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Effect of nursery storage and site preparation techniques on field performance of high-elevation *Pinus contorta* seedlings

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ABSTRACT

After five years of growth at high-elevations (~3000 m) in Utah, container lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) seedlings survived well (80–95%) and grew to similar heights regardless of nursery storage method and site preparation technique. Seedlings received one of three storage treatments: (1) spring-sown in the nursery, overwintered in cooler storage and outplanted in July; (2) spring-sown, overwintered in freezer storage, and outplanted in July; or (3) winter-sown, no storage, and hot-planted in late August. We outplanted seedlings at two locations that were clearcut and had received two treatments of surface organic matter (coarse wood, logging slash, and forest floor) removal: surface organic matter (OM) piled with a bulldozer and burned or surface OM remaining *in situ*. Compared to adjacent uncut stands, both site preparation treatments increased total soil bulk density, but retaining surface OM *in situ* maintained soil OM, carbon, and nitrogen levels. After one growing season, seedlings planted where surface OM had been bulldozed were taller and had more biomass, although survival was similar (≥96%) across site preparation treatments. The height growth advantage disappeared after five growing seasons and although overall survival was good, survival was highest where site preparation involved removal of surface OM and freezer-stored seedlings were planted. Total non-structural carbohydrates tended to be higher in roots than in shoots and were also higher in hot-planted seedlings than in stored seedlings. Our results indicate that nursery and forest managers have several options for successful nursery production and outplanting of container lodgepole pine seedlings in the central Rocky Mountains. Using hot-planted seedlings allows for a faster turnaround time (from seed to plantable seedling) and maintaining surface OM may be a cost-effective alternative to dozer piling and burning.
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1. Introduction

Following harvest operations site preparation is often used to create seedbeds for natural regeneration. Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) is widespread in the coniferous forests of high-elevation sites in the western USA and is often the species of choice for reforestation. Natural regeneration can be delayed on sites that have a poor seed year at time of harvest, have low soil moisture, ectomycorrhizal inoculum, fertility, or temperatures (Bradbury et al., 1998; Fleming et al., 1998), or when seed predation is high (Page-Dumroese et al., 2002). In such cases, artificial regeneration of lodgepole pine may be used, but success of plantings can be highly variable because of effects of container shape, nursery conditions, storage regime, and/or planting site conditions (van den Driessche, 1991; Balisky and Burton, 1997; Jones et al., 2002). Recently, more emphasis has been placed on planting directly into the surface organic matter (coarse wood, logging slash, and forest floor [which includes all surface organic horizons]) remaining on the site to reduce planting costs, reduce erosion, and lessen compaction associated with mechanical treatments (Heineman, 1998; Campbell et al., 2006).

Survival and growth of outplanted conifer seedlings at high elevation is dependent on seedling quality and soil microsite conditions (Balisky and Burton, 1997; Folk and Grossnickle, 1997). Depending on soil surface conditions, temperature extremes can occur for years after harvest, affecting soil biotic and abiotic processes (Balisky and Burton, 1997; Fries et al., 1998). In some areas, microclimate and soil surface properties may be the

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