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Growth, yield and secondary metabolite production of *Drosera* species cultivated in peat beds in Finland

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Cultivation experiments on *D. rotundifolia* and *D. anglica* were carried out in peat beds in Mikkeli, south Finland (61°44′N, 27°18′E) in 1992–1997. Plants were propagated by direct sowing and transplanting of small seedlings in peat beds (size 3 m^2, depth 0.7 m) filled with non-fertilized peat (pH 4.0). Seed germination, growth, flowering cycle as well as fresh herb and seed yields were measured. To increase the growth, plants were regularly fed milk powder. The 7-methyljuglone, quercetin and kaempferol contents of the flowers, leaves and stems were determined from sown and transplanted, fed and non-fed *Drosera* plants. Both *Drosera* species were successfully cultivated in peat beds. Direct sowing in autumn followed by natural winter stratification seemed to be the best propagation method. Flowering started after the second and third growing years. Feeding the plants milk powder increased growth by 27–113%. The fresh yield during the third, fourth and fifth years ranged between 0.05 and 0.9 kg m^{-2}, being highest in the first and second harvest years. Plant density decides the yield of small-sized species. The average yield was about 50 times higher in peat beds than in the nature. Feeding milk powder did not affect the secondary metabolite contents. The 7-methyljuglone content was 13–81% higher in the fed *Drosera rotundifolia* plants than in the non-fed ones. The quercetin and kaempferol contents were lower in the fed plant, 10–30% and 1–10% lower in *D. rotundifolia* and 30–60% and 1–15% lower in *D. anglica,* respectively. According to the results, it seems to be possible to grow *Drosera rotundifolia* and *D. anglica* under controlled conditions outside the natural ecosystem. The results also suggest that higher yields can be expected by cultivation of these species.

Key words*:* *Drosera rotundifolia, Drosera anglica,* peat, cultivation methods, regular feeding, yield, 7-methyljuglone

INTRODUCTION

Drosera rotundifolia and *D. anglica* ("sundew") are very small-sized species widely distributed around Finnish peatlands (Hämet-Ahti et al. 1998). They grow very slowly and their population densities vary greatly in the nature. Their growth in the nature depends on the natural conditions, and in natural peatlands one can find plants of different ages and sizes.

D. rotundifolia is regularly collected from the nature for pharmaceutical purposes. According to our measurements, the plant weight in the nature varied between 0.02 and 0.6 g plant^{-1} (Galambosi et al. 2000).

As one kilogram of fresh *Drosera* comprises about 5 000–10 000 small flowering plants, the question has arisen whether it is possible to cultivate sundew to replace collection from the nature? According to the First International Symposium on the Conservation of Medicinal Plants in Trade in Europe, this question is highly topical. Due to the harmful environmental effects on peatlands, *Droseras* have become distinct and threatened plants in several European countries (Dudley 1987, Aapala & Kokko 1988). The collection of sundew is regulated in some countries, and efforts have to be made to increase research on the cultivation of sundew (Lange 1998).

Cultivation experiments on *Drosera* species have been reported mainly in conjunction with tissue culture (Kukulczanka and Czastka 1988) and for decorative and demonstration purposes (Phillips 1986). There is scant information and experience of cultivation methods for larger-scale commercial purposes.

In this cultivation experiment, methods for commercial cultivation of *D. rotundifolia* and *D. anglica* to replace collection from the nature were elaborated.

The objectives of this study were: to determine the agrobiological features of *Drosera species,* to use inexpensive techniques for constructing peat beds, to stimulate growth, to increase the bioproductivity of sundew withouth affecting the secondary metabolites, and to obtain data on the biomass potential of cultivated *Drosera* species.

METHODS

Construction of peat beds

The experiments were carried out at the Agricultural Research Centre of Finland, Ecological Production, Karila, Mikkeli (61°44'N, 27°18'E). The experimental field, 24 m^2 in size, was situated 20 m east of a forest with sunshine from morning until 2 p.m and consisted of eight peat beds. The peat beds, 3 × 1 × 0.7 m, were constructed in September 1992. The growing medium was non-fertilized commercial peat, pH 3.5. A white plastic foil of thickness 0.1 mm was placed at the bottom of the beds. The results of the peat analyses are presented in Table 1.

Propagation and maintenance of peat beds

Sundew seed was collected from natural mires around Mikkeli in September 1992. On 25 October 1992, part of the seed was sown directly in the peat beds, 0.2 g m^{-2}. For equal sowing, the small seeds were mixed with sand in a ratio of 1:10. Equal sowing was obtained by dividing the seed into two parts and sowing twice crosswise. The rest of the seed was sown on the peatbed on 1 November 1992 for seedling production, using plastic cells of 5 × 5 cm, 188 peat cells m^{-2}. The cells were kept outdoors during the winter and transferred into a greenhouse at the end of April. The cells were kept moist by letting them stand in water. Germination started in May and the seedlings grown in the cells were transplanted in the beds on 10 June 1993.

During the whole cultivation period special attention was paid to agronomical practices required to assure the specific peat circumstances for the *Drosera species* which are strongly adapted to peat conditions.

Plain tap water (pH 7) was used for regular simple drip irrigation to ensure constant moisture throughout the whole growing season. In the winter the peat beds froze and remained under the snow. In the summer weeds were picked regularly, and animals and snails were kept away. During the first year, the beds were covered with mosquito nets to protect the small seedlings from heavy rains.

In order to stimulate plant growth, 4 × 2 m^2 areas of the beds were sprayed evenly with milk powder 1 g m^{-2} at 7–10-day intervals. The milk powder was originally meant for human consumption. It was produced by Kuivamaito Oy, Nastola. The composition of the milk powder was: protein 35 g 100 g^{-1}, fat 1 g 100 g^{-1}, carbohydrate 52 g, Ca = 1400 mg kg^{-1}, energy 1500 kJ 100 g^{-1}.

During the third year of the experiment, different moss species (*Polytichum*) spread agressively on the surface of the beds. To reduce their dominance at the end of May, when the mosses had reached their new height, but the growth of sundew had not yet started, we cut the moss below the height of sundew using a clearing saw.

Observations and measurements

Seed germination, plant density, overwintering, growth and flowering cycle were observed during six years. The seeds were germinated in Petri dishes at room temperature by the top paper method using 4 × 100 seeds after 1-, 2-, 4- and 8-week stratification at 1 to 5 °C.

Plant density in the beds was measured by counting the leaf rosettes of any size inside a 10 × 10 cm frame in 20–30 repetitions and the results were calculated for 1 m^2. For determination of plant density in peat cells, small seedlings in 20–30 cells were counted.

The flowering cycle was evaluated by counting the flowering stems in a 0.25 m^2 area, and the results were calculated for 1 m^2.

For determination of biomass production, leaf length, height of flowering stems and plant fresh weight were measured from 20–50 individual plants. Fresh yields were harvested and measured for directly sown and transplanted, fed and non-fed populations, from 0.25 m^2 areas in 4–6 repetitions for both species. The herb harvests were carried out by picking the whole plants in full flowering (*D. rotundifolia*) or cutting the upward-growing leaves with scissors (*D. anglica).* The

Table 1. Analytical results of commercial peat, tap water and peat flow water in 1992–1995 (mg l^{-1}).

Taulukko 1. Kaupallisen turpeen, kasteluveden ja penkkien valumaveden analyysituloksia vuosina 1992–1995 (mg l^{-1}).

Analyses (mg l^{-1})	Commercial peat 1992	Tap water 1993	Peat flow water			
			1993		1994	1995
			13.6.	16.9.	6.10.	13.9.
Conductivity µs/cm	1.3	0.27	0.54	0.49	0.19	0.18
pH	3.6	6.9	< 3.5	< 3.5	3.75	3.95
NO_3-N	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
NH_4-N	14.1	< 1.0	3.7	6.9	5.1	4.1
P	9.6	0.55	12.0	10.0	2.3	2.1
K	46.1	3.8	19.0	20.0	5.7	5.7
Ca	250.0	28.0	22.0	15.0	2.6	3.0
Mg	69.8	4.8	9.3	6.6	1.5	1.3
S	23.3	14.0	20.0	14.0	1.5	2.6
Fe	113.0	0.39	16.0	15.0	6.5	4.1
Mn	140.0	< 0.01	1.8	0.63	0.14	0.13
Zn	2.1	0.04	0.27	0.14	0.04	0.05
Na	141.0	8.0	4.2	5.8	3.3	5.4
Cl	8.2	21.0	13.0	23.0	24.0	10.0
Al	39.4	< 0.05	2.5	1.8	0.76	0.82
Si	1.0	6.1	11.0	13.0	13.0	14.0

seed were harvested by hand in September.

At the end of the growing seasons, the water obtained from the bottom of the growing beds was analysed by the Soil Analysis Service Ltd in Mikkeli.

Chemical analyses

Determination of 7-methyljuglone

Fresh leaves or flowers (0.1 g) were homogenized with sea sand and extracted with benzene at 10°C. The extract, after filtration through a sintered glass, was evaporated to dryness under vacuum and resuspended in ethanol. Juglone (Serva) was used as the internal standard. At the same time, the amount of dry mass was determined after drying at 105 °C. 7-Methyljuglone was prepared by TLC. The identity was confirmed by GC-MS (Blehova et al. 1995).

Aliquots (20 ul) were injected into a separon SGX C18 column (150 × 3.3 mm i.d.,Tessek TM, Prague). Solvent (methanol:0.2 M acetic acid adjusted to pH 3.5 with triethylamine, 65:35) was used in isocratic condition. The flow rate was 1.0 ml min^{-1}. Detection was carried out at a wavelength of 426 nm (Hewlett Packard 1050). Data obtained by integration was used in the calculations.

Determination of flavonoids

Homogenized dry plant material (0.025 g) was refluxed with 75% methanol and hydrolyzed with 6% HCL (1 h). The gradient method was used for flavonoid aglyka determination. The instrument and column conditions were the same as mentioned above. Mobile phases: A-water:acetonitrile: H3PO4, B-acetonitrile: methanol: H3PO4. Program: % B, minutes -24.0: 30,5; 55.10: 100.15; 24.20. Detection at 370 nm. Standard compounds of quercetin (Sigma) and kaempferol (Roth) were used for quantification.

RESULTS

Germination and plant density

The seed of sundew species germinate at room temperature very poorly and irregularly. The best germination results have been achieved by stratification of seeds close to natural conditions: 2-month stratification at 1–5 °C in moist conditions. There were clear differences in the germination patterns between the two species. In Petri dishes the germination rates of *D. rotundifolia* were always higher (60–85%) than those of *D. anglica*

Table 2. Plant density in artifical peat beds from direct sowing in 1993–1995.

Taulukko 2. Kasvien tiheys turvepenkissä suorakylvössä vuosina 1993–1995 .

Year	n	Plant number*/100 cm^2	
		Mean	Range
Drosera rotundifolia			
1993	30	25.7	10–60
1994	20	9.2	1–10
1995	20	16.4	7–27
Mean		17.1	
Drosera anglica			
1993	30	27.1	15–49
1994	20	16.2	8–29
1995	20	20.2	10–44
mean		21.2	

* any size of leaf rosettes

(5–10%).

The seed sown in autumn for seedling production and kept outdoors during the winter started to germinate after 2–3 weeks when transferred into a warm greenhouse. The initial growth is very slow, a size suitable for transplanting was obtained after 43–45 days. In the 1993 autumn sowings in beds, newly germinated small plants were observed after four and five years of cultivation, which emphasises the importance of additional research on the seed biology in terms of cultivation.

The density of directly sown plants ranged between 920 and 2710 plants m^{-2} (Table 2). The differences are due to the unequal sowing and germination. The density of the transplanted pots was lower due to the 7 × 7 cm pot distances. The number of plants in one pot of *D. anglica* averaged 37 (range 13–69). Due to the prostrate growth habits of *D. rotundifolia,* the average number of plants in the pots was only 6.5 (3–10).

Plant growth and size

The growth of sundew was very slow after germination. During the first year the plants developed leaf rosettes only. The diameter of the rosettes at the end of the first year ranged between 1.33 and 2.94 cm.

Only a small percentage of plants, especially *D. anglica,* developed flowering stems during the second year. The first harvest of the profusely flowering plants was obtained in the third growing year 1995 (Table 3).

The plant size of sundew in the natural peat is very variable and strongly affected by the growing conditions (full sunshine, shadow, grass). The plants cultivated in peat beds were more uniform. The average stem height of the third-year *D. rotundifolia* and *D. anglica* plants was 12.3 cm and 10.6 cm, respectively, and the individual fresh weight was 0.25 and 0.33 g, respectively (Table 4).

Feeding increased the plant growth significantly. All growing parameters studied were higher in those plants which were regularly fed milk powder. Feeding increased the length of leaves by 1–37%, plant weight by 27–76%, stem height by 12–22% and number of flowers by 19–113% (Table 4). Because of the accelerated growth, the fed plants developed more flowering stems and flowered more abundantly (Table 3).

Effect of feeding and propagation methods on the secondary metabolites

Feeding with milk powder had a positive effect on the 7-methyljuglone content in the different parts of the *Drosera* species. Plant parts contained 13–81% more 7-methyljuglone compared to the non-fed control plants, especially *D. rotundifolia* (Table 5). At the same time, regular feeding decreased the flavonoid contents. However, the two species reacted in a different way. The differences were smaller in *D.anglica* than in *D. rotundifolia.* The quercetin contents of *D. rotundifolia* ranged from 4.05–6.17%, being highest in the flowers. The quercetin contents of the fed plants was 10–29% lower. The quercetin contents of *D. anglica* was slightly lower, 3.34–5.03%, being highest in the leaves.

The kaempferol content was lower in both species, 0.039–0.51 %, being highest in the flowers in both species. The use of milk powder decreased

Table 3. The flowering rhythm of *Drosera* species in peat beds 1993–1995 (Figures are means of 3–10 observations of 0.5 m^2 areas).

Taulukko 3. Kihokkien kukinnan rytmi turvepenkeissä vuosina 1993–1995 (Luvut ovat 0.5 m^2 ruutujen 3–10 havainnon keskiarvoja).

	Number of flower stems/m^2		
	2nd year	3rd year	
		No milk	With milk
Drosera rotundifolia			
Direct sowing	28.3	410	980
Transplantation	34.0	344	648
Mean	31.0	377	814
Drosera anglica			
Direct sowing	1.3	326	605
Transplantation	0.3	216	533
Mean	0.8	271	569

the kaempferol content more in *D. rotundifolia* than in *D. anglica*. The kaempferol contents in the flowers and stems decreased by 0.2% and 13%, respectively, and increased by 6% in the leaves. The contents of 7-methyljuglone of both species was generally higher in the directly sown plants than in the transplanted plants. The contents measured in the flowers, leaves and stems of the directly sown *Drosera rotundifolia* plants ranged 2.02–2.09%, 0.90–1.40% and 0.59–0.62%, while the corresponding figures for the transplanted plants were 1.84–1.95%, 0.65–0.85% and 0.11–0.47%, respectively (Table 6).

A similar trend can be observed in the case of *D. anglica*, with two exceptions: the 7-methyljuglone contents of the transplanted plants fed milk powder were higher in the leaves (2.26%) than in the stems (0.62 %) (Table 7). The variation of the aglycone contents was quite similar in both species: in the control plants the contents of quercetin and kaempferol were higher in the directly sown plants, while after feeding them milk powder in some cases the quercetin and kaempferol contents were higher in the transplanted plants (Tables 6 and 7).

Table 4. Growth of directly sowed *Drosera rotundifolia* and *D. anglica* in peat beds 1993–1995.

Taulukko 4. Pyöreä- ja pitkälehtisen kihokin kasvu turvepenkissä suorakylvöstä vuosina 1993–1995.

Feature		1st yr. 1993	2nd yr. 1994	3rd yr. 1995
D. rotundifolia				
Leaf length (cm)	no milk	0.60	1.70	1.80
	with milk	–	2.02	2.46
Plant weight (g)	no milk	0.16	0.16	0.25
	with milk	–	0.28	0.44
Stem height (cm)	no milk	–	10.1	12.3
	with milk	–	12.3	15.6
Seedcase/stem	no milk	–	3.1	5.7
	with milk	–	6.6	7.2
D. anglica				
Leaf length (cm)	no milk	0.81	3.00	4.78
	with milk	–	–	4.85
Plant weight (g)	no milk	0.026	0.19	0.33
	with milk	–	–	0.42
Stem height (cm)	no milk	–	6.20	10.6
	with milk	–	–	11.9
Seedcase/stem	no milk	–	1.0	2.6
	with milk	–	–	3.1

Yields

The fresh yields of *D. rotundifolia* were highest in the first harvest year, 1995, and decreased year by year, since whole flowering plants were taken away from the population every year (Fig. 1). In direct sowing, the yields harvested in 1995, 1996 and 1997 were 138, 88 and 42 g m^{-2}, respectively. With milk powder the fresh yields were higher, i.e. 337, 257 and 183 g m^{-2}, respectively. The lower plant density of transplanted plants resulted in lower yields. Without milk powder the yields were 18, 48 and 52 g m^{-2} and with milk powder 85, 310 and 263 g m^{-2}, respectively. Due to the larger leaves, the yield of *D. anglica* was higher than that of *D. rotundifolia,* and the highest yields were harvested during the second year after using milk powder. In direct sowing and transplantation, the highest yields were 651 and 939 g m^{-2}, respectively, in 1996 (Fig. 2). Comparing the average yields of *D. rotundifolia* with those collected from the nature (4.4–5.7 g m^{-2}), it can be concluded that in the more densely cultivated population the yield is about 50 times higher (Fig. 3).

Irrigation and weeding

According to the 6 years of experience, tap water can be used for irrigation in artificial sundew cultivation. The neutral pH of tap water increased slightly the pH of commercial peat (from 3.6 to 3.95) after 3 years of irrigation, but this change had no visible effect on the plant growth. According to the analytical result presented in Table 1, all microelements leached from the peat as a result of continuous irrigation. The only detrimental effect was observed in 1993, when one bed was covered with plastic foil and the high sulphur content of the peat (20 and 14 mg l^{-1}) had apparently concentrated in the air around the young plants, killing many of them. The bed was replanted in the spring of 1994.

The beds were weeded 3–5 times during the summer. Only a few common weeds, e.g. *Epilobium sp.,* grew in the beds. The frequent occurrence of *Betula sp.* and *Pinus sylvestris* seedlings was more problematic as the seed of these trees flew from the nearest forest and germinated among the sundews on the continuously moist peat

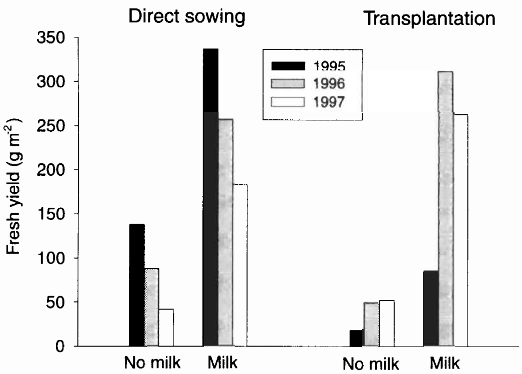

Fig. 1. Fresh yield of *Drosera rotundifolia* grown in peat beds in 1993–1997.

Kuva 1. Pyöreälehtikihokin tuorepaino turvepenkeissä vuosina 1993–1997.

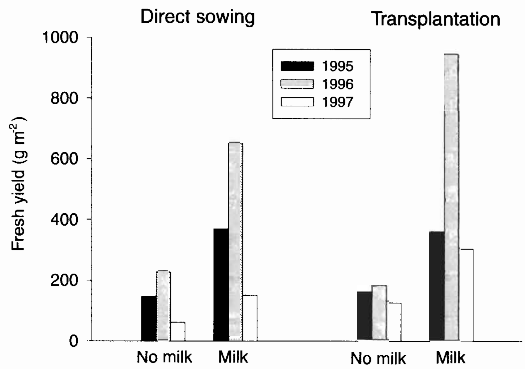

Fig. 2. Fresh yield of *Drosera anglica* grown in peat beds in 1993–1997.

Kuva 2. Pitkälehtikihokin tuorepaino turvepenkeissä vuosina 1993–1997.

Table 5. The effect of nutrition by milk powder 3-years-old *Drosera rotundifolia* and *D.anglica* on secondary metabolite content (% of compound in dry mass) in 1995.

Taulukko 5. Maitojauheen vaikutus kolmevuotisen pyöreä-ja pitkälehtisen kihokin vaikuttavien aineiden pitoisuuteen (% kuiva-aineesta) v. 1995.

Species	Plant organ	Control		With milk		T-test significance (p)
		$\bar{x}$	S_x	$\bar{x}$	S_x	
D. rotundifolia			*7-methyljuglone*			
	leaf	1.13	0.572	0.78	0.422	0.188
	flower	1.96	0.833	1.98	0.990	0.969
	stem	0.36	0.319	0.53	0.304	0.300
			quercetin aglycone			
	leaf	5.65	0.694	4.05	0.306	< 0.001
	flower	6.17	0.460	5.54	0.298	0.001
	stem	4.93	0.517	4.29	0.279	0.002
			kaempferol aglycone			
	leaf	0.14	0.037	0.07	0.010	< 0.001
	flower	0.38	0.071	0.29	0.031	0.002
	stem	0.06	0.022	0.04	0.011	0.019
D. anglica			*7-methyljuglone*			
	leaf	1.25	0.828	1.83	0.512	0.162
	flower	1.01	0.309	1.49	0.604	0.074
	stem	0.41	0.150	0.54	0.192	0.199
			quercetin aglycone			
	leaf	5.03	0.375	4.98	0.658	0.853
	flower	3.34	0.393	3.35	0.211	0.955
	stem	4.30	0.413	4.33	0.219	0.868
			kaempferol aglycone			
	leaf	0.09	0.017	0.10	0.042	0.290
	flower	0.51	0.064	0.50	0.080	0.663
	stem	0.05	0.012	0.05	0.008	0.223

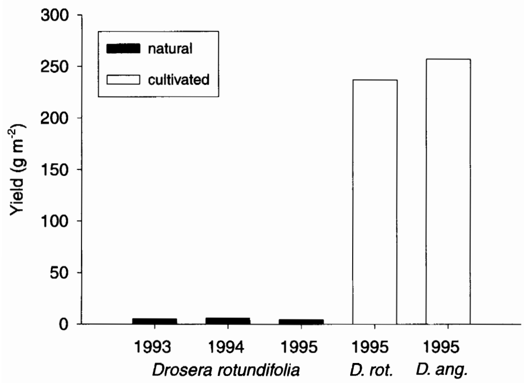

Fig. 3. Average fresh yield of *Drosera rotundifolia and D. anglica* in the nature and in peat beds in 1993–1995.

Kuva 3. Pyöreä- ja pitkälehtikihokin keskimääräinen tuorepaino luonnossa ja turvepenkeissä vuosina 1993–1995.

surface. These must be removed carefully, because, with the strong hairy root system of the *Betula* seedlings, a number of sundew seedlings and plants are removed with the peat lumps.

Another special problem was the moss on the surface of the peat bed. Contrary to natural peatland, where the dominating species are *Sphagnum sp.*, in the peat beds *Polytrichum* species spread from the neighbouring forests. They grew agressively and quickly covered the clean peat surface. At the end of the second year they covered about 50% of the beds, in 1995 nearly 75–95%, and in 1996 100%. Since they grew faster, and were taller (5–7 cm) than sundew, a significant part of the *Drosera anglica* yield could not be cut. *D. rotundifolia* was more competitive. The special cutting of *Polytrichum* moss species, us-

Table 6. The influence of growing methods of *Drosera rotundifolia* in feeding experiment on secondary metabolites content (% of compound in dry mass) in 1995.
Taulukko 6. Lisäysmenetelmien vaikutus pyöreälehtisen kihokin vaikuttavien aineiden pitoisuuteen v. 1995 (% kuiva-aineesta).

Plant organ	Direct sowing		Transplanting		T-test significance (p)
	$\bar{x}$	S_x	$\bar{x}$	S_x	
			7-methyljuglone		
			control		
leaf	1.40	0.607	0.85	0.438	0.191
flower	2.09	0.895	1.84	0.880	0.699
stem	0.62	0.238	0.11	0.079	0.007
			with milk		
leaf	0.90	0.595	0.65	0.137	0.439
flower	2.02	0.255	1.95	1.490	0.932
stem	0.59	0.428	0.47	0.152	0.605
			quercetin aglycone		
			control		
leaf	6.18	0.584	5.30	0.527	0.009
flower	5.89	0.416	6.37	0.400	0.045
stem	5.05	0.210	4.83	0.641	0.365
			with milk		
leaf	3.97	0.335	4.21	0.188	0.292
flower	5.50	0.362	5.63	0.104	0.584
stem	4.21	0.296	4.45	0.177	0.232
			kaempferol aglycone		
			control		
leaf	0.14	0.012	0.15	0.047	0.538
flower	0.33	0.026	0.42	0.071	0.014
stem	0.04	0.005	0.07	0.023	0.02
			with milk		
leaf	0.07	0.009	0.06	0.009	0.077
flower	0.31	0.027	0.26	0.012	0.032
stem	0.04	0.014	0.04	0.003	0.937

ing a clearing saw, did not damage the sundew, but inhibited the growth of the moss. In this way we increased the competitiveness of sundew.

DISCUSSION

Since sundews originate from a special natural ecosystem, similar circumstances, i.e. original peat substrate, low pH and continuous water supply, must be guaranteed in cultivation to achieve normal growth. Additionally, special cultivation practices have to be developed to increase the biomass production of these very slow-growing and small-sized natural plant species.

These practices have to be studied continuously during the domestication process to avoid any negative effects on the growth and production of secondary metabolites. In the case of *Drosera* species, these special practices include, e.g., construction of peat beds, continuous irrigation, feeding and weed control.

According to the results of the 6-year domestication experiments, both *Drosera* species may be succesfully cultivated outdoors in peat beds. The plants were propagated from seeds using natural stratification methods with natural, pre-winter sowing times. Direct autumn sowing proved to be a simpler and less laborious method than transplantation of seedlings. Due to the higher plant density it also resulted in higher yields. Generally the contents of the secondary metabolites were higher in the directly sown plants than in the transplanted ones.

In some previous studies, the optimum range for growth was pH 3–5 for *Drosera rotundifolia* (Rychnovska-Soudkova 1953) and pH 4.0–4.5 for

Table 7. The influence of propagation methods of *Drosera anglica* in feeding experiment on secondary metabolites content in 1995 (% of compound in dry mass).
Taulukko7. Lisäysmenetelmien vaikutus pitkälehtisen kihokin vaikuttavien aineiden määrään v. 1995 (% kuivasta aineesta).

Plant organ	Direct sowing		Transplanting		T-test significance (p)
	$\bar{x}$	S_x	$\bar{x}$	S_x	
			7-methyljuglone		
			control		
leaf	1.60	0.917	0.91	0.663	0.269
flower	1.21	0.238	0.80	0.236	0.051
stem	0.44	0.132	0.39	0.182	0.647
			with milk		
leaf	1.61	0.353	2.26	0.620	0.163
flower	1.86	0.188	0.74	0.229	0.003
stem	0.50	0.203	0.62	0.204	0.543
			quercetin aglycone		
			control		
leaf	5.12	0.439	4.93	0.309	0.416
flower	3.30	0.264	3.39	0.514	0.700
stem	4.41	0.563	4.19	0.173	0.384
			with milk		
leaf	5.29	0.553	3.36	0.319	0.033
flower	3.43	0.206	3.21	0.153	0.148
stem	4.39	0.242	4.20	0.092	0.237
			kaempferol aglycone		
			control		
leaf	0.09	0.018	0.08	0.009	0.041
flower	0.51	0.055	0.51	0.078	0.987
stem	0.06	0.007	0.05	0.009	0.005
			with milk		
leaf	0.12	0.037	0.06	0.004	0.034
flower	0.47	0.087	0.55	0.030	0.178
stem	0.05	0.007	0.04	0.080	0.076

D. aliciae (Small et al. 1977). Although we used normal tap water (pH 6.9), after three years of irrigation the original pH 3.5 had increased only to 3.95. There were no significant differences in the other mineral element contents of the growing substrate.

Special attention was paid to the stimulation of growth and biomass production using artificial feeding.

There are numerous experimental results which demonstrate the impact of additional feeding on the growth, leaf size, flowering, seed production and nitrogen content in the overwintering hypocotyl of sundew species. For additional feeding, different N-containing substrates were used in the literature like dipeptides in tissue culture of *Drosera rotundifolia* (Simola 1978), cheese for *D. aliciae* (Small et al. 1977), beef extract for *Utricularia exoleta* (Pringsheim &Pringsheim 1962), as well as *Drosophila melanogaster* for *D. intermedia, D. rotundifolia* (Thum 1988) and for *D. filiformis* (Kraft & Handel 1991).

In feeding experiments, different organic preparations were tested and their beneficial effect on sundew species was verified (Galambosi et al.1999). For practical and economical reasons we used dry milk powder. Regular additional feeding had a positive effect on the accumulation of plant biomass and slight negative effect on the production of secondary metabolites monitored by the 7-methyjuglone content and some flavonoids of sundew species. The different reactions of the compounds examined in this experiment warrant further studies.

The fresh yields were about 50 times higher in these cultivation conditions than in the nature. Although the individual plant weight increased, in the growing beds the decisive factor in the higher yields seems to be plant density. The average plant number in the nature was 20–55 m^{-2}, the plant density in the growing beds was about 45 times higher, ranging from 920–2710 plants m^{-2}.

On the basis of these experiments, cultivation of *Drosera* species seems possible. Peat beds allow the production of sundew raw material in a locally concentrated, controlled cultivation system without a natural mire ecosystem. As opposed to higher yields, cultivation of sundew in peat beds involves costs related to cultural techniques and maintenance of plants, like with other horticultural crops. For non-domesticated species which are highly adapted to special swamp conditions, all elements of the growing system, like irrigation, weeds, competitive organsims, animals and other unfavourable effects need to be controlled continuously. Further research is necessary to improve and test these experimental results in a larger-scale pilot production system with economic evaluation.

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TIIVISTELMÄ

Soilla kasvavia kihokkeja *(Drosera sp.)* kerätään farmaseuttisiin tarkoituksiin. Suoalan pienenemisen vuoksi kihokit ovat nykyään uhanalaisia monissa Euroopan maissa (Dudley 1987, Aapala & Kokko 1988) ja niiden keruu luonnontilaisilta soilta on säännösteltyä. Tämän vuoksi on viime aikoina alettu tutkia mahdollisuuksia kihokkien viljelyyn kasvihuoneissa (Galambosi et al. 1999). Tässä tutkimuksessa selvitettiin eri viljelymenetelmien ja ruokinnan vaikutusta turvepenkeissä kasvatettujen pyöreä- ja pitkälehtikihokin *(Drosera rotundifolia, D. anglica)* kasvuun ja vaikuttavien aineiden tuotokseen.

Pyöreä- ja pitkälehtikihokkia *(Drosera rotundifolia, D. anglica)* viljeltiin turvepenkeissä vuosina 1992–1997 Mikkelissä, Etelä-Suomessa (61°44´N, 27°18´E). Turvepenkit olivat kooltaan 3 × 1 × 0.7 m ja ne oli täytetty lannoittamattomalla turpeella (pH 4.0). Alle oli levitetty paksu muovi. Kasveja lisättiin luonnosta kerätyistä siemenistä. Siemenet kylvettiin syksyllä 1992 suoraan tupeeseen (0.2 g m^{-2}) ja taimikasvatuksessa ruukkuihin (5 × 5 cm). Ruukkutaimet istutettiin kesäkuussa 1993 7 × 7 cm tiheydelle. Siementen itävyys, lajien kasvu- ja kukintarytmi, tuore sato, siemensato, lehtien, kukkien sekä varsien 7-metyylijugloni-, kamferoli- ja kversetiinipitoisuudet määritettiin. Kihokeille annettiin viikottain maitojauhetta 1 g m^{-2}. Viljelmät kasteltiin juomavedellä.

Molempien lajien koeviljely onnistui turvepenkeissä. Suora kylvö syksyllä osoittautui tehokkaimmaksi kylvötavaksi. Kukinta alkoi toisena ja kolmantena kesänä. Maitojauhe lisäsi kihokkien kasvua 27–113%.

Tuoresato korjattiin kolmantena, neljäntenä ja viidentenä kasvuvuotena ja sadon määrä vaihteli 0.05–0.9 kg m^{-2}. Sadon määrä oli korkeimmillaan ensimmäisenä ja toisena korjuuvuotena. Viljelmästä saatu sato oli keskimäärin 50 kertaa suurempi kuin luonnosta kerätty sato. Pienikokoisen kasvin sadon määrä riippuu ensisijaisesti kasvuston tiheydestä.

Maitojauhe ei vaikuttanut merkitsevästi vaikuttavien aineiden pitoisuuksiin. Ruokitun pyöreälehtikihokin 7-metyylijuglonipitoisuudet olivat 13–81% ruokkmattomia korkeammat. Samanaikaisesti flavonoidiglykonipitoisuudet olivat ruokituissa kasveissa hieman alhaisemmat: pyöreälehtikihokin kversetiini- ja kamferolipitoisuudet olivat 10–30% ja 1–10% alhaisemmat ja pitkälehtikihokin vastaavat pitoisuudet olivat 30–60% ja 1–15% alhaisemmat.

Tulosten perusteella molempien lajien viljely onnistuu turvepenkeissä ja kontrolloiduissa viljelyoloissa raaka-ainesato voi olla luonnonvaraista satoa korkeampi.

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