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Influence of weed composition, abundance, and spatial proximity on growth in young hybrid poplar plantations

David Henkel-Johnson [a,*], S. Ellen Macdonald [a], Edward W. Bork [b], Barb R. Thomas [c]

[a] Department of Renewable Resources, University of Alberta, 751 General Services Building, Edmonton, Alberta T6G 2H1, Canada
[b] Department of Agricultural, Food and Nutritional Science, University of Alberta, 410 Agriculture/Forestry Centre, Edmonton, Alberta T6G 2P5, Canada
[c] Department of Renewable Resources, University of Alberta, 442 Earth Sciences Building, Edmonton, Alberta T6G 2E3, Canada

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ABSTRACT

Hybrid poplar plantations have the potential to produce a large amount of biomass for the forest industry; however, competition for resources by neighbouring vegetation can severely reduce that potential. Intensive vegetation control of all neighbouring vegetation is potentially costly and an inefficient use of limited resources, thus identifying the characteristics of competing vegetation most detrimental to tree growth is essential for optimizing plantation inputs and yields. Our objectives were to model tree growth losses as a function of neighbouring vegetation composition, abundance, and spatial proximity. We then tested different vegetation control treatments for their effectiveness with different neighbouring vegetation. Field work took place on four operational plantation sites in northeastern Alberta over the course of three years, and commenced at the beginning of the second growing season after plantation establishment. Regression tree and Nonmetric Multidimensional Scaling (NMDS) analyses indicated that perennial grasses in general, and *Elytrigia repens* in particular, were detrimental to hybrid poplar growth – especially for younger trees. Planting site also played a large role in determining tree productivity, although it is difficult to quantify its influence relative to competition because site and vegetation community differed among sites. Increasing intensity of vegetation control treatments did not increase tree survival rates in any of the sites, but did result in commensurate increases in tree growth on most sites. Intensive vegetation control with herbicides dramatically increased tree growth on sites containing populations of perennial grasses. Using only cultivation as a form of vegetation control was the least effective option, and was ineffective for control of perennial grasses compared to other treatments. These results suggest that control of perennial grasses by means of herbicides over the other forms of competition control tested will have the greatest impact on reducing losses in tree growth due to competition.

1. Introduction

The productivity of naturally growing forests in boreal regions is limited by short growing seasons. Plantations of fast growing tree species, such as poplar (*Populus* spp.), aspen (*Populus* spp.), and willow (*Salix* spp.), are a valuable alternative source of biomass in boreal climates due to their high growth rate and cold hardiness (Weih, 2004; Park and Wilson, 2007). Hybrid poplars are particularly prevalent in the Canadian forest industry, and have been planted on approximately 28,000 hectares (Derbowka et al., 2012). Plantations of hybrid poplar can reduce transportation costs if established close to the processing area, and may offer the additional benefit of generating carbon offsets (Park and Wilson, 2007; Anderson et al., 2015). Given their benefits and growing popularity, knowledge concerning the impacts of competing vegetation on hybrid poplar growth, and how to best minimize such impacts, is needed for effective and economical plantation management.

Hybrid poplars are sensitive to competition from herbaceous species (Pinno and Belanger, 2009; Otto et al., 2010), particularly when under four years of age (Buhler et al., 1998; Shock et al., 2002). Aside from tree age, competition effects on hybrid poplar growth are influenced by the abundance and identity of competitors (Kabba et al., 2007). Impacts of competition include not only a loss of tree biomass, but also altered crown architecture (Marino and Gross, 1998). Conversely, neighbouring vegetation can also have facilitative effects on *Populus* species (Powell and Bork, 2004b). Previous investigations into hybrid poplar response to neighbouring vegetation include comparing tree growth across

* Corresponding author at: Laurentian Resource Conservation and Development, 19 Highway 61 West, Esko, MN 55733, USA.
E-mail address: dhenkeljohnson@gmail.com (D. Henkel-Johnson).

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different vegetation control treatments (Hansen et al., 1984; Green et al., 2003), manipulating neighbouring vegetation in tightly controlled container experiments (Kabba et al., 2009; Messier et al., 2009), and simulation modeling (Welham et al., 2007; Kabba et al., 2011). However, we have found no studies which model growth losses as a function of the identity, abundance, and spatial proximity of neighbouring vegetation naturally occurring within operational hybrid poplar plantations.

The overall goal of this study is to help managers implement more effective vegetation control plans within operational hybrid poplar plantations by improving our understanding of the impacts of neighbouring vegetation and vegetation control treatments on hybrid poplar growth and survival in young plantations. Identifying particular species or growth forms which are highly detrimental to hybrid poplar growth, and determining the effectiveness of vegetation control treatments for these, will help plantation managers prioritize plantations for vegetation control efforts and select customized vegetation control treatments, as appropriate. To address this goal, our study objectives were to: (1) quantify reductions in tree growth within young hybrid poplar when grown in operational plantations as a function of neighbouring vegetation covering a wide range of plant species composition, abundances, and spatial proximities; and (2) test the effectiveness of different vegetation control treatments on tree growth under varying levels of competition. We expected that growth losses in the trees would vary as a function of neighbouring plant composition, abundance, and spatial proximity, and thus it would be possible to model those losses based on measurements of competing vegetation. We also expected that the effectiveness of different herbaceous control treatments that altered tree growth would vary depending on the composition and abundance of competing vegetation at each site. We addressed these objectives with a field study in four operational hybrid poplar plantation sites, all established using the same hybrid poplar clone.

2. Methods

2.1. Study sites

From May 2011 through September 2013, we examined four sites distributed across two operational hybrid poplar plantations (North and South – named for their relative positions to each other) in north-central Alberta, Canada, near the town of Athabasca (Latitude 54°43′N; Longitude 113°17′W). These plantations had been established in June 2010 with over-winter dormant, 1-year old rooted cuttings of the female hybrid poplar clone 'Walker' (*Populus deltoides* × (*P. laurifolia* × *P. nigra*)) planted in a systematic grid pattern with 2.8 m spacing. Ten centimeter long cuttings taken the previous winter from commercial stooling beds were grown at a commercial nursery the previous summer, and stored at −4 °C for the winter, prior to planting. Prior to establishment, both plantations were in a hay crop. In late summer the year prior to planting, plantations were site prepared with an application of 1.85 L/ha Vantage Plus (360 g/L glyphosate) and 1.33 L/ha PrePass (50 g/L florasulam and 360 g/L glyphosate) followed by two passes with a 2 m wide disc cultivator. Both plantations also received 4.5 L/ha Lorax (480 g/L linuron) 1–2 weeks prior to planting.

The plantations are situated in the Dry Mixedwood Boreal forest natural subregion (Beckingham and Archibald, 1996). Across all field sites, the terrain varied from flat to moderately undulating with an elevational range of 540–640 m a.s.l. The mean annual temperature of the region from 1981–2010 was 2.3 °C, with an average of 480 mm of total precipitation, of which 70% falls during the growing season as rain from May through September inclusive (Environment Canada, 2014).

Both plantations are located on private land maintained under lease agreements by Alberta-Pacific Forest Industries Inc. (Al-Pac), and are approximately 17 km apart. Two sites, a minimum of 300 m apart were sampled within each plantation. Each site was internally uniform in ecosite (e.g. slope, aspect, soil, drainage, etc.), and together represent a range of growing conditions typical of plantations in the region. The South plantation contained sites A and B, and the North plantation contained sites C and D. The sites were not fenced.

2.2. Experimental design

Beginning in 2011 (the trees' second growing season after planting) we evaluated tree growth responses to neighbouring vegetation and different treatments intended to control neighbouring vegetation. As the trees were planted the year prior to study commencement (i.e. 2011 or year 1 of the study was growing season 2 for the trees, planted in 2010), specific years are hereafter referenced to by growing season so as to avoid confusion between study year and tree age. At each site we established a permanently marked grid of approximately 20 × 20 trees surrounded by the remaining plantation trees (Fig. 1A). From the trees within the grid we randomly selected 140 individuals of which 35 were assigned to each of four weed control treatments ($n = 35$ per treatment). Treatments included: (1) cultivation of mid-rows with a 2 m wide disc plow approximately four times each growing season (CULT), (2) cultivation (as for treatment 1) plus spot application (by hand) of glyphosate herbicide twice per season in growing seasons 2, 3, and 4 (2011, 2012, and 2013) to provide continuous control to all neighbouring vegetation within 1.4 m of the tree base (HERB), (3) cultivation (as for treatment 1) plus spot application (by hand) of glyphosate herbicide twice per season in growing seasons 3 and 4 (2012 and 2013) (i.e. delayed herbicide treatment; DHERB), and (4) business-as-usual (BAU). The BAU treatment represented conventional management currently in place and included cultivation plus broadcast spray application of linuron and/or glyphosate herbicide in spring when the trees were dormant, and later, during the growing season, additional applications of sethoxydim or glyphosate as needed (determined by Al-Pac plantation managers). Cultivation was done in consecutive passes in a north–south and east–west direction. Selection of BAU trees was constrained to the outer two rows on all sides to facilitate herbicide application with large-scale field equipment, with at least one tree row between these and the other treatment trees to safeguard against herbicide drift into an adjacent treatment (Fig. 1A). For trees exposed to the HERB and DHERB treatments, neighbouring vegetation around each tree was sprayed with a 10% solution of glyphosate out to a distance of 1.4 m. Application was done with hand sprayers in conjunction with shields to minimize drift and avoid damage to the trees.

2.3. Field sampling

Cover estimates of neighbouring vegetation were made adjacent to each study tree in mid-June and late-August of growing seasons 2 and 3. At every tree we visually estimated the percent cover of each plant species in a total of 12 quadrats (35 cm × 25 cm); three contiguous quadrats covering a 25 cm wide area from the tree base out to 105 cm oriented in each of the four cardinal directions (Fig. 1B). In growing season 2 vegetation was assessed only in the trees from the CULT and DHERB treatments ($n = 70$/site); all these trees were subject to the same control treatment (cultivation only) in growing season 2. In growing season 3 vegetation was assessed in trees from all treatments ($n = 140$/site).

Following vegetation assessment in August of growing season 2, vegetation near trees of the DHERB treatment was cut at ground