

Frost hardiness of mycorrhizal and non-mycorrhizal Scots pine (*Pinus sylvestris* L.) roots and needles in two fertilization treatments

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Background and aims

Survival and functioning of mycorrhizal associations at low temperatures is not known well. The aim was to compare the frost hardiness (FH) of roots and needles of mycorrhizal (*Hebeloma* sp.) and non-mycorrhizal Scots pine (*Pinus sylvestris* L.) seedlings with two fertilization treatments and two hardening treatments.

Material and methods

Mycorrhizal (ECM: *Hebeloma* sp.) and non-mycorrhizal (NM) seedlings were cultivated in four blocks with low and high fertilization level (Table 1). The FH of the roots and needles was assessed for unhardened and hardened seedlings using controlled freezing tests (6–7 temperatures) and electrolyte leakage tests (REL).

Results

- ECM roots were slightly more frost hardy than NM roots, no difference in needles (Table 2).
- The fertilization treatments did not affect the FH of roots or needles.
- The needles hardened significantly in SDLT but not roots.
- The interaction between mycorrhizal and hardening treatment was close to significant for roots. Roots of the ECM seedlings were more frost hardy than NM seedlings in LDHT but not in SDLT.
- The FH of ECM and NM roots did not differ at HF. At LF, ECM roots were more frost hardy than NM ones.
- Dry weight of the roots, stems and needles were significantly smaller in LF than HF or in SDLT than LDHT. The ECM treatment did not affect the dry weight and its allocation.

Table 1. Growth chamber conditions and number of seedlings in each block (n=4) by treatments. Abbreviations: ECM mycorrhizal, NM non-mycorrhizal, HF high fertilization, LF low fertilization, LDHT long day and high temperature, SDLT short day and low temperature.

| Treatment | Seedlings, n | Time, weeks | Growing conditions | Photoperiod day/night, h | Temperature day/night, °C | Humidity, % | Fertilization: N content, mg/l |
|---------------|-----------------|-------------|--------------------|--------------------------|---------------------------|-------------|---------------------------------|
| Pre-growth | 304 | 3 | LDHT | 19/5 | 22/15 | 80 | - |
| Mycorrhiza | 152 ECM, 152 NM | 6 | LDHT | 19/5 | 22/15 | 80 | 10 (4.5 weeks) → 30 (1.5 weeks) |
| Fertilization | 76 ECM, 76 NM | 3 | LDHT | 19/5 | 22/15 | 80 | 80(HF) |
| | 76 ECM, 76 NM | 3 | LDHT | 19/5 | 22/15 | 80 | 40(LF) |
| Hardening | 38 ECM, 38 NM | 4 | LDHT | 19/5 | 22/15 | 80 | 40 |
| | 38 ECM, 38 NM | 4 | SDLT | 6/18 | 8/3 | 90 | 40 |

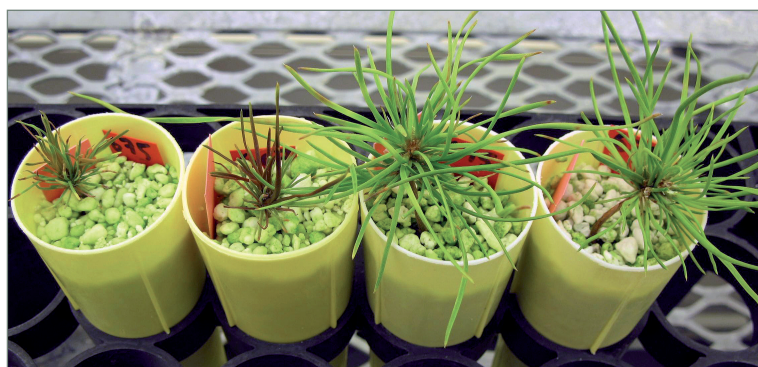


Fig. 1. 16 weeks old mycorrhizal pine seedlings from SDLT (left) and LDHT (right) treatment (both with high fertilization treatment). Photo: Anna Korhonen.

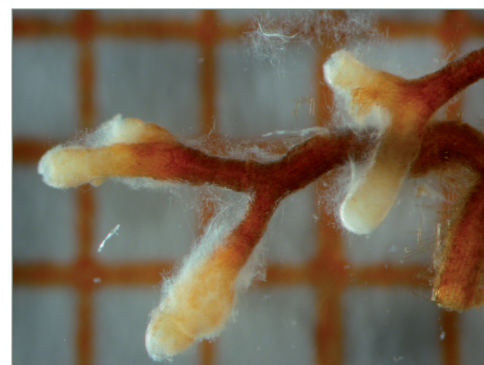


Fig. 2. Mycorrhizal (*Hebeloma* sp.) root sample (grid 1 × 1 mm). Photo: Anna Korhonen.

Table 2. The LT₅₀-values and the significance of difference between treatments (for abbreviations see Table 1). N=4.

| Treatment | LT ₅₀ , °C | | | |
|-----------------|-----------------------|------|---------|------|
| | Roots | SE | Needles | SE |
| ECM / HF / LDHT | -11.2 | 0.27 | -8.3 | 1.00 |
| ECM / LF / LDHT | -11.2 | 0.51 | -9.4 | 1.20 |
| NM / HF / LDHT | -10.7 | 0.39 | -8.6 | 0.81 |
| NM / LF / LDHT | -9.1 | 0.35 | -7.7 | 0.95 |
| ECM / HF / SDLT | -8.6 | 0.18 | -13.5 | 0.27 |
| ECM / LF / SDLT | -9.3 | 0.78 | -14.3 | 0.86 |
| NM / HF / SDLT | -9.2 | 0.66 | -13.9 | 1.56 |
| NM / LF / SDLT | -8.7 | 0.30 | -14.9 | 1.31 |

| Source of variation | Significance, P | |
|------------------------|-----------------|--------------|
| | Roots | Needles |
| ECM / NM (M) | 0.065 | 0.890 |
| HF / LF (F) | 0.317 | 0.476 |
| SDLT / LDHT (H) | 0.000 | 0.000 |
| M * F | 0.056 | 0.515 |
| M * H | 0.060 | 0.400 |
| F * H | 0.215 | 0.588 |
| M * F * H | 0.811 | 0.454 |

Conclusions

Mycorrhizal infection had a small effect on frost hardiness of roots of the unhardened seedlings and with low fertilization. More information is needed on the role of different mycorrhizal fungi on frost hardiness.

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