BALANCING GROWTH AND WOOD QUALITY OF *INTSIA BIJUGA* UNDER MANAGEMENT: COMPLEXITY OF SILVICULTURE CONSERVATION DECISIONS

TE Marler

Western Pacific Tropical Research Center, University of Guam, UOG Station, Mangilao, Guam 96923; thomas.marler@gmail.com

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MARLER TE. 2015. Balancing growth and wood quality of *Intsia bijuga* under management: complexity of silviculture conservation decisions. *Intsia bijuga* plants were protected from natural infestations of the native psyllid in Guam, *Insnesia glabrascuta*, to determine the influence on plant growth and morphological traits. The primary goal was to contrast growth and wood density responses to protection from the ubiquitous arthropod herbivore. Growth increased as a result of protecting the plants with insecticides and the relative increase was greater for plants derived from Philippine seeds than Guam seeds. Wood density decreased with insecticide treatment to 65% (Guam) or 49% (Philippines) of wood density in psyllid-infested trees. Results pointed out complexities in silviculture conservation decisions. Managing *I. bijuga* in a tree farm as means of conserving the natural forest trees may use protection from psyllid damage to seek a shorter production cycle but a concomitant change in wood quality may be an unavoidable consequence.

Keywords: *Insnesia glabrascuta*, natural infestations, growth and morphological traits, native plants, psyllid

INTRODUCTION

Intsia bijuga is a highly prized tropical tree that yields attractive dense wood and is one of the most valued timbers. The wood is highly resistant to decomposition such that it is often used as a benchmark against which durability of wood from other species is compared (Anonymous 1979). *Intsia bijuga* was upgraded to vulnerable status on the International Union for Conservation of Nature's Red List in 1998 (World Conservation Monitoring Centre 1998). The main threat that justifies conservation interventions is over-harvesting. The bark and leaves of this important timber tree have also been exploited for medicinal uses in some cultures throughout its considerable indigenous range (Burkill 1966, Altschul 1973), evincing another reason to protect the species as a means of sustaining traditional knowledge.

One of the psyllid species that occurs in the western Micronesian islands is *Insnesia glabrascuta* (Tuthill 1964, Figure 1a). *Intsia bijuga* in Guam co-evolved with this psyllid and are chronically characterised by heavy infestations (Marler & Lawrence 1994). The infestation traits and plant responses are typical of many homopteran pests in that feeding is restricted to expanding leaf and stem tissues (Figure 1b). Infested leaflets typically abscise prior to full expansion, and those that do not abscise are stunted and misshapen. Damage to the trees is never lethal and the extent of damage to each recurring episode of primary stem growth is dependent on when the psyllid adults find the expanding tissue and oviposit.

Several insecticides proved useful for protecting *I. bijuga* trees from this pest (Miller 2004). All insecticides evaluated were initially effective in controlling psyllid outbreak but they had different duration of residual protection. While this study was informative for selecting insecticides and formulations within an integrated pest management approach, no attempts to quantify plant responses were included.

More information on the relationship between plant and pest is clearly needed for managing the production of *I. bijuga* wood for use by local artisans. The importance of *I. bijuga* to the culture of Guam's indigenous peoples was

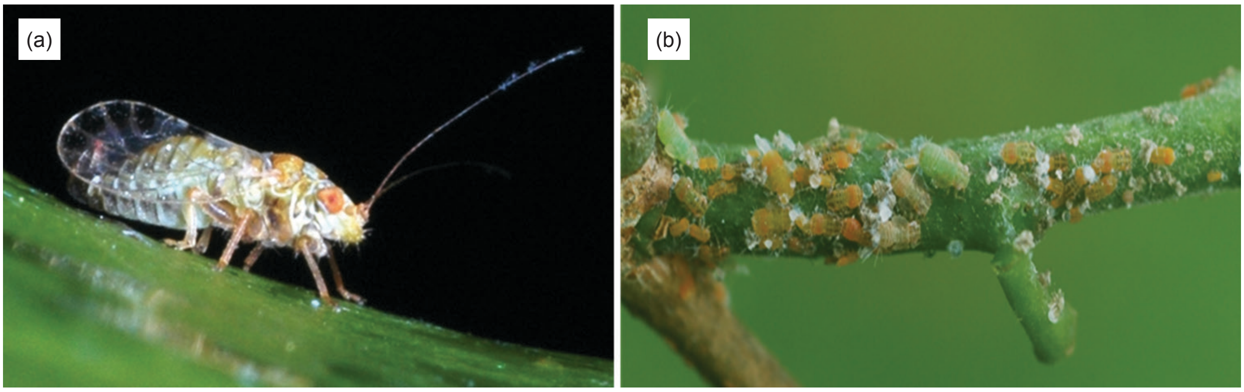

Figure 1 (a) *Insnesia glabrascuta* adults seek out *Intsia biguga* stems that are in primary growth phase and oviposit eggs on expanding stems and leaves and (b) high density of *I. glabrascuta* nymphs feeding on the plant tissue

validated by the designation of this tree as the official territorial tree in 1969 in the Territorial Public Law 10-52 (www.guamlegislature.com). Over-harvesting of Guam's *I. bijuga* trees was reported more than a century ago (Safford 1905). Continued harvesting of trees to sustain these uses would place greater threats to the diminishing tree population in Guam.

In order to preserve the traditional carving skills of local artisans and to conserve the existing natural tree population, the government of Guam enacted a law in 1991 to set aside 20 ha for plantation-style production of *I. bijuga* trees (Territorial Public Law 21-54, www.guamlegislature.com). When enacted, Guam's efforts would be unique in that there have been few attempts to cultivate the species in plantations (Anonymous 1979). To date, no empirical studies have been published that can be used to inform the management of plant growth and wood quality in this plantation.

The broad objective of this study was to determine the influence of psyllid infestations on *I. bijuga* plant growth and morphology. The two most important questions under that objective addressed critical conservation concerns, namely, (1) would psyllid protection alter wood quality, thereby affecting value for use by artisans? and (2) would genotypes from the Philippines behave differently under pressure of the psyllid population than local genotypes from Guam?

MATERIALS AND METHODS

Container-grown *I. bijuga* seedlings were employed to initiate two field studies in Yigo, Guam. This field is characterised with Guam soil series consisting of shallow cobbly clay loams that are formed in sediments overlying coralline limestone (clayey, gibbsitic, nonacid, isohyperthermic, Lithic Ustorthents) (Young 1988). Mature *I. bijuga* trees occur in forests adjacent to the experimental site.

The first experiment was conducted with seedlings produced from a composite of seeds harvested in 1993 from three mother trees in northern Guam. Twenty-six uniform plants were selected from a nursery pool, then six were removed from the population for destructive analysis. These plants were bare-rooted, separated into roots, stems and leaves, then dried at 70 °C until constant weight was achieved. The remaining 20 plants were 102 ± 3 cm tall with 14 ± 1 mm basal diameter when they were transplanted in a 2-m grid in the field on 16 November 1994. Other initial measurements were canopy diameter, total stem length and leaf number.

The second experiment was conducted in 2011–2012 using *I. bijuga* seeds originating from the Philippines. Twenty-six uniform plants were selected from the nursery stock and six were destroyed to obtain leaf, stem and root dry weights. The 20 plants used for field study were 99 ± 3 cm tall with 14 ± 1 mm basal diameter when they were transplanted on 2 November 2011.

The plants were irrigated with micro-sprinklers to apply 13 mm of water every 3 days. Fertilisation comprised 0.22 kg complete fertiliser (8 N:2.6 P:6.6 K) per plant. Applications were made on the day of planting and later after 2 and 4 months. This formulation, rate and frequency gave 110 g N per tree per year. Half of the trees were protected from psyllid infestations with weekly sprays of Dursban®. The experimental layout was completely randomised and the plot had a single-tree border surrounding the experimental plants. Psyllid nymph infestations were unambiguously identified (Figure 1b) and every tree was inspected for infestation prior to weekly sprays of insecticide.

Final non-destructive measurements were obtained for the Guam trees on 20 May 1995 which included plant height, stem basal diameter, canopy diameter, total stem length and leaf number. All trees were harvested by complete excavation on 21–23 May 1995. Plants were separated into roots, stems and leaves. Basal 10 cm of stem from each plant was cut from the remainder of the stems to determine wood density. Bark was removed from this section and added back to the bulk stem sample for each tree. Volume of the remaining wood was determined by water-displacement and weight was obtained after drying to constant weight at 70 °C. Wood density was calculated from dry weight and volume. Root, stem and leaves of each tree were dried to constant weight at 70 °C to determine final dry weight. The weight of the stem section used for density measurement was added to the final stem dry weight. Non-destructive measurements were obtained for the Philippine trees on 1 May 2012. The trees were harvested by complete excavation on 2–4 May 2012. All final measurements were conducted as described for the Guam tree experiment.

Every growth variable was assessed as the difference between final and initial measurements. For the non-destructive traits, initial measurements were obtained from each individual replication. For the dry weights, mean root, stem or leaf dry weights from the initial six trees that were destroyed were subtracted from the final dry weights for each part to calculate the increase in each variable.

This approach allowed plants to grow under the prescribed experimental conditions for 6 months in each study. Data within each of the two experiments were subjected to t-test to determine effects of insecticide on the control of psyllid infestations on *I. bijuga* trees.

RESULTS

No signs of current or past psyllid infestations were observed on sprayed trees throughout both experiments. During periods of primary growth, control trees contained psyllid eggs or nymph infestations for every replication and every observation date, as is typical throughout Guam.

Treated Guam *I. bijuga* had 2.7- to 4.3-fold increase in plant height, canopy diameter, stem diameter and stem length compared with untreated trees (Table 1). Treated trees increased in leaf number by 67 whereas the unprotected trees exhibited a net loss of leaves during the 6 months of psyllid infestation. The increase in root dry weight of psyllid-infested trees was only 5% that of protected trees. Increase in stem dry weight of psyllid-infested trees was 20% that of protected trees. Leaf dry weight increased in protected trees about the same amount that it decreased in psyllid-infested trees.

Growth variables for the Philippine trees exhibited trends that were similar to those of the Guam trees, but protection from psyllid pressure caused greater relative enhancement in growth (Table 1). Canopy growth variables increased 3.6- to 5.1-fold in sprayed trees compared with unprotected trees. The increases in root and stem dry weights of psyllid-infested trees were 2.5 and 18% respectively of that for sprayed trees.

Wood density of the basal stem section of the treated Guam trees was reduced to 65% of that for the psyllid-infested trees (Figure 2) while that of the sprayed Philippine trees was 49% of that for the infested trees.

DISCUSSION

This initial assessment confirmed that slow growth reported for *I. bijuga* in Guam was due to constraints imposed by a native psyllid, *I. glabrascuta*. This pest was ubiquitous in Guam and the substantial decrease in wood density following protection from the psyllid indicated that this co-evolved native insect was partly responsible for the famed wood quality of this valuable tree species.

This study revealed that protecting trees from psyllid infestations substantially increased plant growth rate but also reduced wood density. Managers of *I. bijuga* trees may use these outcomes to consider the balance between

Table 1 Difference between final and initial measurements of growth and morphological traits of *Intsia bijuga* plants damaged by the native psyllid *Insnesia glabrascuta*

Trait	Sprayed	Not sprayed	Significance
Guam seed source			
Tree height (cm)	73 ± 5	23 ± 3	**
Canopy diameter (cm)	35 ± 5	13 ± 4	*
Stem diameter (mm)	9.3 ± 0.6	2.2 ± 0.6	**
Stem length (cm)	423 ± 28	138 ± 25	**
Leaf number	67 ± 5	-9 ± 5	**
Root dry weight (g)	82 ± 7	4 ± 4	**
Stem dry weight (g)	135 ± 7	27 ± 7	**
Leaf dry weight (g)	39 ± 6	-35 ± 3	**
Philippine seed source			
Tree height (cm)	83 ± 4	21 ± 2	**
Canopy diameter (cm)	36 ± 4	7 ± 3	**
Stem diameter (mm)	10.9 ± 0.7	2.6 ± 0.6	**
Stem length (cm)	436 ± 26	120 ± 26	**
Leaf number	78 ± 7	-9 ± 6	**
Root dry weight (g)	79 ± 7	2 ± 4	**
Stem dry weight (g)	132 ± 11	24 ± 7	**
Leaf dry weight (g)	37 ± 7	-45 ± 4	**

Values are means ± standard errors, n = 10, *, ** significant, $p \leq 0.05$ and ≤ 0.01 respectively

enabling a shorter production cycle and altering wood quality. Although alterations of wood density by psyllid herbivory of these juvenile trees may not conform to that of mature trees, the results do point to that probability. Undoubtedly, the compromised wood density resulting from plant protection might cause detrimental effects in house or furniture construction. Less clear is the effects of reduced density on wood used for carvings, which is the intended ultimate use of the codified *I. bijuga* tree farm in Guam.

A second critical issue that can be highlighted from this study concerned the risks of using non-local genotypes when growing native tree species in managed landscapes. Planting foreign seeds of indigenous tree species can cause irreversible invasion of non-local genes into the resident population of trees (Marler 2002). Results from the two seed sources in this study cannot be subjected to a single statistical analysis because the data were derived from distinct experiments. However, the results implied that the Philippine-sourced trees performed differently than local trees when infested with Guam's ubiquitous psyllid. First, growth was similar for both seed sources when the plants were subjected to natural infestation of psyllid. However, with insecticide protection, growth was greater in the Philippine stock, indicating that its growth capacity was more constrained by psyllid infestation than the Guam genotypes. Second, wood density of psyllid-infested plants was similar for both seed sources. However, wood density was reduced to a greater extent in the Philippine genotypes with insecticide application. This study shows how seed source may influence the conservation decisions required to adequately manage silviculture plantings of rare and threatened plant species.

Wood density following only 6 months of psyllid herbivory was almost double that of wood density following 6 months of protection from herbivory. Initial stem diameter contained secondary growth that occurred in a container-nursery setting and wood in this secondary growth was produced prior to the field insecticide treatments. The nursery setting never exhibited insect infestations so the nursery phase secondary

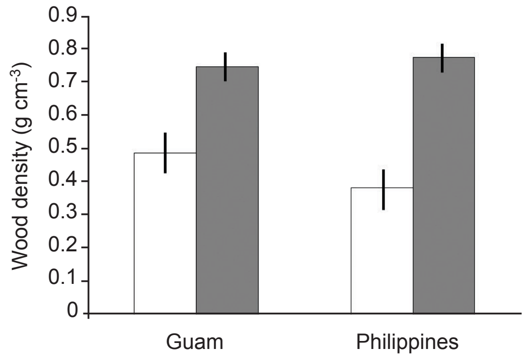

Figure 2 *Intsia bijuga* wood density following growth with natural damage by the native psyllid *Insnesia glabrascuta* (no insecticide, grey bars) or with protection from psyllid infestations (sprayed with insecticide, open bars) for local and non-native seed sources; differences within each seed source were significant at $p \leq 0.01$, mean ± standard error, n = 10

growth with relatively low wood density occurred for every experimental unit. Therefore, bulk density of the entire final stem cross-section was diluted by the inadvertent inclusion of this initial wood that was constructed prior to the field treatments. As a result, the difference in wood density between protected versus psyllid-infested trees would likely become greater with longer periods of insecticide protection.

Wood density is widely used as a functional trait indicative of tree life history and biomechanical or physiological strategies. Wood properties across large biogeographic gradients indicate that wood mechanical properties are positively correlated with wood density, and that wood density is a key trait that determines potential tree growth rates (Chave et al. 2009, Rüger et al. 2012). Similarly, a tight link between tree growth rates and wood density exists across a wide range of species (Poorter et al. 2008, Hérault et al. 2011). Wood density also influences various aspects of economic value of wood products, so understanding wood density traits is important in wood processing industries and appreciating consumer choices for wood products (Ramananantoandro et al. 2013). Protection of *I. bijuga* trees from psyllid damage through silviculture management has the potential to change many factors that are linked to wood quality.

In managed tree farms, plasticity of wood density deserves scrutiny especially if the harvested wood is destined for use by artisans for sustaining traditional skills. The factors that influence this plasticity merit thorough vetting in order to help silviculture managers of agroforest or production farm settings in their planning and decision-making. For native tree species with growth that is naturally constrained by native specialist herbivore, stimulating plant growth by mitigating effects of that herbivore creates a response that may reduce wood quality and complicate managerial decisions.

In summary, protecting *I. bijuga* trees from the native psyllid greatly increased plant growth. However, the rapid growth produced wood with reduced density, potentially altering the quality of wood for use by artisans. Although plantations of *I. bijuga* would reduce the potential of harvesting wood from natural trees, long-term management decisions should be adapted with ultimate evaluation of wood quality.

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