

**Plasticity of red spruce and balsam fir seedlings:
response to sudden shifts in light environment**

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Principal findings

- Under conditions of sufficient but not excessive light, combined with ample soil moisture and high atmospheric humidity red spruce has the capability to far exceed balsam fir in growth rates.
- When resources, particularly water, become limiting or in excessive light environments a more conservative, less plastic allocation pattern would select for fir in dominance of regenerating stands.

Introduction

Red spruce and balsam fir are two principal components of conifer-dominated forests in the Acadian Region. Both of these shade-tolerant species share similar ecological profiles, regenerating through advance-regeneration in the understory of an existing stand and growing towards canopy height following a disturbance that provides them with necessary sunlight, water and mineral resources. Although reproductive efforts and seedling establishment have been shown to be similar between these co-occurring and competing conifers, forest inventory data show that fir is becoming more abundant in the Acadian Forest Region at the expense of spruce. This presents a concern due to the higher value of spruce for sawlogs. In our continuing efforts to understand the ecology and physiology of spruce-fir interactions, we tested the relative ability of first-year and second-year red spruce and balsam fir seedlings to respond to sudden changes in light environment, such as would be experienced following harvest with substantial overstory

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removal. This included the productivity metrics growth, photosynthetic rates and carbon allocation, along with plasticity in responses to light-stress through the xanthophyll cycle components and non-photosynthetic quenching of absorbed solar energy.

Methods

Seedlings were grown in a shade frame that simulated the forest understory under a uniform canopy by permitting only about 20% of incident sunlight to be transmitted to the seedlings. In mid-growing season an experimental group of seedlings were moved to full sunlight to simulate an overstory removal harvest, while a control group remained shaded. Six blocks of seedlings were tested as first-year germinants, and a second set as two-year-old seedlings the following summer. After six weeks of exposure to the open canopy, both treatment and control seedlings were measured for maximum photosynthetic rates, stomatal conductance, and chlorophyll fluorescence parameters. This was followed by postharvest measurements of biomass distribution between foliage, stems and roots, and allocation to the xanthophyll pigment cycle, which serves to protect photosynthetic components from damage from excessive absorbed sunlight.

Results

Spruce seedlings allocated far more resources to photosynthetic shoots than to roots, which, combined with a plastic ability to continue (neoformed) development for a longer period, resulted in strikingly superior growth. In this study spruce seedlings accumulated over twice as much biomass as fir in year one and, due to compound investment effects and significantly higher photosynthetic rates, nearly 10x as much biomass in year two. In contrast, fir invested a greater proportion of its biomass in root production, showing root-shoot ratios over twice those of spruce. While both species showed similar ratios of active to total xanthophylls, fir seedlings had a greater total xanthophyll pool than spruce. Likely related to this photoprotective strategy, the fluorescence parameter F_v/F_m , used to assess damage to the photosynthetic system, suggests that fir suffered a lower decrease in photochemical efficiency when exposed to a high-light environment than does red spruce.

Growth rates suggested that red spruce should be far more competitive during the seedling stage than fir. However, the conservative seedling strategy of fir may be a principal factor selecting for landscape-level competitive superiority in stochastically variable forest environments. Overall, fir exhibited a more conservative approach allocating more resources to photoprotection and roots relative to foliar biomass and photosynthetic systems. Spruce allocated more to foliage and photosynthesis resulting in much greater biomass and height growth, especially in its second year. Therefore, spruce seedlings would have a competitive edge due to

its greater photosynthetic rates and leaf area in post-harvest or post-disturbance environments only when (1) moisture was not limiting and (2) light stress was moderated by a partial overstory. In higher energy environments, where light and moisture stresses are highly correlated, the more conservative seedling life-stage strategy of balsam fir would likely be competitively superior.

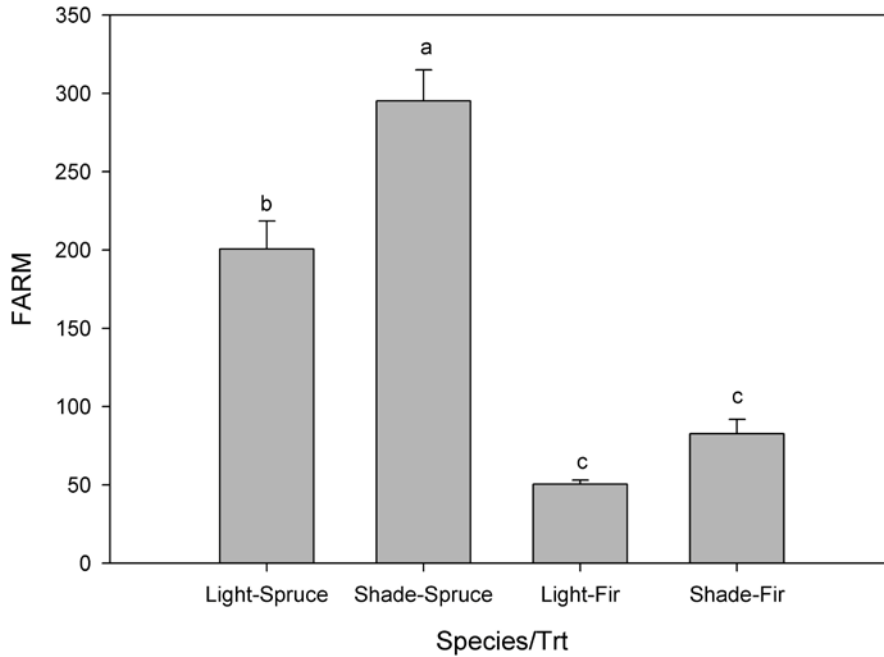
Products

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Foliage area to root mass ratio (FARM) for first-year germinants of red spruce and balsam fir. The high ratio of spruce germinants is very competitive as long as soil moisture content remains high and evaporative demand from the atmosphere remains low. However, the more conservative strategy of balsam fir will become more adaptive under less ideal conditions.



First-year red spruce (upper left) and second-year balsam fir (lower right) seedlings establishing on a rotting log. With its low resource allocation to roots, the spruce germinant will be less likely to survive even a brief period of drought. (M. Day photo).