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ScienceDirect
South African Journal of Botany 74 (2008) 432–444
SOUTH AFRICAN JOURNAL OF BOTANY
www.elsevier.com/locate/sajb

# Can riparian seed banks initiate restoration after alien plant invasion? Evidence from the Western Cape, South Africa

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Received 15 August 2007; accepted 22 January 2008

**Abstract**

Riparian zones are complex disturbance-mediated systems that are highly susceptible to invasion by alien plants. They are prioritized in most alien-plant management initiatives in South Africa. The current practice for the restoration of cleared riparian areas relies largely on the unaided recovery of native species from residual individuals and regeneration from soil-stored seed banks. Little is known about the factors that determine the effectiveness of this approach. We need to know how seed banks of native species in riparian ecosystems are affected by invasion, and the potential for cleared riparian areas to recover unaided after clearing operations. Study sites were selected on four river systems in the Western Cape: the Berg, Eerste, Molenaars and Wit Rivers. Plots were selected in both invaded (>75% Invasive Alien Plant (IAP) canopy cover) and un-invaded (also termed reference, with <25% IAP canopy cover) sections of the rivers. Replicate plots were established at two elevations (mountain stream and foothill) and in three moisture regimes (dry, wet and transitional bank zones). Soil samples were taken, surveys were done of the aboveground vegetation, and comparisons were made between invaded and non-invaded sites. Seed bank communities were clearly defined by the state of the river (reference or invaded) and moisture regimes (wet and dry bank zones). Comparisons at a landscape scale showed no clear pattern, as the composition of both aboveground and seed bank species assemblages were strongly influenced by site history, especially the extent of invasion and fire frequency. Even after heavy and extensive invasion, riparian seed banks have the potential to initiate the restoration process. However, not all riparian species are represented in the seed bank. Based on these results, restoration recommendations are outlined for alien-invaded riparian zones.


*Keywords:* Biological invasions; Community recovery; Invasive alien plants; Restoration ecology; Soil-stored seeds; Species assemblages

## 1. Introduction

Riparian areas worldwide are very susceptible to invasion by alien plant species. This is because of the exposure of riparian vegetation to frequent natural and human-induced disturbances, the dynamic nutrient levels and hydrology, water-aided dispersal of propagules, and the role of stream banks as a reservoir for propagules of both indigenous and exotic species (Rowntree, 1991; Planty-Tabacchi et al., 1996; Galatowitsch and Richardson, 2005; Richardson et al., 2007). Woody invasive alien plants (IAPs) remove large quantities of water daily, changing water table levels (Rowntree, 1991). Invasive species also disrupt vegetation dynamics by altering colonisation ability, thereby affecting vegetation structure and indigenous plant establishment (Cohn, 2001; Muotka and Laasonen, 2002; Ladd et al., 2005). To curb such impacts, the South African government supports various alien-plant clearing initiatives, most of which give priority to river corridors to reduce the spread of propagules along rivers and into adjoining terrestrial areas (Richardson et al., 1997). The largest initiative is the Working for Water (WfW) programme which was launched in 1995 with the aims of improving and increasing both the quality and quantity of water, conserving biodiversity, and providing employment (Van Wilgen et al.,

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doi:10.1016/j.sajb.2008.01.170

1998). This programme aims for full recovery of riparian vegetation after removal of the invasive species, but a limited budget precludes active restoration at a large scale (Holmes, 1998, 2001). Inadequate recovery of riparian vegetation can result in soil erosion, loss of soil-stored propagules of native species, poor water quality, and a high risk of re-invasion by alien plant species (Holmes, 2001).

In their study of riparian scrub recovery after alien-plant clearing in the Fynbos Biome, Galatowitsch and Richardson (2005) highlighted the need for research into the recruitment dynamics of disturbed riparian zones. It is important to ascertain whether the main supply of new propagules for recolonisation comes from external sources, via water, wind or animal dispersal, or from *in situ* seed banks stored in the soil. The seed bank is defined as 'a reserve of viable seeds, fruits, propagules and other reproductive plant structures in the soil' (Goodson et al., 2001). Seed bank data can yield information on three features of the potential new vegetation: (1) the species composition, (2) the relative abundance of species, and (3) the distribution of each species (Welling et al., 1988). Additionally, analyses of the compositional data of both the seed bank and aboveground vegetation can reveal which desirable species are lacking in the seed bank and may need to be re-introduced by other means (e.g. replanting). Soil seed banks contribute significantly to the regeneration of plant cover following a disturbance in many vegetation types (Musil and De Witt, 1990; Holmes and Marais, 2000) but little research has focused on riparian zones. Restoration of a degraded landscape usually aims to return the area to some pre-disturbance condition where ecosystem functioning is sustainable in the long term (Rutherford et al., 2000; Richter and Stromberg, 2005). A thorough understanding of the role of seed banks, especially of the most influential species (in this paper assumed to be those that are most common and frequently occurring), is important for designing effective restoration projects.

Much work has been done in terrestrial (Thompson, 1992, 1993; Warr et al., 1993; Goodson et al., 2001; Holmes, 2002) and wetland (Van der Valk, 1981; Welling et al., 1988; Leck, 1989) systems on the dynamics of seed banks. Surprisingly little information is, however, available for riparian seed banks. Many processes are implicated in burying seeds in the soils of riparian ecosystems. Flood water disperses propagules and buries them under sediment (Richter and Stromberg, 2005). Mechanical translocation of soil during damming or canalization may also disperse propagules. Disturbance, and the resulting removal of indigenous vegetation, allows non-native species to become established in riparian systems (Bunn et al., 1998). Bare patches of soil are typically colonized by ruderals and longer-lived competitors (like many riparian tree invaders e.g. *Acacia mearnsii* in South Africa) may replace the ruderals. When open patches reoccur, they may be colonized by residual species that have persisted in the seed bank, or by immigrants dispersed from nearby vegetation patches or off-site seed banks. This process makes riparian zones diverse but also makes them vulnerable to invasion by alien invasive trees and shrubs.

Most restoration projects in invaded systems begin with the removal of alien vegetation, and this is often seen as the final goal. However, in some cases, additional attention may be required to set the system on a trajectory towards recovery of key indigenous species and aspects of ecosystem functioning (Holmes and Richardson, 1999; Galatowitsch and Richardson, 2005; Harms and Hiebert, 2006). A recent North American study on the invasive species Tamarisk (*Tamarix* spp.) found that the removal of aliens alone was inadequate to promote the re-establishment of a healthy riparian community (Harms and Hiebert, 2006). Propagule supply is thought to play a significant role in both alien plant invasion and habitat recovery rate. Renöfält et al. (2005) found that the delivery of propagules by flood events increases plant species richness in un-invaded rivers. However, if the upper catchment is degraded and the seed source depleted (through invasion or deforestation), the down-stream areas are less likely to have successful post-disturbance recovery.

This study investigates the potential of native seed banks in riparian zones of the Western Cape, South Africa, to drive unaided recovery of natural vegetation following mechanical clearing of invasive alien trees and shrubs. By describing seed banks we investigated the following key questions:

- To what extent do riparian seed banks have the potential to regenerate vegetation that is compositionally similar to undisturbed riparian vegetation?
- What happens to the species composition of the riparian seed bank after invasion and is it adequate to initiate ecosystem recovery?
- What are the implications for restoration of riparian vegetation in the Western Cape?

## 2. Materials and methods

### 2.1. Data collection

Four river systems within the southwestern part of the Western Cape (Berg, Eerste, Molenaars and Wit Rivers) were chosen for their variety of reach types, history of alien plant invasion, and for their close proximity to the research facilities. Details of the riparian vegetation of three of these rivers (all except the Berg) are provided by Prins et al. (2004). The sampling method combined subjective selection of plots within homogeneous plant assemblages and objective, random placement of sampling quadrats within these plots. Fieldwork at all sites was done during late summer (March–April 2005 and 2006). Plots were selected in both relatively undisturbed areas (also termed reference with $<25\%$ alien plant canopy cover) and heavily invaded (considered "closed" alien stands with $>75\%$ alien canopy cover) riparian sections of the rivers.

The major zones of the riparian system were sampled on a lateral scale as the aquatic zone, the wet bank zone and the dry bank zone; and on a longitudinal scale as mountain stream and foothill zones (Davies and Day, 1998; Boucher and Tlale, 1999). The aquatic zone was subdivided into a zone that dries up during the dry season and the zone that is always wet. The wet bank zone consists of a sedge zone and a shrub zone, flooded respectively by the low flow and high flow during the wet season. The dry bank is divided into a lower dynamic zone