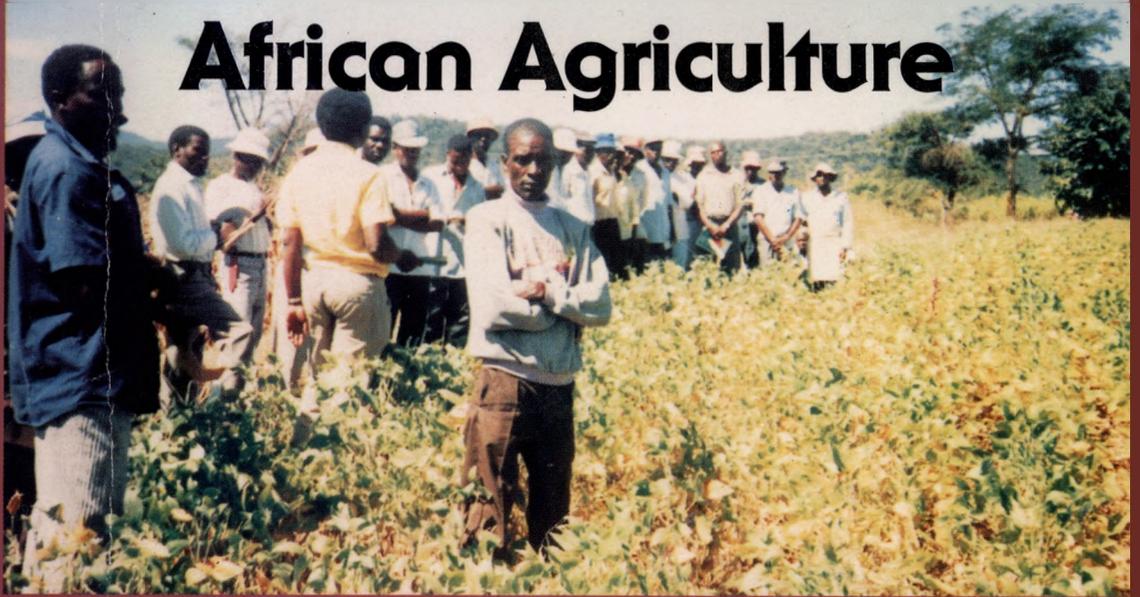


Harnessing Biological Nitrogen Fixation in African Agriculture



Challenges and Opportunities



edited by
Sheunesu M. Mpeperekwi
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6.5 Genetic improvement of *Racosperma* spp. for agroforestry in sub-Saharan African countries

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Summary

Racosperma auriculiformis (formerly *Acacia auriculiformis*) and *R. mangium* (formerly *Acacia mangium*), two woody leguminous plants, have been introduced in many sub-Saharan African countries for reforestation and agroforestry purposes. Nodulation with *Rhizobium* and vesicular-arbuscular (VA) mycorrhizal associations contribute much to the growth of both species, especially in soils poor in nutrients.

Improved methods of enzyme extraction and horizontal starch gel electrophoresis were developed in order to study the mating system, the genetic diversity and its architecture within and among populations of both species. Analysis of the mating system revealed a predominantly outcrossing mode. The use of allozyme markers showed that populations were found with low apparent inbreeding and that diversity resided predominantly within populations.

Early genecological tests showed that variation in quantitative characters follows patterns of geographic variation for both species. These tests permitted the selection of Papua New Guinea provenances as the most productive and adapted for use in agroforestry. Such a screening was also conducted for rooting ability, for its use in production of monospecific and hybrid varieties. To maximise plant productivity, a two-step selection procedure is suggested, the first step regarding the host plant and the second one the microsymbiont strains.

Introduction

Agroforestry is one of the most promising technological options for reversing soil degradation, restoring tree cover, and maintaining or even increasing the productive capacity of agro-ecosystems on a sustainable basis. Improvement of multipurpose tree and shrub species for agroforestry systems should take into account farmers' needs for tree products and services, compatibility with companion crops, sustainability and enhancement of land productive capacity, and maximisation of economic returns in the shortest time (see Owino, 1992; Simons, 1992; Nair, 1993). Sustainability and enhancement of land capacity require selection of trees and shrubs that can improve soil fertility as well as the selection of the best provenances, families or clones for that purpose (Dommergues, 1987; Avery, 1991).

Of particular importance are four major groups of symbiotic associations: *Rhizobium* — leguminous and non-leguminous woody perennials; *Frankia* — actinorrhizal plants; ectomycorrhizae — host woody perennials; and endomycorrhizae — host woody perennials. *Racosperma auriculiformis* (Cunn. ex Benth.) Pedley (formerly *Acacia auriculiformis*) and *R. mangium* (Wild.) Pedley, comb. nov. (formerly *Acacia mangium*), two woody leguminous plants,

have been introduced in many sub-Saharan African countries. Nodulation with *Rhizobium* and vesicular-arbuscular (VA) mycorrhizal associations contribute much to growth of both species, especially in soils poor in nutrients (Khasa *et al.*, 1994a). These species are extensively cultivated throughout many sub-Saharan African countries and particularly in Zaire for industrial tree planting programmes and as a component of agroforestry systems (Khasa *et al.* 1994a). In this paper, we briefly present some strategies for the development of an integrated genetic improvement programme of *R. auriculiformis* and *R. mangium* for their use in agroforestry systems.

Reproductive biology and genetic diversity of *R. auriculiformis* and *R. mangium*

Information regarding reproductive biology and genetic diversity is essential for designing efficient sampling strategies for the conservation and management of genetic resources as well as in tree breeding programmes. Improved methods of enzyme extraction and horizontal starch gel electrophoresis were developed in order to study the mating system and the amount and structure of the genetic diversity of *R. auriculiformis* and *R. mangium* by means of allozyme markers (Khasa *et al.*, 1993a). Analysis of the mating system of *R. auriculiformis* in an exotic seed production area in Zaire (Khasa *et al.*, 1993b) and in natural stands (Moran *et al.*, 1989a) revealed a predominantly outcrossing mode. Substantial inbreeding was also noted due to sibling matings (Khasa *et al.*, 1993a). Because of the correlated matings, collecting large numbers of pods from different parts of individual trees will likely result in a genetically more diverse sample and will best optimise strategies for *ex situ* gene conservation.

The study of genetic variability and architecture within and among 26 populations of both species showed low apparent inbreeding and genetic diversity residing predominantly within populations. Thus, artificial selection at the intraspecific level and *ex situ* conservation strategies should emphasize primarily sampling within populations, particularly for *R. mangium*, which showed weaker differentiation among populations (Khasa *et al.*, 1994b). For *R. auriculiformis*, more genetic diversity and more intense geographical differentiation was observed (Khasa *et al.*, 1994b), which suggest, for conservation purposes, more intensive sampling of populations from all main parts of the species range.

In addition, *R. mangium* showed much lower levels of genetic diversity and narrower ecological amplitude (Moran *et al.* 1989b; Khasa *et al.*, 1994b), and it was suggested that this species is recently derived from *R. auriculiformis* (Khasa *et al.* 1994b). The amplitude of the interspecific genetic distance between the two species was low (Khasa *et al.*, 1994b), suggesting a weak reproductive isolation and the possible use of reciprocal recurrent selection scheme for genetic improvement of the two closely related species (Khasa and Bousquet, 1994).

Provenance trials have been established in a few sub-Saharan African countries including four impoverished sites in Zaire (Khasa, 1993). The study of genecological diversity in quantitative traits in Zaire indicated that *R. auriculiformis* was more plastic than *R. mangium*, while both showed a geographical pattern of population differentiation. For both species, provenances with the greatest productivity at 21 months and showing good adaptation to the variety of sites tested were from Papua New-Guinea. Additional genetic gains could be obtained through selection and breeding of superior individuals from these provenances without elimination of useful alleles and reduction in effective population size (see Khasa and Bousquet 1994). Significant genotype x environment interactions were also noted, which could allow for the selection of more productive site-specific varieties. All provenances of *R. auriculiformis* were nodulated naturally by wild *Rhizobium* strains on the four testing sites whereas all provenances of *R. mangium* did not nodulate in the marine salted soil of the Atlantic coast site. The nodulation of provenances of *R. mangium* was also irregular in the higher plateau of Shaba (Zaire) where soils have a low pH and a high content of exchangeable Al.

Production of genetically improved seedlings is feasible in *Racosperma* species and differences between species and among provenances within species were observed. These differences were

maximized when cuttings were treated with root-promoting hormone (Khasa *et al.* 1994c). The development of an integrated genetic improvement programme adapted to agroforestry has been proposed by Khasa and Bousquet (1994) for these species.

An integrative approach for the use of *R. auriculiformis* and *R. mangium* in agroforestry systems

In parallel to the genetic tree improvement, it is important to identify the most effective *Rhizobium* strains adapted to different soil types for both species. Because the nitrogen-fixing potential is conditioned by the genotypes of both the host plant and the associated microsymbiont (Sougoufara *et al.* 1992), the interactions between *Racosperma* genotypes and *Rhizobium* strains must be better known in order to maximize the productivity of this symbiotic system in agroforestry. The maximum nitrogen input will be obtained by using stress-tolerant and high nitrogen-fixing host genotypes together with stress-tolerant and effective *Rhizobium* strains. Because the nodulation of *R. mangium* provenances is irregular, systematic artificial inoculation with stress-tolerant and efficient strains must be performed in agroforestry trials (Galiana *et al.* 1991).

To optimize the role of biological nitrogen fixation in agroforestry, a two-step selection procedure is therefore suggested, the first step regarding the host-plant and the second one the microsymbiont strains (Sougoufara *et al.* 1992). The first step should emphasize the selection of species, provenances, clones, or new varieties obtained by hybridisation, which would exhibit high nitrogen-fixing potential as well as good adaptation to the site conditions and multiple purposes for the farmers. The second step should aim at the selection of the most efficient *Rhizobium* strains, together with efficient mycorrhizal fungi or other beneficial soil microorganisms. More research is also needed to develop affordable and simple methods of measuring nitrogen fixation *in situ*. The establishment of breeding seedling orchards that perform the combined functions of resource population, breeding population, progeny test and seed production area would appear to offer distinct advantages and be best suitable for the release of planting stocks to small farmers.

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