Germination ecology of Galeopsis bifida (Lamiaceae) as a pioneer species in forest succession

Veikko Hintikka


The occurrence of Galeopsis bifida on clear-cut and burned forest soil and its disappearance in 4–6 years after disturbance is attributed to its germination ecology. Initially the seeds are dormant 96–100 % and remain dormant in nylon gaze bags in different types of forest humus layers at least 10 years. Dormancy is released in laboratory 1) by treatment of 100 ppm aqueous solution of GA3; 2) by heating the dormant seeds to 40–55°C for 1–5 h and 3) by 1 % KNO3 solution. It is concluded that conditions in clear-cut and burned areas favour germination of seeds in regard to temperature and content of nitrates in contrast to humus of closed forest vegetation where the seeds remain dormant.

Peltopiliikke (Galeopsis bifida) ilmaantuu avohakkuusaloille hakkuusta seuraavina vuosina ja saattaa olla dominoiva kasvilaji, mutta häviää 4–6 vuoden kuluttua eikä esiinyyt suljetussa metsäkaasuviljelussa. Emokasvistia varistesaa siemenet (lokhkedelmät) ovat 96–100 %:ssä lepotilaassa ja säilyvät nylonharjapussahin suljettuina metsähumuksessa lepotilaisina ainakin 10 vuotta. Siemenen lepotilan päästymisen saavat laboratoriossa aikana 1) käsitellyt 100 ppm gibberellinaasideoluyksikön lisäksi ja 2) 1 % kaliumnitraatiliusiksen sekä 3) kuunennus 40–55°C 1–5 h. Siemenet säilyvät ilmeisesti metsähumuksessa lepotilaisina pitkä aikaa ja avohakkus- ja kuloalojen lämpöolosuhteet sekä humuksen korkeampi nitraattititoisuus herättävät kasvuun eikä koko kiertoajan humuksessa lepotilaisia säilyneet siemenet.

Keywords: Galeopsis bifida, germination ecology, forest succession, release of seed dormancy

ODC 182.2+176.1 Galeopsis bifida +181.52+161.41

Correspondence: Veikko Hintikka, Department of General Botany, University of Helsinki, Viikki, SF-00101 Helsinki, Finland.

Approved on 17.11.1987
1. Introduction

The success in colonization of disturbed forest soil after fire and clear cutting depends on several types of adaptations. The pioneer plant species have either highly dispersed diasporas, deeply rooted rhizomes, by which they escape disturbance, or the seeds form a long-living dormant seed bank in forest humus (Heinselman 1981). In agricultural soils, the seed bank is of central importance in the emergency of seeds, and Finnish agricultural soils may contain up to 65 000 seeds/square meter (Paatela & Erviö 1971). The role of dormant seeds in the succession of Nordic forests has received much less attention. A well-known example is Geranium bohemicum, the seeds of which require heating to germinate, and the species occurs almost exclusively on recently burned forest soil to disappear in following years, but the seeds may remain in forest humus dormant for decades (Jalas 1980). Kujala (1926) suggested that certain other species occurring on burned forest soil have emerged from old dormant seeds. Rintanen (1982) has studied an occurrence of Lotus corniculatus on a recently ploughed forest soil in SE-Finland, and based on 14C-determinations of seeds found in the soil, comes to the conclusion that the individuals have emerged from old dormant seeds. According to Granström (1982) there is considerable amount of seeds in the humus of old spruce forests in northern Sweden, and seeds of Lactuca plosa may form a persistent seed bank. In America, seeds of the pioneer shrub Prunus pensylvanica remain dormant in the soil the whole rotation period (Marks 1974). On the other hand, seeds of Nordic forest trees, e.g. those of Betula, seem not to be able to survive longer periods in the soil (Granström & Fries 1985).

One of the few annual pioneer species in the succession of Finnish forests is Galeopsis bifida. Although it occurs as a noxious weed in agricultural soils (Mukula et al. 1969, Raatikainen & Raatikainen 1975, Raatikainen et al. 1978), and in abandoned fields after 1–3 years after cultivation (Hokkanen & Raatikainen 1977), it is found also as a native plant species on rocky outcrops and especially on larger erratic blocks (Erkamo 1980), on sea-shores and as a pioneer species in clear-cut and burned areas.

As its occurrence is largely limited to habitats free from competition, it was suggested that the germination biology plays a significant role in the distribution both in space and time. The main emphasis was laid on its occurrence as a primary colonizer of disturbed forest habitats.

This study was financed in years 1986–87 by the Academy of Finland.

2. Observations on the occurrence of G. bifida in nature

In summers 1970–86 observations on the occurrence of Galeopsis were made on ca. 15 clear-cut areas, ca. 20 rocky outcrops and ca. 30 erratic blocks mainly in Helsinki, Ruotsinpyhtää, Vesijärvi and Siböle experimental forests of the Finnish Forest Research Institute and in Ruotsinpyhtää archipelago (Fig. 1). Most of the places were visited during 5–8 successive years. Based on observations, the species appeared in clear-cut areas especially in more fertile habitats as isolated individuals in summer immediately after clear-cut in previous winter. In following years the species becomes sometimes a dominant plant species. Fig. 2 shows ca. 3 year old clear-cut area in Vesijärvi experimental forest, where G. bifida was very abundant. The site was a stony Mytilus type. Similarly in a drained spruce swamp in Ruotsinkylä it was very dominant after 2–3 years from logging, and the individuals attained height up to 50–80 cm. In all clear-cut areas, the species declined rapidly, the individuals became smaller and the species disappeared after 6–7 years or occurred only on places disturbed later. The species does not occur in closed forest vegetation.

In Evo State forest and in Ruotsinkylä experimental forest Galeopsis was commonly seen on ploughed forest soil after clearcut as isolated, but rather frequent individuals. It occurred often abundantly in ditches and margins of newly build forest roads and recent landing places for timber in Vesijärvi 1974 and 1977, but disappeared in 1–2 years when the places were left undisturbed.

G. bifida occurs also as an early colonizer of burned soil. It was met with several times in vicinity of Helsinki and Hyytiala as isolated individuals on burn-over areas. In Mustavuori, city of Vantaa, it was seen in September as flowering individuals around remains of a hay barn, which was burnt at midsummer, and the seedlings grew so close that the germination had to been taken place after the fire.

On rocky outcrops and on large erratic blocks, on which the species is a permanent component of the vegetation, the numbers and size of individuals varied considerably.

Fig. 1. Localities mentioned in the text. 1: Helsinki and Vantaa, 2: Toussula; Ruotsinkylä and Ruutjärvi, 3: Bromary, Siböle, 4: Lammi, Evo, 5: Padajoki, Vesijärvi, 6: Lapinjärvi, 7: Ruotsinpyhtää, 8: Juupajoki, Hyytiala and 9: Punkaharju.

Fig. 2. An extensive and almost pure stand of Galeopsis bifida in a clear-cut area in Vesijärvi experimental forest in summer 1974. The species declined in following years and in 1978 only occasional small individuals were seen. In 1982 the species was totally absent under planted pine saplings.
between successive years. In moist summers, e.g., in 1974 the individuals were large and numerous, but in drier years smaller. In extremely dry years, mainly in 1975, on many rocky outcrops and erratic blocks no one of the seedlings in the spring reached fruiting stage due to drought. However, after drought year of 1975 the species appeared again on the same rocky outcrops and erratic blocks as earlier. In summer 1986 on several erratic blocks in late September Galeopsis was beginning to flower, although in normal years

fruits ripen in early August. In early summer of 1986 there were long drought periods in South and Central Finland, e.g., in Helsinki from June 10 to July 10 the amount of rainfall was only 13.2 mm, but in the month of August 159.9 mm. The occurrence on such places can be explained either by originating from a dormant seed pool in humus, or from dispersal after drought from agricultural and ruderal places. For this reason the germination ecology of Galeopsis bifida was studied both in the field and laboratory.

3. Material and methods

3.1. Experiments with seeds of Galeopsis bifida

Nutlets (here called seeds) on Galeopsis bifida were collected in natural habitats by taking fruiting shoots into large plastic bags, allowed to stand overnight in laboratory and then gently shaken to remove seeds. The majority of the seeds were considered ripe. In collecting special care was attached to the presence of flowers, by which the species is easiest to tell apart from similar G. speciosa, which commonly grows in mixed stands together with G. bifida. The collected seeds were dried for 1 day at room temperature in laboratory and stored in a refrigerator at +5 – +6°C.


3.2. Survival of Galeopsis seeds in forest humus

As many weed seeds remain in soil dormant extensive periods, preservation of

Galeopsis seeds in forest humus was studied in following way. 100 seeds were placed in nylon gauze bags, ca. 7 × 7 cm, mesh size 0.4 mm, closed with nylon thread and placed into forest humus layer to a depth of 5–10 cm, to which depth seeds probably may get when they fall on the surface of humus. After 1–10 years, bags were taken into laboratory, seeds placed on filter paper in petri dishes and moistened with 100–1000 ppm gibberellic acid (GA3) solution in order to break dormancy. Results in Table 1. Locals refer to experimental forests of the Finnish Forest Research Institute (Fig. 1). Seeds of Galeopsis remained in forest humus alive at least following periods: dry pine forests (VT): 6 years (germination 67 %), mesic spruce forests (MT): 10 years (37 %), eutrophic forests of OMT-type 10 years (12 %) spruce swamps: 9 years (1–68 %), rock surface: 6 years (11 %). Evidently these values do not represent maximum preservation times, and it is possible that seeds may remain dormant in humus longer, perhaps the whole rotation time of forest stands.

3.3. Germination experiments in laboratory

Germination experiments were carried out in 10 cm glass or plastic petri dishes either on filter paper or in long-term experiments on

Table 1. Survival and germination of seeds of G. bifida after being buried in forest humus in nylon gauze bags for different periods. The seeds were treated in laboratory after the excavation with 100 ppm aqueous solution of GA3.

<table>
<thead>
<tr>
<th>Locality and biotype</th>
<th>laid in humus</th>
<th>taken into laboratory</th>
<th>time in humus</th>
<th>germination % in laboratory after GA3-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruotsinkylä, protected OMT birch-spruce forest on drained swamp</td>
<td>29.9 -73</td>
<td>4.7 -83</td>
<td>9 y 9 mo</td>
<td>32 left, of which 10 germinated = 10 %</td>
</tr>
<tr>
<td>Ruotsinkylä, moist dense birch-spruce swamp, leaf litter</td>
<td>29.9 -73</td>
<td>12.6 -82</td>
<td>7 y 8 mo</td>
<td>36 %</td>
</tr>
<tr>
<td>Ruotsinkylä, spruce swamp in Sphagnum giganteum</td>
<td>29.9 -73</td>
<td>4.7 -82</td>
<td>9 y 9 mo</td>
<td>53 left, one germinated = 1 %</td>
</tr>
<tr>
<td>Ruotsinkylä, birch-spruce stand, OMT</td>
<td>29.9 -73</td>
<td>4.7 -83</td>
<td>9 y 9 mo</td>
<td>95 left, 68 germinated = 68 % (1000 ppm GA3 added)</td>
</tr>
<tr>
<td>Ruotsinkylä, dense spruce plantation, in needle litter</td>
<td>29.9 -73</td>
<td>4.7 -83</td>
<td>9 y 9 mo</td>
<td>Bag 1.21 seeds, no germination</td>
</tr>
<tr>
<td>Ruotsinkylä, old MT spruce forest under Picea sitchensis</td>
<td>29.9 -73</td>
<td>23.6 -82</td>
<td>8 y 9 mo</td>
<td>24 %</td>
</tr>
<tr>
<td>Ruotsinkylä, protected OMT drained spruce-birch swamp</td>
<td>29.9 -73</td>
<td>13.6 -84</td>
<td>10 y 8 mo</td>
<td>When taken up from humus, 8 of seeds were germinating, probably due to the fact that the bag was (due activity of rodents) near surface of the soil. In laboratory 4 additional seeds germinated, total 12 seeds viable.</td>
</tr>
<tr>
<td>Ruotsinkylä, old MT spruce stand, under carpet of Picea sitchensis et Hymenosporum</td>
<td>29.9 -73</td>
<td>13.6 -84</td>
<td>10 y 8 mo</td>
<td>When taken out of humus, 4 of the seeds were germinating, 37 % germinated in laboratory</td>
</tr>
<tr>
<td>Punkaharju, protected moist mixed stand, MT</td>
<td>13.8 -74</td>
<td>27.7 -83</td>
<td>8 y 11 mo</td>
<td>bag 1:55 left, 20 germinated = 20 % bag 2:19</td>
</tr>
<tr>
<td>Solbõe, open rock surface under a Cladonia plate</td>
<td>1.10 -73</td>
<td>21.5 -81</td>
<td>6 y 7 mo</td>
<td>11 %</td>
</tr>
<tr>
<td>Rusutjärvi, rock surface under Cladonia</td>
<td>11.11 -74</td>
<td>11.8 -80</td>
<td>5 y 9 mo</td>
<td>15 %</td>
</tr>
<tr>
<td>Rusutjärvi, Ledum pine bog, under Sphagnum</td>
<td>29.12 -74</td>
<td>20.6 -82</td>
<td>7 y 5 mo</td>
<td>a) 46 % b) 25 % c) 17 % (3 bags).</td>
</tr>
<tr>
<td>Ruotsinkylä, MT pine-spruce forest under Picea sitchensis</td>
<td>8.11 -76</td>
<td>29.6 -82</td>
<td>5 y 8 mo</td>
<td>56 %</td>
</tr>
<tr>
<td>Ruotsinkylä, young VT pine forest, needle litter</td>
<td>8.11 -76</td>
<td>29.6 -82</td>
<td>5 y 8 mo</td>
<td>55 %</td>
</tr>
</tbody>
</table>

Veikko Hinikka

Silta Fennica 21 (3)
Table 1. cont.

<table>
<thead>
<tr>
<th>Locality and biotype</th>
<th>laid in humus</th>
<th>time in laboratory</th>
<th>germination % in laboratory after GA_3 treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruotsinkylä, pole-aged pine stand, VT</td>
<td>8.11.-76</td>
<td>6 8 mo</td>
<td>96 left, 67 %</td>
</tr>
<tr>
<td>Ruotsinkylä, moist grass-herb alder forest</td>
<td>9.11.-76</td>
<td>3 9 mo</td>
<td>55 %</td>
</tr>
<tr>
<td>Ruotsinkylä, moist spruce swamp, under Sphagnum girgensohnii and Polytrichum commune</td>
<td>9.11.-76</td>
<td>3 9 mo</td>
<td>41 %</td>
</tr>
<tr>
<td>Lapinjärvi, dry VT pine forest (Calluna, Picea)</td>
<td>10.11.-76</td>
<td>3 9 mo</td>
<td>54 %</td>
</tr>
<tr>
<td>Lapinjärvi, OMT spruce stand</td>
<td>10.11.-76</td>
<td>7 6 mo</td>
<td>68 %</td>
</tr>
<tr>
<td>Lapinjärvi, moist dense MT spruce forest on clay soil</td>
<td>10.11.-76</td>
<td>7 6 mo</td>
<td>51 %</td>
</tr>
<tr>
<td>Lapinjärvi, old MT spruce stand under thick Picea moss carpet</td>
<td>10.11.-76</td>
<td>7 6 mo</td>
<td>82 %</td>
</tr>
<tr>
<td>Ruotsinpyhtäjä, shady MT spruce forest, under Picea</td>
<td>14.11.-76</td>
<td>4 11 mo</td>
<td>a) 64 % b) 64 %</td>
</tr>
<tr>
<td>Ruotsinpyhtäjä, open MT spruce forest under Picea</td>
<td>14.11.-76</td>
<td>4 11 mo</td>
<td>52 %</td>
</tr>
<tr>
<td>Rusunjärvi, spruce swamp under Sphagnum girgensohnii</td>
<td>16.11.-76</td>
<td>3 9 mo</td>
<td>68 %</td>
</tr>
<tr>
<td>Rusunjärvi, moist MT mixed forest on clay soil</td>
<td>16.11.-76</td>
<td>3 9 mo</td>
<td>74 %</td>
</tr>
<tr>
<td>Ruotsinkylä, dense spruce swamp, in Sphagnum girgensohnii</td>
<td>16.11.-76</td>
<td>6 7 mo</td>
<td>93 left, 76 germinated = 76 % (1000 ppm GA_3 added)</td>
</tr>
</tbody>
</table>

4. Results

4.1. Germination of newly collected seeds

When seeds of *G. bifida* were placed immediately after collection on moist filter paper, the germination percentage was as a rule very low, for seed source E 1.86 % (5100 seeds) and 0.00 % for K. Grime et al. (1981) reports the same for *G. tetrahit*. When placed on quartz sand in petri dishes and kept in laboratory continuously moist, they remained dormant up to 5 years. The dormant condition was indicated by treating the seeds in following ways.

4.2. The effect of nitrate

Dry seeds were immersed in 1 % KNO_3 solution for 24 hours, washed several times with deionized water and allowed to germi- fine quartz sand or on Whatman GF/A glass microfibre filter in order to avoid mould contamination. The filter paper and quartz sand was kept continuously moist by adding deionized water at irregular intervals. In many cases on quartz sand the seeds remained almost free from mould interference for several years. The petri dishes were kept in a light laboratory room, and the temperature varied +22 - +26°C.

4.3. The effect of gibberellic acid

Dry seeds were placed on filter paper and moistened with ca. 7 ml of different concentrations of GA_3 (Sigma G-3250). Results in Fig. 3. In another experiment with seed source R, 10 ppm GA_3 caused germination of 31.5 % (600 seeds) and in control 5200 seeds germination was 0.135 %.

4.4. The effect of GA_3 on dormant seeds stored moist

Seeds of *Galeopsis* were kept in petri dishes on moist quartz sand in laboratory for 240 days. Then aqueous solution of GA_3 was added to give a final concentration of ca. 100 ppm. Germination after treatment was in two dishes 67 and 68 %, in control untreated dishes none. In Fig. 4 a similar experiment. Seeds (K) were kept on moist quartz sand in petri dishes in laboratory at room tempera-
4.5. The effect of GA₃ on dormancy seeds which were kept in humus layers extended (1–9) years periods

As described above, seeds of Galeopsis were placed in nylon mesh bags, and allowed to remain in forest humus for different periods. When taken and laboratory, the seeds did not germinate, but treatment of 100 ppm GA₃ solution resulted sometimes almost complete germination of the seeds, which were buried for several years in forest humus.

Based on these experiment, it is concluded that treatment with GA₃ breaks very efficiently the dormancy of the seeds of Galeopsis in laboratory.

4.6. Effects of forest humus, fungus extracts and tree pollen on germination of dormant seeds of Galeopsis

As seeds germinated readily in natural conditions in the spring, an attempt was made to investigate whether there are in forest soils substances which release dormancy like GA₃. Dormant seeds were treated with soil extracts, prepared from different kinds of forest and cultivated soils by allowing soil to stand in deionized water for 12 h and the filtrate was added to petri dishes with dormant seeds. In 30 soil samples no evidence of stimulation of germination was found. In addition, on disturbed forest soil occur regularly characteristic fungus species, e.g. Laccaria laccata and Paxillus involutus (Laiho 1970). Extracts were made from basidiocarps of both species as well as from pure culture mycelium of Paxillus, and added in different concentrations of GA₃ solution. Then the quartz sand was pipetted 3 ml of different concentrations of GA₃ solution. Then sand contained approximately 10 ml moisture. 100 ppm GA₃ solution resulted in germination of 18 %, 250 ppm 11 %, 500 ppm 34 % and 1000 ppm 45 %. In control seeds without gibberellin no germination occurred. Values are based on a single dish/concentration. It seems that the release of dormancy in aged seeds requires relatively high concentrations of GA₃.

4.7. The effect of heat treatment

100 seeds were placed on moist filter paper in petri dishes and allowed to germinate for 40–45 days. Then the petri dishes were placed in a thermostatically controlled laboratory oven, fluctuations 2°C, and heated for 1/2–6 hours. Results in Table 2. Temperatures below 40°C did not have any effect on germination, but temperatures of 43–53°C for 1–3 h greatly increased the germination percentage. Temperatures over 60–65°C evidently injure the seeds based on the fact that they did not react on GA-treatment. In control dishes at room temperature germination was none.

7 petri dishes, in each 100 seeds (source R) on moist quartz sand, were kept moist by additions of deionized water for 330 days. Initial germination during first two weeks was 0.1 %, and after that none. Then the dishes were heated to 45°C for 2½ hours, resulting an average germination of 55 % in two weeks.

Seeds (source V) were kept in 3 dishes on moist quartz sand (100 seeds in each) for 1010 days in laboratory. Then seeds were heated for 1½ hours to 50°C, and the germination percentage was 38, 8 and 0 %.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Duration of heat treatment hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>60°C</td>
<td>10</td>
</tr>
<tr>
<td>55°C</td>
<td>5</td>
</tr>
<tr>
<td>50°C</td>
<td>1</td>
</tr>
<tr>
<td>45°C</td>
<td>1</td>
</tr>
<tr>
<td>40°C</td>
<td></td>
</tr>
<tr>
<td>35°C</td>
<td></td>
</tr>
</tbody>
</table>

4.8. The effect of heating compared with GA₃-treatment

Seeds of G. hifuda were collected in Ruotsinkylä on August 24, 1981 and 100 seeds were placed on moist quartz sand in petri dishes on following day. The sand was kept moist by additions of deionized water until April 1984, during which time no germination occurred. 2 dishes were then treated with 100 ppm solution of GA₃, resulting in germination of 85 and 81 %, two were heated to 43°C for 5 hours, resulting in 19 % and 3 % germination and three were treated both with heating 5 h at 45°C as well as by GA₃ 100 ppm, resulting in germination of 91, 63 and 35 %. Result suggests that gibberellic acid releases dormancy in older seeds more effectively than heat treatment.

5. Discussion

5.1. The role of the seed bank in occurrence of Galeopsis in nature

The occurrence of Galeopsis on disturbed forest soil can be explained either by recent seed dispersal or from dormant seeds in the humus layer. The genus Galeopsis does not produce excessive amounts of seeds, as only 4 nutlets per flower are formed. The number of flowers varies greatly depending plant size, being approximately 10–500 and the number of seeds can be estimated to be some thousands per individual at maximum. The nutlets are large compared with most Nordic native plants, and weigh ca. 4 mg each, and thus contain considerable amount of reserve material. When the seeds of Galeopsis germinate, they produce a rapidly-growing seedling (average growth rate of the primary root at room temperature about 15 mm/day) and the seedling attains a height of 15–20 cm with aid of reserve materials. There are no special adaptations to long-distance dispersal. The size of the nutlets resembles to a part that of cereal grains, and earlier the grain seed has evidently been an important seed source for Galeopsis in the fields. Most seeds are probably strown around mother plant, although spiny calyx may be attached to animal furs (Hasselberg 1940). There are also possibilities to endozoochorical dispersal by cattle (Korsmo 1925). In addition, seeds of Galeopsis are eaten by granivorous birds, e.g. by finches (it is a common sight during autumn migration time to see a flock of finches rise from a stand of Galeopsis), although passerine birds crush the seeds before swallowing, thus making dispersal less probable. Finally, foodrobbing birds, mainly Parsia atricapillus, may store seeds of Galeopsis.
5.2. The role of GA and temperature in the release of seed dormancy in forest humus

Whether GA occurs in forest soils, is not known. According to Lynch (1985), giberellin production by other fungi than Gibberella fujikuroi has not been definitely established. Although it is suggested that mycorrhizal fungi produce giberellin-like substances, their occurrence is not known in detail (Harley & Smith 1983). The present experiment with soil extracts also suggest that giberellin-like substances do not occur at least very commonly in nature. Interestingly is to note that according to Lynch (1985) and Conzales-Lopez et al. (1986), Agrobacterium evidently produces giberellic acid. This bacterium is characteristic to neutral soils and in theory this bacterium could induce germination of Galoposis seeds.

Although there are numerous investigations on the effect of giberellins on seed germination, relatively few studies concern the effects of GA on aged seeds of low viability. Puls & Shuttleworth (1974) studied the effects of GA on ten-year-old seeds to tomato, but there was no influence on final germination percentage. Present experiments suggest that giberellin may induce germination of forest dormant seeds of Galoposis, and evidently still older, too.

Based on above experiments, in nature temperature seems to be an important factor controlling seed germination in forest soils. According to Dahlgren (1928), seeds of this species require at least 35°C heat treatment to germinate and germinate well when kept 18 hours in 60°C water and remain alive for heating to 100°C (Skärman 1919, Dahlgren 1928, Jalas 1980). The seeds of Galoposis seem to be considerably less tolerant to high temperatures. They do not according to present experiments survive even short heating to 100°C, but the lower limit for induction seems to be fairly similar. Similarly, seeds of Geranium bohemicum are supposed to remain in forest soils dormant for extensive periods, according to Malme (1928) ca. 30 years in a documented observation (although not supported by burial experiments) and only when the soil is heated, they germinate.

5.3. The role of nitrate in the germination of seeds to Galoposis in nature

Stimulation of seed germination by nitrate is fairly widely spread among plants and is evidently ecologically important. E.g. Freijus et al. (1987) have found that seeds of nitrophilous Cynoglossum officinale germinate in nitrate-rich soils much more completely than in soils lacking nitrate. In forest soils, stimulation of germination by nitrate can be regarded as an adaptation to germinate in disturbed habitats, where competition by other plants is less severe. In closed stands, where seedlings are difficult to establish, nitrate nitrogen is usually accumulated, not at least in Nordic conditions (Hesselman 1937). In contrast of when forest soil is disturbed, nitrification promotes considerable amounts of nitrates, which are not immediately absorbed by roots (Popovic 1972). According to Vitousek et al. (1979) increase in nitrification after disturbance in forest ecosystems seems to be an almost universal phenomenon. In extreme cases water in rivers coming from closed-cut areas is so badly polluted with nitrates that it is undrinkable. In North Finland, Kuhni (1984) have found in the soil and running water from closed-cut areas a definite increase of nitrates. It should be noted that in incubation experiments, which partly correspond a disturbed humus layer, a considerable increase of nitrates takes place, especially in humus of more fertile site types (Tamm & Pettersson 1969). When humus in ploughing of forest soil for regeneration get mixed with mineral soil, its nitrate content rises up to 12000 mgN/1. Under these conditions, in burned forest soil nitrification increases (Måkken 1982). Galoposis occurs in addition sometimes in forest fertilized heavily with urea, where the rate of nitrification is also often increased (Måkken 1978, Marktiken 1984). Based on this review, it seems possible that increased nitrification and formation of nitrates in disturbed forest soil may at least in theory induce germination of dormant seeds. When germination of Galoposis seeds takes place, the seedling very rapidly grows in size due to large nutrient reserves in the seed.

The above observations and experiments suggest that dormant seeds of Galoposis have a mechanism, possibly in the biosynthesis route
succession is consequently to a considerable extent determined by the germination biology.

References

Kannattajajäsenet — Supporting members

CENTRALSKOOGSNÄMNDEN SKOGSKULTUR
SUOMEN METSÄTEOLLISUUDEN KESKUSLIIHTTO
OSUUSKUNTA METSÄLIHTTO
KESKUSOSUUSLIITKE HANKKIIJA
OY WILH. SCHAUMAN AB
KEMPZ OY
METSÄ-SELE OY
KYMMENE OY
KESKUSMETSAUTAKUNTA TAPIO
KOIVUKESKUS
A. AHNSTRÖM OSAKEYHTIÖ
TEOLLISUUDEN PULYHDISTYYS
OY TAMPELLA AB
KAJANI OY
KEMI OY
MAATALOUSTUOTTAJAIN KESKUSLIHTTO
VAKUUTUSOSAKEYHTIÖ POHJOLA
VEITSILUOTO OSAKEYHTIÖ
OSUUSPANKKIEN KESKUSPANKKI OY
SUOMEN SAHANOMISTAJAJYHDISTYS
OY HACKMAN AB
YHTEEN PAPERITEHTÄVÄT OSAKEYHTIÖ
RAUMA REPULA OY
JAKKO POYRY OY
KANSALLIS-OSAKE-PANKKI
SOTKA OY
THOMESTO OY
SAASTAMO.INEN OY
OY KESKUSLABORATORIO
METSANJALOSTUSSAÄTÖ
SUOMEN METSANHOITAJALIHTTO
SUOMEN 4H-LIHTTO
SUOMEN PUULEVYTEOLLISUUSLIITTO R.Y.
OY W. ROSENLEW AB
METSMÄJSTEN SÄÄTIÖ
SÄÄSTÖPANKKIIEN KESKUS-OSAKE-PANKKI
ENSÖ-GUTZLIT OY
Instructions for authors – Ohjeita kirjoittajille

Manuscripts are to be sent to the editors as three full, completely finished copies, including copies of all figures and tables. Original material should not be sent at this stage.

The editor-in-chief will forward the manuscript to selected examiners for expert appraisal. The editorial board will then decide, on the basis of the examiners' recommendations, whether to publish the manuscript. Decision will be made within four months after the editors have received the copies of the manuscript.

The author is responsible for the scientific content and linguistic standard of the manuscript. The author may not have the manuscript published elsewhere without the permission of the editors of Silva Fennica. Silva Fennica accepts only manuscripts that have not earlier been published.

The author must take into account any suggested changes proposed by the examiners or editorial board. If the author informs the editor-in-chief or editorial board of a differing opinion, they will, if necessary, reconsider the matter. Following final approval, no essential changes may be made to the manuscript without the permission of the editor-in-chief. Major changes presuppose a new application for acceptance.

The author is to forward the manuscript and original pictures to the editors within two months after acceptance. The letter accompanying the manuscript must clearly state that the manuscript in question is the final version, ready to be printed.

Käsikirjoituksesta lähetetään toimitukselle kolme täydellistä, viimeisteltyä kopiora, joihin sisältyy myös kopiot kaikista kuvista ja taulukoista. Originaliaiaineistoa ei tässä vaiheessa lähetetä.


Tekijän on otettava huomioon ennakkotarkastajien ja toimituskunnan korjaukseistykset tai ilmoitettava erilavat mielepitiensä vastaavalle toimittajalle tai toimituskunnalle, joka tarvittaessa käsittelee asian uudemleen. Hyväksymisen jälkeen käsikirjoituksen ei saa tehdä olennaisia muutoksia ilman vastaavan toimittajan lupaa. Suuret muutokset edellyttävät uutta hyväksymistä.

Tekijän tulee lähetettä käsikirjoitus ja kuvaoriginalit toimituksele kahden kuukauden kuluessa hyväksymispäätöksestä. Käsikirjoituksen saatetta tulee selvästi ilmetä, että kysesiä on lopullinen, kirjainnoon tarkoitettu kappale.

Contents – Sisällys

Pukkala, T. & Kuuluvainen, T. Effect of canopy structure on the diurnal interception of direct solar radiation and photosynthesis in a tree stand. Tiivistelmä: Latvuston rakenteen vaikutus metsikön päivittäiseen suoran päiledyn pidätymiseen ja fotosynteesiin. 237–250


Lindholm, T. & Vasander, H. Vegetation and stand development of mesic forest after prescribed burning. Seloste: Kasvillisuuden ja puuston kehitys tuoreella kankaalla kulutuksen jälkeen. 259–278


Hintikka, V. Germination ecology of Galeopsis bifida (Lamiaceae) as a pioneer species in forest succession. Tiivistelmä: Peltopillikkeen itämisekologia ja esiintyminen metsäsukskeen pionerilajina. 301–313