. villosa* and *U. wallichiana* hardwood stem cuttings treated with different indole-butyric acid concentrations.

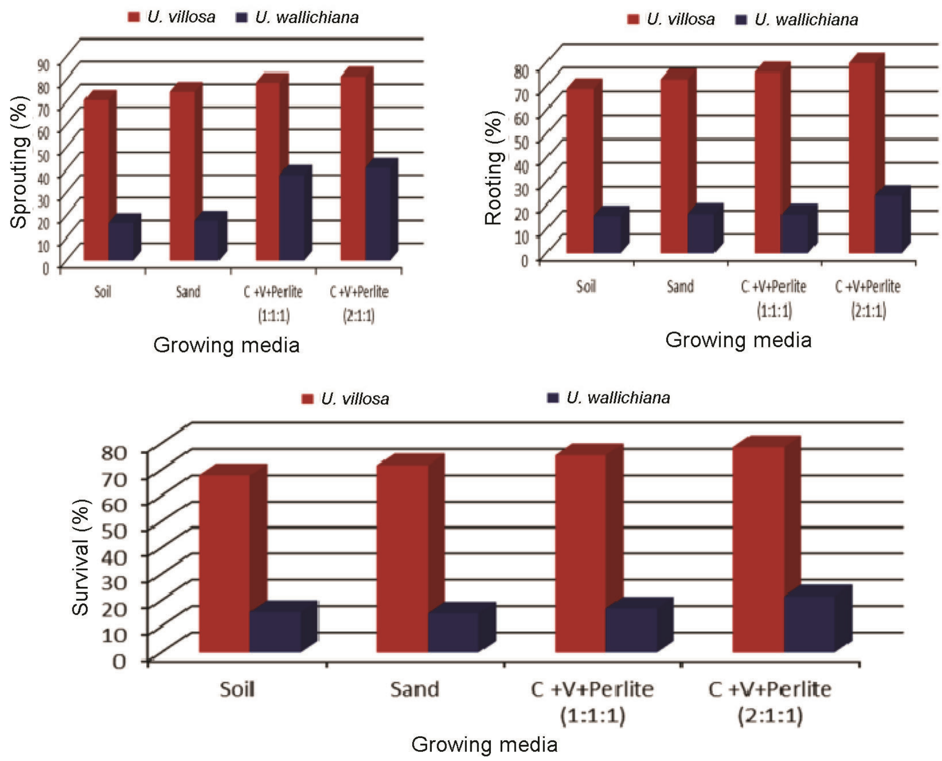

Figure 3. Mean percentage of *U. villosa* and *U. wallichiana* hardwood stem cuttings treated with different growing media.

level of moisture content and aeration given by the physical properties of cocopeat[23].

It has been reported in jojoba (*Simmondsia chinensis*) that highest survival percentage, height of plant (cm), number of shoots and leaves per plant were recorded using the medium containing peat moss, vermiculite and perlite (1 : 1 : 1) compared to the other media used, either individually or in combinations[24]. The highest number of shoots and length of shoots recorded in cocopeat + vermiculite + perlite may also be due to easy translocation of water and mineral nutrients to the above-ground parts of the cuttings, leading to their rapid growth and multiplication. Compared to soil and sand, the mixture of cocopeat + vermiculite + perlite is loose in texture, thus allowing for more aeration and water flow. The significant high rooting in the mixture of cocopeat + vermiculite + perlite may therefore be attributed to better aeration and water drainage, because high aeration and porosity are responsible for promoting root development[25,26].

Various materials can be used for rooting in stem cuttings of *U. villosa* and *U. wallichiana*, but mixture of cocopeat + vermiculite + perlite (2 : 1 : 1) appears to be most appropriate for rooting in both the species. Mass propagation of these species by hardwood stem cuttings treated with optimum IBA concentrations can be successfully used to multiply planting materials in Kashmir on a large scale. This technique can raise the quality planting stock and will overcome the problems of poor seed viability and irregular seed-bearing, which hinder nursery production of these species.

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