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Research paper

Allometric relationships from coppice structure of seven North American willow (*Salix*) species

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ABSTRACT

Biomass yield and component coppice growth traits were assessed in up to 20 clones from seven native North American willow species, *Salix amygdaloides* (SAM), *Salix bebbiana* (BEB), *Salix discolor* (DIS), *S eriocephala* (ERI), *Salix humilis* (HUM), *Salix interior* (INT), and *Salix nigra* (NIG), established together in a clonally replicated common-garden field test. Aboveground mass, coppice stem number, stem length, and stem basal diameter measurements on up to 20 of the largest stems from 2-yr-old coppiced plants showed that ERI had the greatest aboveground mass, followed by INT, and then a close grouping of BEB, DIS, and HUM; the "tree" willows, AMY and NIG, had the lowest yields. The tree willows were not as prolific in coppice stem sprout production as were the shrub willows. The greatest number of stem sprouts was produced by ERI, with one coppice producing 67 2-yr-old stem sprouts, and ERI also showed an atypical, non-negative relationship between stem size and stem number; whereas the other six willows showed a varying but expected negative relationship between coppice stem size and stem number. Species differences in allometric relationships highlight the need to develop species-specific models for more accurate non-destructive biomass yield estimation.

1. Introduction

With more than 350 species worldwide, willows (*Salix* spp.) are widespread across the northern hemisphere, with 76 willow species native to Canada [1]. Yet despite this species richness and ecological importance, especially in early successional environments following site disturbances [2–4], native willows have received limited attention in North America as potential sources of woody biomass for industrial purposes [5–8]. More recently, native willows have been investigated for land reclamation purposes on highly disturbed sites following mining operations [4,9–11], where some willows grew surprising well on infertile coal mine overburden [12–16].

For short-rotation intensive culture (SRIC) biomass production based on coppice regrowth, it is important to understand variability in coppice growth form and allometric relationships in order to (1) assess biomass suitability and economic viability, (2) select superior clonal material for operational purposes [12,17], and (3) model growth and predict yield [13,18–22]. There are few studies using clonally replicated common-garden studies of woody perennials, such as willows, to compare allometric growth and yield relationships in a number of closely related species within the same genus [13,18,23].

Salix amygdaloides (SAM), *Salix bebbiana* (BEB), *Salix discolor* (DIS), *S. eriocephala* (ERI), *Salix humilis* (HUM), *Salix interior* (INT), and *Salix nigra* (NIG) are native to much of eastern and central Canada, with several of these species extending as far west as the Rocky Mountains and beyond (e.g., AMY, BEB, DIS, and INT). These willows were selected as promising species for SRIC biomass production plantations [5,12–14,16]. Although these willows are all commonly associated with seasonally wet areas and riparian zones, they are also adapted to a wider range of ecological conditions on disturbed sites. For instance, BEB, DIS, and HUM can also be found colonizing well-drained, upland sites [12]; whereas ERI, INT, and NIG are most commonly associated with the fast-flowing water of riparian habitats, and AMY is most often found along the edges of hardwood swamplands (Table 1). This group of seven species consists of both tree-forming willows that can reach heights of up to 20 m across their geographic range (e.g., AMY and NIG) and shrub-forming species that normally attain heights of 2–8 m (e.g.,

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Table 1
Native North American willow (*Salix*) species field tested for biomass production and restoration of highly disturbed areas.

Salix species	Height and habit	Natural habitat
S. amygdaloides	8–15 m, tree	poorly drained, standing wetlands
S. bebbiana	4–6 m, shrub	seepage slopes, ditches, upland sites
S. discolor	4–10 m, shrub/small tree	seepage slopes, wetlands, and ditches
S. eriocephala	4–6 m, shrub	fast-flowing stream banks
S. interior	4–6 m, shrub	river banks, sandbars, floodplains
S. humilis	2–3 m, shrub	well-drained upland sites, forest openings
S. nigra	10–12 m, tree	river banks and floodplains

BEB, DIS, ERI, HUM, and INT).

Our objective was to use a common-garden and population genetics approach to assess seven willow species for variation in coppice structure and biomass yield for the purpose of identifying superior clonal material both for biomass production plantations and for land reclamation purposes. We wanted to quantify the important differences among species and clones in coppice structure and growth performance for the purposes of clonal selection for superior biomass production and to report important species-specific equations for various biomass growth relationships. The latter would be helpful for a simple nondestructive aboveground biomass yield estimation.

2. Material and methods

2.1. Common-garden experiments

During the winter of 2008, stem sections (cuttings) were collected from five clones from each of four natural populations located in southern and eastern Ontario and adjacent areas of the Ottawa River Valley in the province of Quebec, Canada (Fig. 1; Table 2) for each of seven native willow species. Natural populations of willows usually occur as small, isolated patches arising in response to localized disturbances. Therefore, we tended to collect whatever clones were available in a given patch, and no attempt was made to collect cutting material from plants with specific characteristics. Stem cuttings approximately 20 cm long were collected from vigorous 1- and 2-yr-old branches from plants located in natural populations and then stored in a freezer at −5 °C at the Atlantic Forestry Centre (AFC) in Fredericton, New Brunswick (NB), Canada. In preparation for field establishment, stem cuttings were removed from frozen storage to a refrigerator at 3 °C for several days of thawing, followed by 48 h of soaking in water immediately prior to establishment in a common-garden field test located at the AFC nursery in Fredericton, NB (Lat. 45°94′ N, Long. 66°62′ W). Fredericton has a climate with an average annual temperature of 5.6 °C and an annual precipitation of 1124 mm [24].

The AFC nursery site consists of an artificially constructed soil of

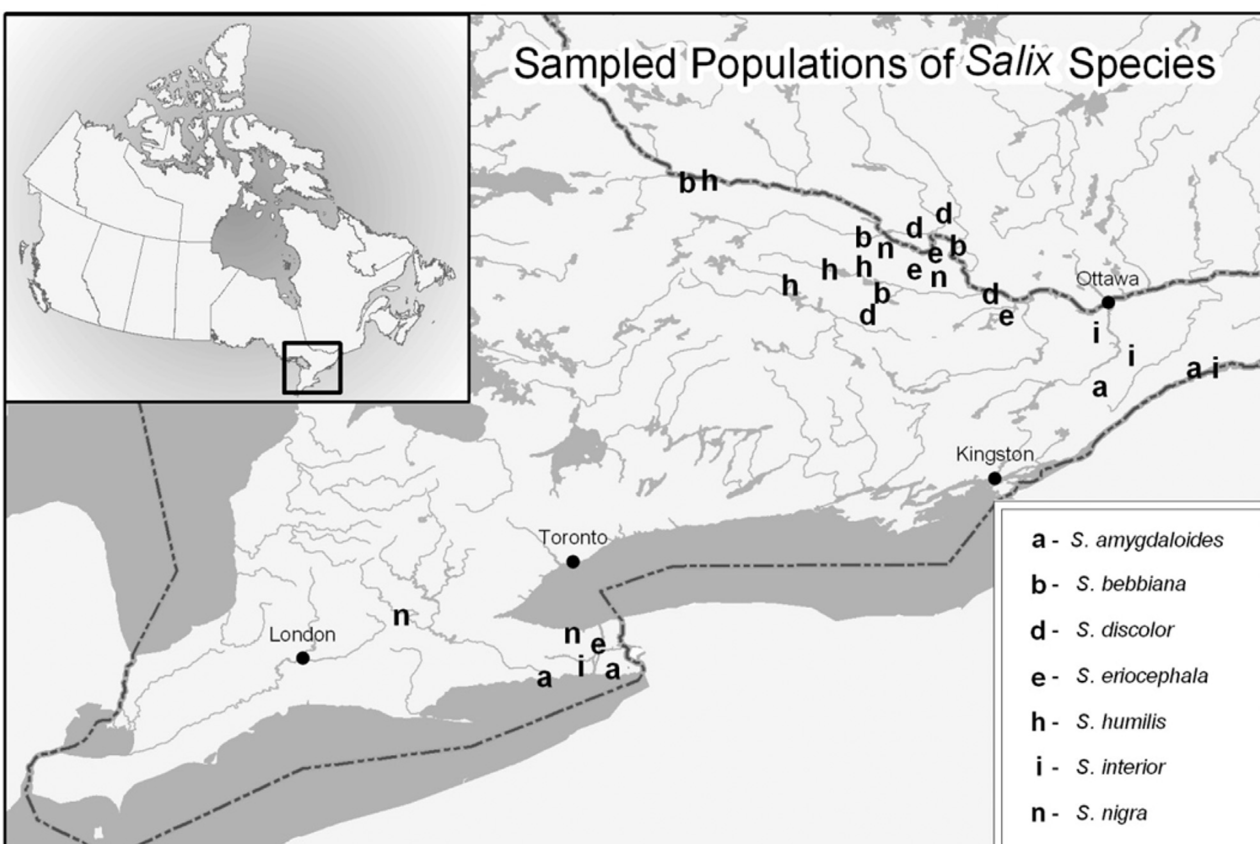

Fig. 1. Map showing the locations of populations from which plant material was collected for clonal propagation and common-garden establishment.