Survival and Growth of Tree Seedlings on Reclaimed Oil Sand Site in Response to Fertilizer and Ground Cover Grass Species

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ABSTRACT

Every year, oil sands mining results in a significant area of degraded land which needs to be reclaimed. In reconstructed mine sites, ground cover is helpful to minimize soil erosion by stabilizing soil. Besides soil erosion control, ground cover may also influence the establishment success of tree seedlings by affecting soil nutrient and moisture availability. Barley (*Hordeum vulgare* L.) and oats (*Avena sativa*) are the ground cover species being recommended for oil sands reclamation operations, but interactions of the ground cover with planted tree seedlings are not fully understood. The objective of this study was to evaluate the effect of different fertilizer rates on survival and growth of trembling aspen (*Populus tremuloides*) and white spruce (*Picea glauca*) tree seedlings planted with two cover crops (barley and oats). To fulfill the objective a greenhouse bioassay experiment and a field experiment were conducted. Under greenhouse conditions, soil moisture significantly increased height, root collar diameter (RCD) and biomass yield of tree seedlings. Fertilizer application significantly increased height and RCD in greenhouse, but not under field conditions. Even without ground cover competition, tree seedlings responded poorly to NPK fertilizer. Furthermore, survival rates of tree seedlings were significantly decreased with increased fertilizer application rates, and no positive growth and yield responses were observed in the field. Vigorous growth of ground cover species with high fertilizer application rates largely controlled survival and growth responses of tree seedlings. Trembling aspen was more sensitive to ground cover competition and negatively affected by barley and oats with added fertilizer, whereas white spruce was unaffected. Therefore, adding fertilizer to these systems appears to be of little benefit to early establishment and growth of tree seedlings as well as for successful reclamation.

INTRODUCTION

Available surface mineable land in Alberta is approximately 4,800 km^2 out of which 715 km^2 has already been disturbed (Government of Alberta, 2011), which needs to be reclaimed. One of the sustainable reclamation strategies for post mining site is reforestation. Rapid reforestation of reclaimed sites largely depends on the establishment success of planted tree seedlings. The success of reforestation is generally difficult in mine land areas. It depends on early survival and growth of tree seedlings, which are often affected by several factors such as low soil fertility, soil compaction, and competition from weeds (Moffat, 2004; Casselman et al., 2006).

In addition to lower plant nutrient availability on newly reclaimed sites, use of different ground covers to minimize erosion rates may adversely affect outplanting success of tree seedlings by accentuating the impacts of moisture and nutrient stress. In particular, it is not well known how these cover crops interact with fertilizer to improve or adversely affects early survival and growth of tree seedlings.

The selection of suitable tree species is another important factor for the successfully reforestation of reclaimed sites. Trembling aspen (*Populus tremuloides*) and white spruce (*Picea glauca*) mixture is the main portion of the boreal forest and commercial uses of both tree species are also observed in Canada. Regeneration of trembling aspen and white spruce mixture is often difficult in mine land areas considering the critical seedling establishment phase which depends on the capacity of the seedlings to efficiently capture available resources (Dunabeitia et al., 2004). In disturbed sites, nutrient loss and transformation predominantly from NH_4^+ to NO_3^- occurs and might be limiting for these seedlings establishment. Lower use of NO_3^- by white spruce seedlings was recorded and this might be a critical interruption for seedling establishment on disturbed sites (Kronzucker et al., 1997). Better growths of conifers are reported on NH_4^+ than NO_3^- dominated soil (Lavoie et al., 1992). Trembling aspen returns more nutrients in soil although their requirement is almost same. The capacity of effective nutrients use is therefore very important for species establishment in reconstructed sites. If unfavourable site conditions are limiting the establishment of pioneer trees, methods for reforestation of these sites may require more intensive management, including fertilization of pioneer seedlings (Pinard et al., 1996). Therefore, it is necessary to optimize and standardize the fertilizer application rate.

MATERIALS AND METHODS

A greenhouse and a field experiment was carried out to complete this research. The greenhouse bioassay experiment was initiated in October, 2010 at University of Saskatchewan using soil materials from Suncor's reclamation sites to examine the interspecific competition for soil nutrients and moisture affecting growth and yield of tree seedlings. Factor tested include tree species (Trembling Aspen and White Spruce), soil moisture (with and without moisture stress), the NPK fertilizer at 0, 700 (half rate) and 1,400 (full rate) kg ha^{-1}; and grass species (control, barley, oats). For better explanation, and to understand the tree seedlings-grass interactions in field, a fertilizer dose response trial was established in spring 2011. The field study was a 2 x 3 x 8 factorial experiment laid out in RCBD with total 144 experimental plots by replicating each treatment combination three times. This experiment was established on a reconstructed reclamation site of Suncor Energy Inc., at Fort McMurray, Alberta to evaluate wide range of fertilizer rates on the performance of tree seedlings that were planted with native and planted (barley and oats) ground cover grass species.

RESULTS AND DISCUSSION

1.0 Greenhouse study

1.1 Height and diameter growth

Fertilization and increased soil moisture significantly increased height and RCD growth of trembling aspen seedlings (Figure 3.1). With and without fertilization, height ($p = 0.0009$) and RCD ($p = 0.0253$) growth of trembling aspen seedlings were significantly higher than corresponding growth of white spruce seedlings (Figures 1.1a and 1.1b). Height and RCD growth of trembling aspen seedlings increased by 18–29 cm and 1.7–3.2 mm, respectively and by 2.8–3.1 cm and 1.7–3.2 mm for white spruce seedlings. Apparently, interspecific competition modified seedling response to fertilizer and soil moisture (Figure 1.2). With and without fertilizer addition, barley and oats suppressed height growth of tree seedlings by 50% (Figures 1.2a and 1.2b). The effects were significant for RCD at half and full rates, indicating that suppressive effects of cover crops could not be overcome by fertilization. Fertilization of cover crops may further increase demand for moisture and nutrient uptake. Cover crop species reduced both height ($p = 0.0007$) and RCD ($p = 0.0018$) of tree seedlings at 40 % and 80 % field capacity (Figures 1.2c and 1.2d). The overall effects of grass competition for nutrients and soil moisture were more pronounced in trembling aspen seedlings than for white spruce seedlings (Figures 1.2e and 1.2f). Both RCD ($p < 0.001$) and height ($p < 0.001$) of trembling aspen seedlings in mixture were reduced by 54% and 63% in barley treatments compared to 47 % and 46 % in oats treatments. These results indicate that trembling aspen seedlings were more sensitive to interspecific competition and barley competed more strongly for growth resources than oats.

1.2 Biomass yield of tree seedlings

Fertilizer application did not significantly increase shoot and root biomass yields of trembling aspen and white spruce seedlings (Figures 1.3a and 1.3b). Trembling aspen seedlings recorded a 30 % decrease in root biomass ($p < 0.0123$) and a 50% decrease in shoot biomass ($p < 0.0001$) at 40% field capacity compared to 80% field capacity (Figures 1.3c and 1.3d).

Fertilization doubled shoot biomass ($p = 0.0191$) and root biomass ($p = 0.0101$) yields of tree seedlings in the no grass treatment relative to barley and oats treatments (Figures 1.4a and 1.4b). Similar results were also noted for shoot and root biomass at 40% and 80% field capacity (Figures 1.4c and 1.4d). As mentioned earlier, the increase indicates that cover crops suppressed yield response of tree seedlings to fertilizer and soil moisture. This effect was more pronounced for trembling aspen seedlings compared to white spruce seedlings (Figures 1.4e and 3.1f), reflecting high sensitivity to competition by the former.

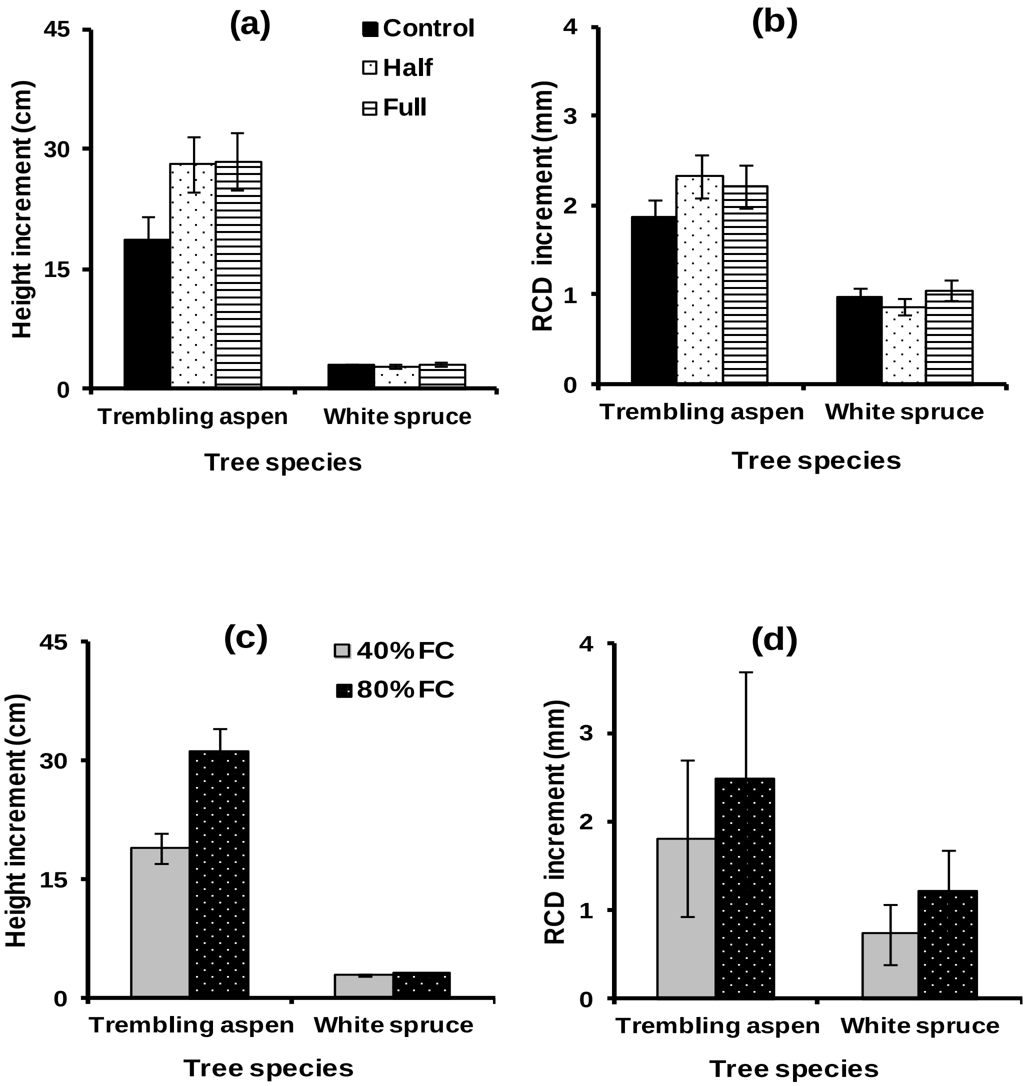

Figure 1.1 Height and root collar diameter (RCD) growth response of tree seedlings to NPK fertilizer (a–b) and soil moisture at field capacity (FC) (c–d) after 16 weeks growth in a greenhouse bioassay experiment. Application rates of the 20–20–20 NPK fertilizer were: control = no fertilizer, half = 700 kg ha^{-1} and full = 1400 kg ha^{-1}. Vertical bars indicate standard error of means (n = 4).

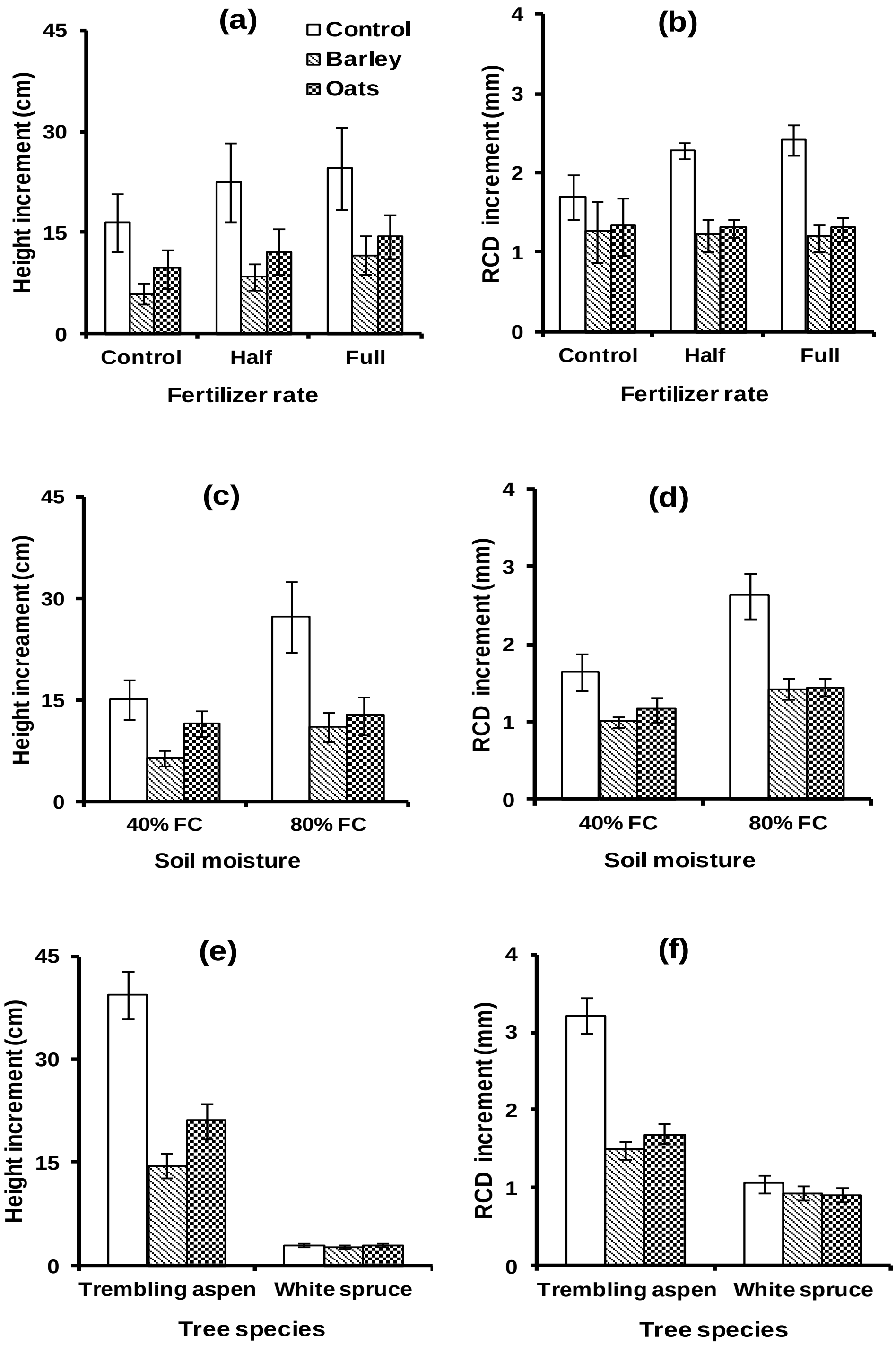

Figure 1.2 **Height and root collar diameter (RCD) increments of tree seedlings for the interactions between cover crops and fertilizer (a–b) or soil moisture at field capacity (FC) (c–d) or tree species (e–f) after 16 weeks growth in a greenhouse bioassay experiment. Application rates of the 20–20–20 NPK fertilizer were: control = no fertilizer, half = 700 kg ha^{-1} and full = 1400 kg ha^{-1}. Vertical bars indicate standard error of means (n = 4).**

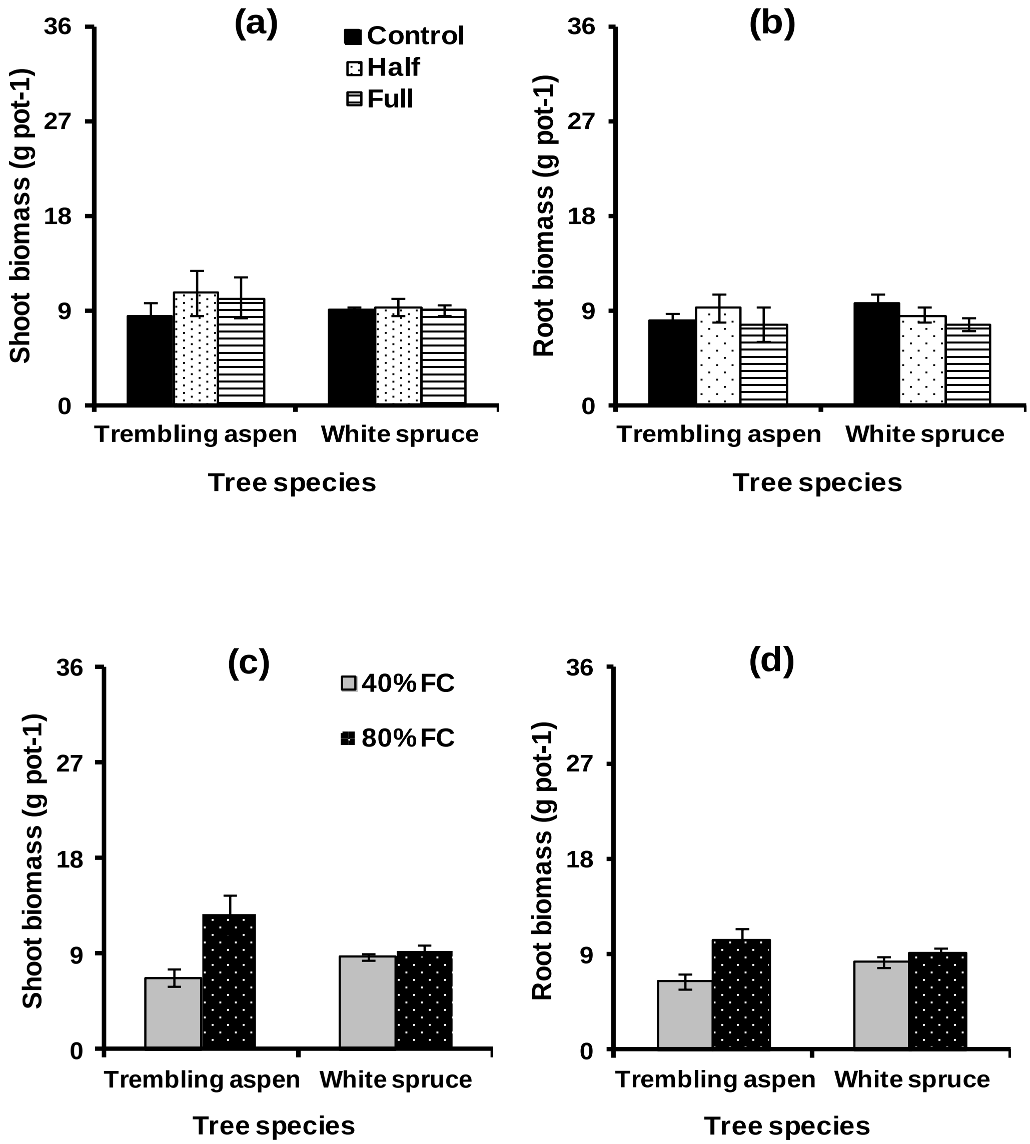

Figure 1.3 Shoot and root biomass yield response of tree seedlings to NPK fertilizer (a–b) and soil moisture (c–d) after 16 weeks growth in a greenhouse bioassay experiment. Application rates of the 20–20–20 NPK fertilizer were: control = no fertilizer, half = 700 kg ha^{-1} and full = 1400 kg ha^{-1}. Vertical bars indicate standard error of means (n = 4).

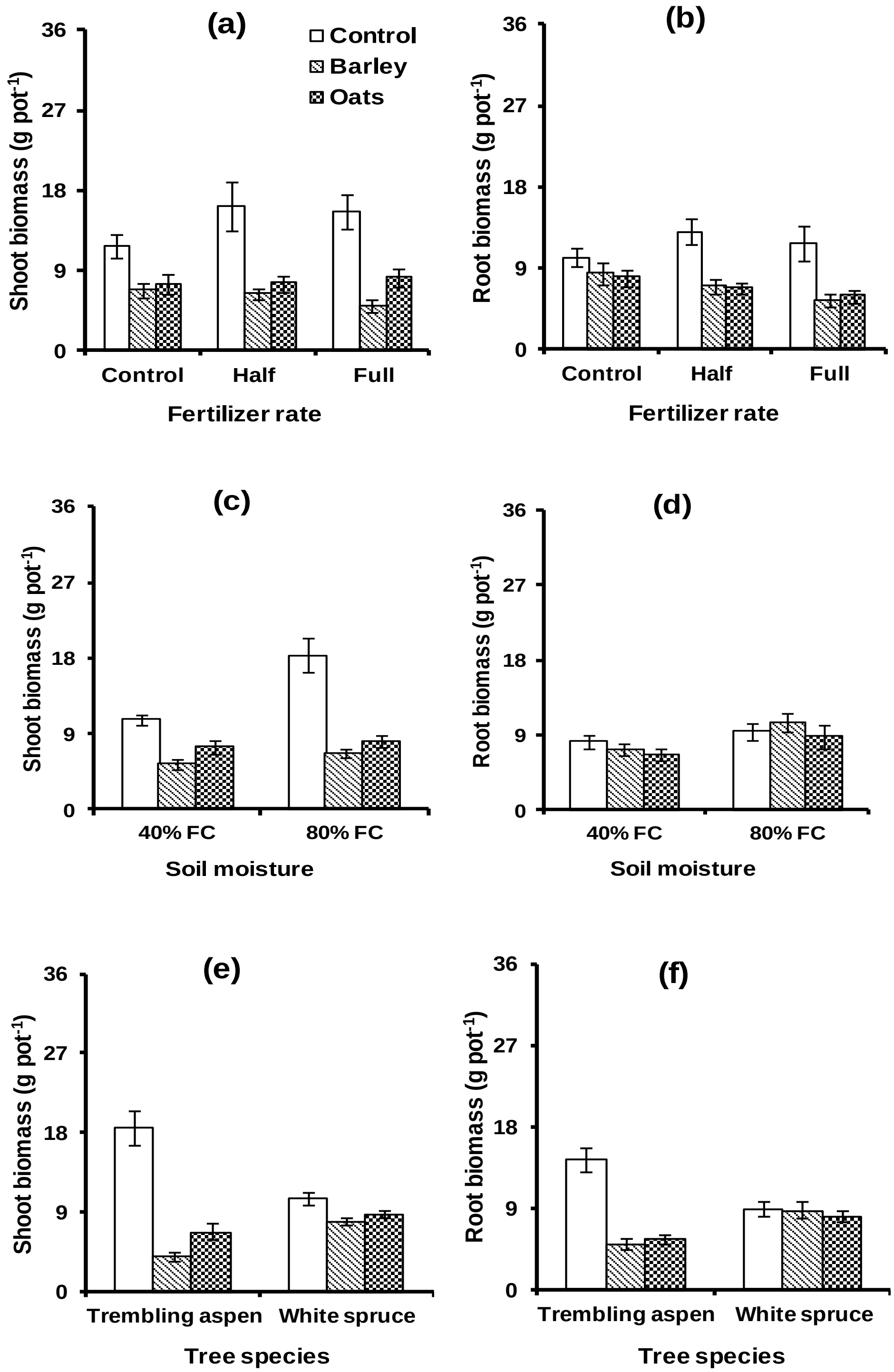

Figure 1.4 **Shoot and root biomass yields of tree seedlings for the interactions between cover crops and fertilizer (a–b) or soil moisture at field capacity (FC) (c–d) or tree species (e–f) after 16 weeks growth in a greenhouse bioassay experiment. Application rates of the 20–20–20 NPK fertilizer were: control = no fertilizer, half = 700 kg ha^{-1} and full = 1400 kg ha^{-1}. Vertical bars indicate standard error of means (n = 4).**

2.0 Field study

2.1 Survival and growth of tree seedlings

Survival of tree seedlings after one growing season was significantly affected by fertilizer application and there was a significant interaction between ground cover and tree species. Tree seedlings survival significantly decreased with increased fertilizer rates (Figure 2.1a). Lower survival rate was recorded for trembling aspen in response to presence of ground cover as barley and oats, while white spruce was not affected (Figure 2.1b). After two growing seasons height, root collar diameter increment, and root and shoot biomass yield of tree seedlings were insignificant for different rates of fertilizer (Figure 2.2a-2.5a). Growth and biomass yield of trembling aspen were also significantly decreased when planted with barley and oats, whereas white spruce was unaffected (Figure 2.2b-2.5b). Results indicating that, trembling aspen was more sensitive than white spruce to ground cover competition and was negatively affected by barley and oats, especially with added fertilizer. These growth responses observed in the field are consistent with those observed and discussed previously for the greenhouse study. Overall, there was no height, RCD or biomass response to added fertilizer without or with cover crops present. During the early stages of growth, horizontally spreading lateral roots near the surface is a prominent feature of aspen (Strong and La Roi, 1983). Rapid growth of annual cover crops like barley and oat would deplete water and nutrients in the same region of the soil profile, restricting root proliferation.

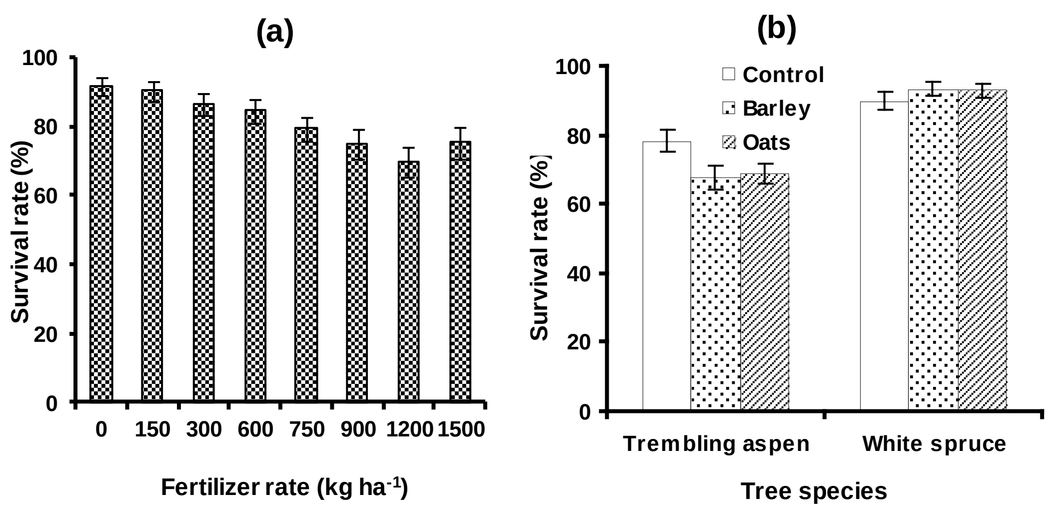

Figure 1.1 Effect of NPK fertilizer (a) and cover crop and tree species (b) on tree seedlings survivals after one growing season in a reconstructed oil sand site. Vertical bars indicate standard error of means (n = 3).

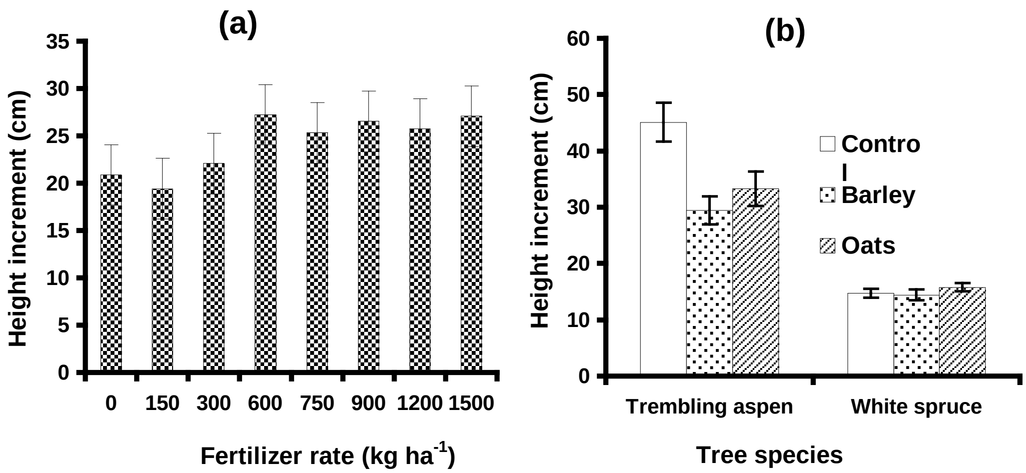

Figure 1.2 **Effect of NPK fertilizer (a) and cover crop and tree species (b) on height increments of tree seedlings with added fertilizer after two growing seasons in a reconstructed oil sand site. Vertical bars indicate standard error of means (n = 3).**

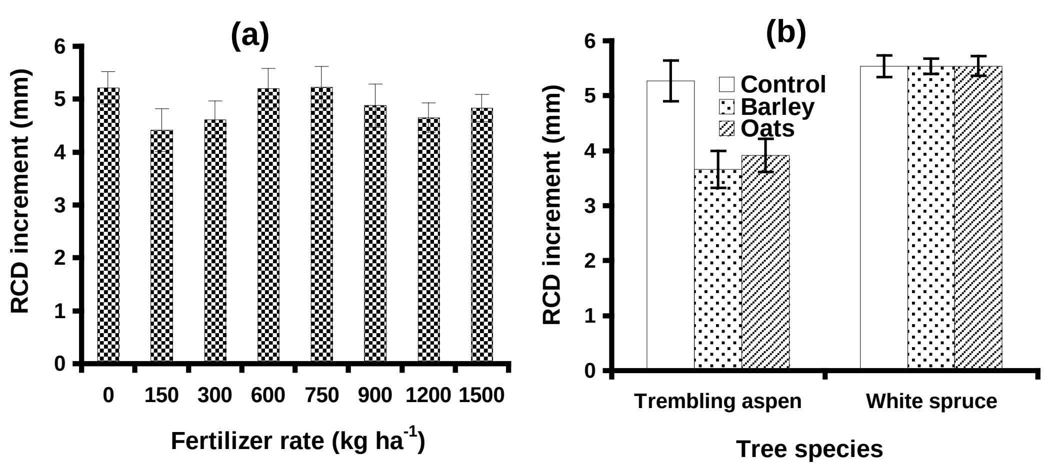

Figure 1.3 **Effect of NPK fertilizer (a) and cover crop and tree species (b) on root collar diameter (RCD) increments of tree seedlings with added fertilizer after two growing seasons in a reconstructed oil sand site. Vertical bars indicate standard error of means (n = 3).**

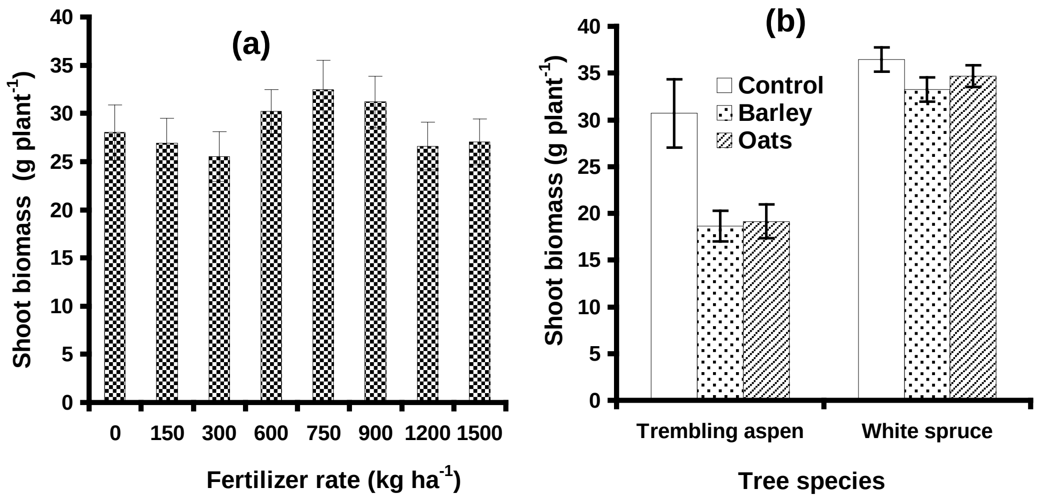

Figure 1.4 Effect of NPK fertilizer (a) and cover crop and tree species (b) on shoot biomass yield of tree seedlings with added fertilizer after two growing seasons in a reconstructed oil sand site. Vertical bars indicate standard error of means (n = 3).

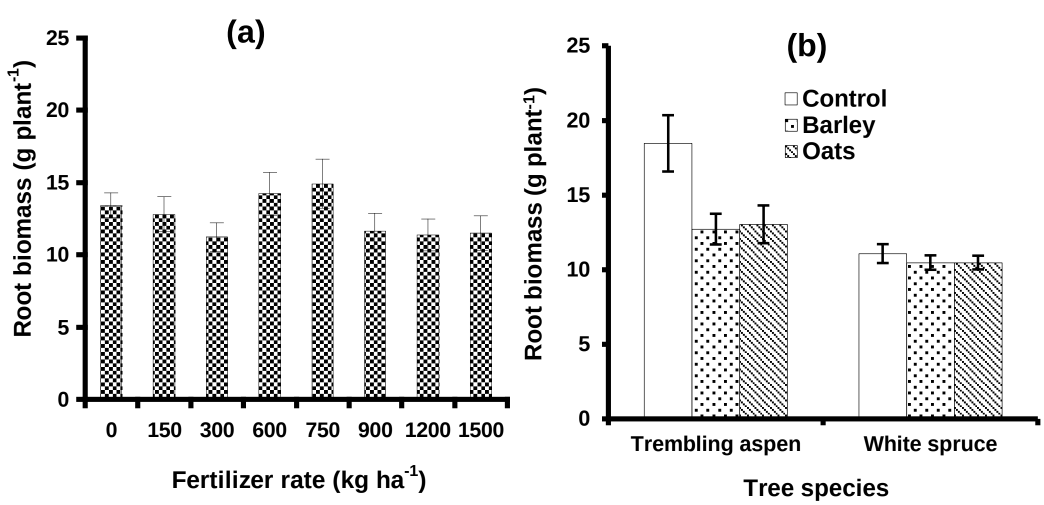

Figure 1.5 Effect of NPK fertilizer (a) and cover crop and tree species (b) on root biomass yield of tree seedlings with added fertilizer after two growing seasons in a reconstructed oil sand site. Vertical bars indicate standard error of means (n = 3).

CONCLUSIONS

In general, height, root collar diameter increment, and root and shoot biomass yield of trembling aspen were significantly decreased when planted with ground cover, whereas white spruce was not affected. Lower survival rate was recorded in field for trembling aspen in response to N,P,K fertilization. Trembling aspen was more sensitive than white spruce to ground cover competition and was negatively affected by barley and oats, especially with added fertilizer.

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