

1 Running head: Reforestation with native trees in Panama

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Responses of 20 native tree species to reforestation strategies for
7 abandoned farmland in Panama

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1 *Abstract.* Deforestation in the tropics often leads to unproductive agriculture, and results in
2 abandoned, degraded grasslands that tree species re-colonize poorly. To evaluate why forests do
3 not regenerate naturally, and to identify potential species for use in reforestation of degraded
4 areas, we planted 15,000 seeds of twenty native tree species varying in seed size and shade-
5 tolerance, in abandoned Panamanian farmland dominated by the exotic grass, *Saccharum*
6 *spontaneum*. To determine the effects of above- and below-ground constraints on tree seedling
7 germination, survival, and growth, we utilized four mowing and shading treatments of the
8 *Saccharum*. Shading the *Saccharum* effectively eliminated it, whereas mowing led to increased
9 light above-ground, but did not reduce *Saccharum* growth rate. Germination, survival, and
10 growth of tree seedlings approximately doubled in shade treatments, compared to the unshaded
11 control, but were lowest when the *Saccharum* was mown three times. Fire significantly
12 decreased germination and survival.

13 Some species did not follow these general trends, though, and we identified four species
14 groups that varied in their response to *Saccharum* competition. Very small-seeded, light
15 demanding species performed poorly, and we do not recommend their use in reforestation
16 because they tolerate neither above- nor below-ground constraints imposed by the *Saccharum*.
17 Light-demanding species with large seeds were limited by above-ground constraints, namely
18 shading. Small-seeded, shade-tolerant species were limited by below-ground constraints imposed
19 by the *Saccharum*. Large-seeded, moderately to highly shade-tolerant species performed well in
20 the *Saccharum*; we recommend a reforestation strategy which includes planting this last group.

21 *Keywords:* abandoned farmland; natural regeneration; Panama; *Saccharum spontaneum*;
22 secondary succession; tropical reforestation.

23 INTRODUCTION

24 Deforestation has left vast areas of primary humid tropical forest in a degraded state
25 (Houghton *et al.* 1991). Central America, for example, is now 10% abandoned agricultural land
26 (Finegan 1992). Land rehabilitation through re-establishment of native trees is becoming
27 increasingly attractive, since native trees have been shown to improve soil conditions

1 significantly within four years on badly degraded tropical land (Fisher 1995). Facilitating natural
2 tree regeneration may be an important management option, but significant barriers to tree
3 regeneration must be overcome. Lack of seed dispersal is often cited as a major limitation to
4 natural regeneration (Guevara *et al.* 1986, Janzen 1988, Nepstad *et al.* 1990, Vieira *et al.* 1994,
5 Aide and Cavelier 1994, Aide *et al.* 1995, da Silva *et al.* 1996), and harsh microsite
6 characteristics including low nutrient status, high irradiance, high temperature, and low soil
7 moisture during the dry season can also limit tree seedling survival (Uhl *et al.* 1988, Nepstad
8 1989, Nepstad *et al.* 1990, Gerhardt 1993).

9 These physiological stresses are worsened when abandoned lands are invaded by exotic
10 grasses that compete with tree seedlings for moisture and nutrients (Nepstad 1989) and increase
11 the propensity for fire (D'Antonio and Vitousek 1992). In Panama, abandoned sites in the Canal
12 area are invaded by the exotic, invasive grass, *Saccharum spontaneum* L. ssp. *spontaneum*.
13 *Saccharum* attains an average height of 2.5 m and grows in dense, impenetrable stands. It is
14 drought-adapted, burns frequently, and does not yield to weeding, mulching, fire, or deep
15 plowing because of its deep rhizomes (Panje 1970). It is listed as one of the most serious weeds
16 in Indonesia, India, Thailand, the Philippines, and Puerto Rico (Holm *et al.* 1979).

17 Reforestation options in *Saccharum* grasslands have not been studied, but there has been
18 considerable research on tree restoration of deforested tropical sites invaded by a similar grass
19 species (*Imperata cylindrica*) in South-East Asia. Nevertheless, no feasible large-scale method
20 has been found for restoring the original tree cover. Planting indigenous tree seedlings directly
21 into the *Imperata* had limited success because of the physical difficulty of planting, grass
22 competition, allelopathy, fire susceptibility, as well as soil degradation and compaction
23 (Kuusipalo *et al.* 1995). Intensive deep plowing followed by planting of a fast-growing exotic
24 tree crop to suppress grass and favour natural regeneration has been recommended (Otsamo *et al.*
25 1995). However, the high cost of site preparation and planting seedlings for this type of
26 restoration program is economically unattractive for large-scale application in tropical countries.
27 Instead, forest rehabilitation and management systems are needed that simultaneously accelerate