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Suckering response of aspen to traffic-induced-root wounding and the barrier-effect of log storage

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ABSTRACT

In a growth chamber, we tested how the seasonal timing of placing a physical barrier (simulating a possible effect of log storage) and inflicting root damage impacted aspen (*Populus tremuloides* Michx.) root systems and their suckering capability. Roots from 4-year-old saplings were used, and one half of these root systems had the above-ground portion cut in the winter (dormant) while the other half was cut during the growing season in the summer. Damage was inflicted to the roots by driving a large farm tractor over them, and a covering treatment was applied using a polystyrene board to prevent suckers from emerging from the soil. Soil temperatures for the winter-cut root systems were kept at 5 °C over the growing season, using a water bath, while for the summer-cut root systems soil temperatures were maintained at 17 °C over the growing season. In the winter-cut root systems, both log storage and root wounding caused a 40% reduction in living root mass and carbohydrate reserves, as well as reducing sucker numbers and their growth performance. In the summer-cut root systems log storage and root wounding reduced living root mass by approximately 35% as well as sucker growth, but had less of an impact on the number of suckers produced.

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1. Introduction

Aspen (*Populus tremuloides* Michx.) regeneration by root suckering is dependent upon the physiological condition of the parent root system as well as the environmental conditions surrounding these roots (Frey et al., 2003). These conditions include hormonal balance, carbohydrate content, root damage, soil temperature, and soil strength and aeration. During harvest, machine traffic can damage the root system and change soil conditions (Bates et al., 1993; Shepperd, 1993; Berger et al., 2004; Zenner et al., 2007), and log storage has been speculated to reduce soil temperature and root carbohydrate reserves (Renkema et al., 2009). As a result, on heavily impacted areas such as roads, landings, and skid trails, aspen regeneration is often poor, or in some instances does not occur at all (e.g. Bates et al., 1990; MacIsaac et al., 2006). To improve regeneration in these problem areas, it needs to be determined how changes in site conditions due to harvest activities affect the parent root system and subsequent suckering density and vigour.

The impact of soil compaction on aspen suckering has been widely studied (Bates et al., 1993; Shepperd, 1993; Zenner et al., 2007). Soil compaction decreases the ability of aspen roots to grow because it increases soil resistance to penetration (Ruark et al., 1982; Standish et al., 1988) and reduces soil aeration which in turn increases root mortality as oxygen for respiration is limited (Landhäusser et al., 2003). Soil compaction can also lead to root wounding although wounding can occur without soil compaction (Shepperd, 1993). Wounding affects the hormonal balance of the root system producing an increase in suckering density and growth (Farmer, 1962; Lavertu et al., 1994; Fraser et al., 2004). However, severe wounding can cause a reduction in suckering due to extensive fragmentation of the root system which limits the suckers access to resources (Zahner and DeByle, 1965) or allows for disease to attack and weaken the root system (Basham, 1988). Studies suggesting that soil compaction with root wounding is detrimental to suckering have rarely examined the root system and do not differentiate between the impacts of wounding and soil compaction (Bates et al., 1993; Zenner et al., 2007) while studies that have looked at the direct impact of wounding used shovels or hand tools to simulate root damage by severing or scraping the aspen roots (Farmer, 1962; Fraser et al., 2004). No studies have directly examined aspen roots impacted by heavy machine traffic and the effect on subsequent suckering performance. Looking at the root systems will help isolate the effects of root wounding from soil compaction and give a better understanding of the impacts of harvesting on subsequent aspen regeneration.

Log storage and its impacts on aspen suckering have also received minimal attention. This is surprising because storage of

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log decks can cause large reductions in suckering (Renkema et al., 2009) and affect a significant portion (6–8%) of a harvested area (MacIsaac et al., 2006). In a field study Renkema et al. (2009) found that log decks built in the fall had less impact on suckering than log decks built in the summer. They hypothesized that the seasonal effect was due to the effect of the log decks on soil temperature. For example, a log deck built during the winter maintains low soil temperature during the growing season due to its insulating ability which slows root respiration (DesRochers et al., 2002) and prevents suckering under the log deck (Landhäusser et al., 2006). Thus, cool soils under the deck allow roots to conserve carbohydrate reserves for longer survival, leading to better suckering and growth once the log deck is removed. In contrast, a log deck built in the summer has warmer soils underneath the deck which results in much higher respiration rates (DesRochers et al., 2002) that could significantly deplete carbohydrate reserves. Additionally, the warmer soils encourage suckering, but any suckers that do emerge under the log deck are unable to photosynthesize and resupply root carbohydrate reserves (Landhäusser and Lieffers, 2002). Thus suckering, once the log deck is removed, could be poor. However; these hypotheses, that the impacts of log storage are largely due to its barrier effects and influence on soil temperature, have never been tested.

The effects of log storage and wounding of parent roots may also interact with each other. For example, prolonged log storage may weaken the ability of a damaged root system to repair and defend itself against decay fungi (e.g. Shigo, 1984). As a result, the impact of wounding may become more detrimental to the root system covered by log decks as it is less able to respond defensively to the root damage caused by the traffic.

The objectives of this growth chamber study were to evaluate how aspen regeneration and parent root survival are related to the simulated effect of log storage and traffic-induced-root wounding as influenced by (i) winter harvest with subsequent coverage of the soil during the following growing season and chilling the soil to 5 °C, and (ii) summer harvest with subsequent coverage of the soil over the remaining part of the growing season but maintaining soil temperature at 18 °C.

2. Methods

2.1. Plant material

One hundred aspen (*P. tremuloides* Michx.) saplings were used in this study. They were grown from seed collected from open-pollinated aspen trees in Edmonton, Alberta. When the seedlings were 1-year-old they were transplanted into rectangular pots (16 cm wide × 15 cm deep × 57 cm long); a single seedling was planted 8 cm from one end of each pot which had been filled with a 3:1 mixture of sand to peat. The transplanted seedlings were grown outside at the University of Alberta (Edmonton, AB) for 3 additional years. The seedlings were regularly watered and fertilized using a commercial fertilizer (20–20–20, N–P–K) with chelated micronutrients and grown to the sapling stage (∼1 m in height; Table 1). During the winters, the pots were covered with 30 cm of loose straw and buried in the snow to prevent frost damage to the roots. Similar potted saplings were used by Landhäusser et al. (2007) which allowed for a dense and laterally spread root system with root sizes up to 20 mm in diameter to develop, and the sand-peat mixture made the roots easy to extract for examination.

2.2. Treatments

The study was separated into two experiments. The first experiment began after a winter-cut (removal of the above-ground portion) of the saplings and the second after a summer-cut. Each experiment followed a 2 × 2 factorial design with the treatments being coverage simulating a physical barrier (no-coverage and coverage) and root wounding by machine traffic (non-wounded and wounded). The separation of the study into two experiments was because the duration and conditions in the coverage treatment were not comparable between the winter-cut and summer-cut.

Table 1
Pretreatment measurements (mean ± SE) from 10 pretreatment root systems/saplings for the winter-cut and summer-cut segments ($n = 10$).

	Winter	Summer
Living root (g)	105 ± 15^a	99 ± 15^a
Root TNC (% dry mass)	38.5 ± 1.4^a	36.3 ± 1.4^a
Root sugar (% dry mass)	23.1 ± 0.1^a	11.8 ± 0.1^b
Root starch (% dry mass)	15.1 ± 1.3^b	24.5 ± 1.3^a
Root collar diameter (mm)	16.2 ± 3.0^a	13.6 ± 2.3^b
Height (cm)	122 ± 14^b	151 ± 22^a
Stem dry mass (g)	54 ± 21^a	69 ± 31^a

Different letters indicate statistical differences between the winter-cut versus summer-cut material.

2.2.1. Winter-cut

The sequence of application and duration of the different treatments are depicted in Fig. 1A. In the fall (October 2007), 50 out of the 100 saplings were randomly assigned to the winter-cut. Ten saplings were sampled to take pretreatment measurements. The other 40 saplings were cut off at the soil surface, and the root wounding treatment was applied to half of these root systems (20) while the other half was left untreated (non-wounded). For the wounding treatment the root masses and bound soil were removed from their pots and placed side-by-side to form a 57 cm-wide by 320 cm-long continuous bed on a hard road surface. Two 320 cm long pieces of lumber 5 cm-high and 10 cm-wide were placed lengthwise under this bed and a heavy logging chain was looped three times on top; these features were used to induce the crushing and shearing processes typical of logging operations. A 7130 Case International Magnum farm tractor, exerting a ground pressure of 63 kPa—similar to loaded skidders (William and Neilson, 2000), made 6 passes over the root systems (based on a preliminary study, 6 tractor passes caused a 70% death of root mass typical of heavily trafficked skid trails and landings (Shepperd, 1993)). No significant soil compaction occurred as a result of the root wounding treatment judged by a visible increase in soil volume when roots and soil were placed back into the pots. Subsequently, all root systems (non-wounded and wounded) were covered with a 2 cm layer of forest floor material obtained from a local aspen stand in Edmonton, Alberta in order to inoculate the pots with natural bacteria and fungi. Root systems were then overwintered outside by covering them with 30 cm of straw and burying them in the snow.

In April 2008, once air temperatures rose above 5 °C, all root systems were brought into a growth chamber with 17 h of light at 18 °C, 7 h of dark at 16 °C, and a relative humidity of 60%. Half of the non-wounded and wounded root systems were assigned to one of the coverage treatments (no-coverage and coverage). The 20 root systems assigned to no-coverage were given 9 weeks to sucker and grow. The coverage treated root systems were tightly fitted with a 2.5 cm thick sheet of polystyrene board that was pressed firmly against the soil surface and affixed to the pot. The bottom of the pots were sealed and placed in a water bath (as described by Landhäusser et al., 2003) to maintain soil temperatures at 5 °C. The root systems remained in the water bath for 7 months until outside air temperatures were below 5 °C in November 2008. Then the polystyrene board was removed, and the root systems were moved outside to overwinter covered with 30 cm of straw and buried in

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