

# Seed weight patterns of *Acacia tortilis* from seven seed provenances across Botswana

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## Abstract

Laboratory-based seed storage systems have been developed as an alternative to *in situ* conservation for indigenous woody plant species. However, interactions between seed quality and environmental variables must be known for each species prior to seed collection, storage and sowing to ensure effective conservation. This study investigated *Acacia tortilis* seed weight/quality patterns across seven Botswana seed provenances in relation to: soil nutrient status, altitude; latitude; slope angle; % grass cover; height and density of other woody plants nearby. The higher rainfall and relatively eutrophic seed provenances of north-western Botswana (Chobe, Okavango and Makgadikgadi) were associated with large *A. tortilis* species and seeds, as well as higher densities of woody plants. Spatial variation in seed weights of *A. tortilis* was principally a function of rainfall and soil organic carbon. Although more work is required to establish the relationship between seed weight and germination rates for *A. tortilis*, this research suggests that seed collection should focus on sites with high levels of rainfall and soil organic carbon.

*Key words:* *Acacia tortilis*, Botswana, indigenous, *in situ* conservation, seed provenances, seed quality

## Résumé

Des systèmes de stockage de graines en laboratoire ont été créés comme solution de rechange à la conservation *in situ* pour les espèces de plantes boisées indigènes. Néanmoins, il est essentiel d'étudier les interactions entre la qualité de graine et les variables environnementales pour chaque espèce avant le recueil, le stockage et la dissémination de la graine, afin d'assurer une conservation efficace. Cette

étude examine des modèles poids/qualité de la graine de *Acacia tortilis* à travers sept provenances de graine au Botswana, en tenant compte de: la condition nutritionnelle du sol, altitude, latitude, pente, % de couverture en herbage, largeur et densité d'autres plantes boisées aux alentours. Les provenances de graine relativement eutrophique avec un taux élevé de pluviosité au nord-ouest de Botswana (Chobe, Okavango and Makgadikgadi) furent associés avec des grands espèces de *A. tortilis* et des graines, ainsi que les densités supérieures de plantes boisées. La fluctuation spatiale dans le poids des graines de *A. tortilis* fut principalement une fonction de la pluviosité et du carbone organique du sol. Tandis que plus de travail s'impose afin d'établir le rapport entre le poids de la graine et les taux de germination pour l' *A. tortilis*, cette étude suggère que le recueil des graines devrait se concentrer sur les lieux avec un taux élevé de pluviosité et carbone organique du sol.

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## Introduction

Despite occupying less than a quarter of the land area (Low & Rebelo, 1996), the forests of southern Africa contain much of the region's biodiversity (Eeley, Lawes & Reyers, 2001). Approximately 43% of the region's forests have been transformed in some way (Macdonald, 1989) by agricultural expansion, altered fire regimes, illegal hunting, encroaching plantation forestry, and uncontrolled removal of plant products (Cunningham, 1989; Geldenhuys & Macdevette, 1989; Eeley *et al.*, 2001). In addition to *in situ* forest conservation programmes, laboratory-based seed storage systems are increasingly being used to protect these forests. This is being done in Botswana through the Forestry Unit of the Ministry of Agriculture and the Forestry Association of Botswana. Extensive knowledge is required for each species prior to

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seed collection, storage and sowing to ensure germination and establishment from good quality seeds. One important component of this knowledge involves seed quality patterns versus specific environmental variables. The present study investigates relationships between *Acacia tortilis* seed quality and a range of physical and edaphic environmental variables. Seed weight is used as a surrogate for seed quality, as this has been correlated with germination rates and seedling biomass in other species of *Acacia* (Cervantes *et al.*, 1998; Shaukat, Siddiqui & Aziz, 1999). This information may be used to target the collection of viable seeds and optimize germination and establishment from stored seeds.

*Acacia tortilis* has a very wide distribution inhabiting most semi-arid land from the Middle East through East Africa to southern Africa, and has several sub-species. Maximum height varies between 5 and 20 m. It grows best on rich soils and does not thrive on deep sand (Timberlake, 1980; Roodt, 1998). It tends to grow in areas with rainfall of 500–1000 mm per annum, at temperatures of 45–50°C maximum and 0°C minimum and at elevations as high as 2000 m (Baumer, 1983; Tanzania Forest Division, 1984).

## Methods

It was hypothesized that Botswana's diverse climatic and edaphic conditions would influence seed characteristics of *A. tortilis*. The whole of Botswana was divided into seven seed zones (Table 1) based on climatic and edaphic factors (Soil Mapping and Advisory Service, 1985; Bhalotra, 1987). Due to resource and accessibility constraints, at

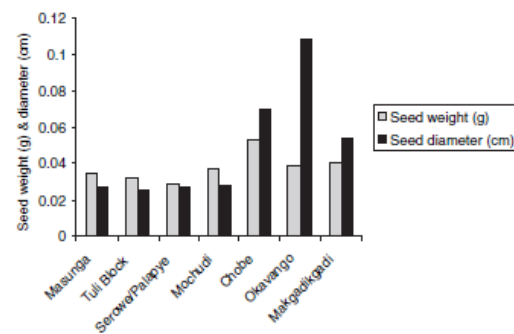
least one sample site was placed within each seed zone. However due to its edaphic heterogeneity, seven sites were sampled in Masunga zone. The following environmental variables were measured: altitude; latitude; slope angle; percentage (%) grass cover; height of species from which seeds were collected and edaphic variables.

Pods were collected from *A. tortilis* in each of the seven zones. Pods were collected from at least three sample trees that were widely spaced to represent the provenance. Trees with very few pods were avoided as they were suspected of insect-attacks and as such may have contained unviable seeds. Fruits were collected from tarpaulins on the ground after shaking the branches, and gently broken using a mortar and a pestle to release the seeds. Fifty seeds from each sampled tree were sun-dried to constant weight and the weight and diameter of each seed was recorded.

The soil under the canopy of each selected tree was sampled at 0–10 cm and 10–20 cm and samples pooled. pH, soil texture and nutrient content (P, K, Na, Mg, Ca, % OC) were determined. Bulk soil samples were air-dried and passed through a 2 mm sieve prior to chemical and physical analysis. Soil particle size composition was determined using the hydrometer method and organic carbon by the Walkley–Black method (Bouyoucos, 1926). Exchangeable calcium, magnesium, sodium and potassium were determined using atomic absorption spectrophotometry. Soil pH was determined potentiometrically in 0.01 M calcium chloride solution using a soil to solution ratio of 1 : 2 while available phosphorus was determined using the method of Bray & Kurtz (1945).

**Table 1** The seven seed provenances, based on climatic and edaphic factors. The sample sites within each provenance are also indicated

Area/provenance	District	Sample sites
Masunga	North-east	Makaleng, Botlaote, Kalakamati, Senyawe, Sebina, Tutume, Ramokgwebana
Tuli Block	Central (east)	Bobonong, Parris Halt
Serowe/Palapye	Central (central)	Mmashoro, Shoshong
Mochudi	Kgatleng	Artesia
Chobe	Chobe	Kasane, Lesoma
Okavango	Ngamiland	Gumare, Shorobe, Maun
Makgadikgadi	Central (north west)	Mopipi, Mosu



**Fig 1** Average seed weights and diameters for *A. tortilis* from the seven provenances

## Results

The average weights and diameters of seeds from each provenance are shown in Fig. 1. Chobe, Okavango and Makgadikgadi provenances are characteristic of large seeds (in terms of weight and diameter), while seeds from Tuli Block and Serowe/Palapye are relatively smaller. The ranges of seed weights and diameters further depict this pattern of larger seeds towards the North/Northwest of the country (Table 2). Chobe, Okavango and Makgadikgadi provenances are characterized by woodlands (Fig. 2) with large *A. tortilis* bearing large seeds, while the shrub lands of other provenances typically bear smaller seeds (Fig. 1).

According to Pearson Product Moment Correlation Coefficient, seed weight was correlated with only seven of the environmental variables in question ( $n = 67$ ; d.f. = 65;  $r = 0.24$ ;  $P = 0.05$ ). From a multi-collinearity assessment, annual rainfall and organic carbon were re-

tained as good predictors of seed weight, and a regression model developed:

$$\text{Average seed weight (g)} = 0.0006C^{0.15}P^{0.62} \quad (1)$$

where  $C$  is the % organic carbon and  $P$  the annual precipitation (mm) ( $r^2 = 0.64$ ;  $P < 0.05$ ).

## Discussion

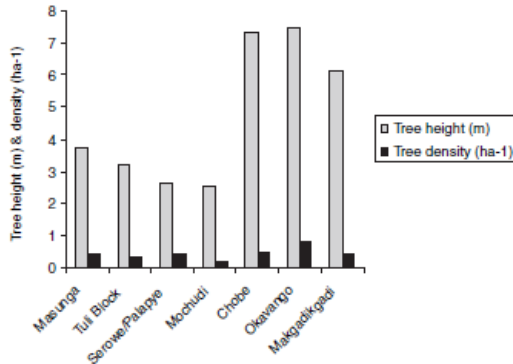
Spatial variation in seed weights of *A. tortilis* was primarily determined by rainfall and soil organic carbon. Although *A. tortilis* seed quality (represented by weight patterns) is a function of both genetic and environmental factors, this study focused on the environmental determinants of seed quality patterns in Botswana.

Temperature and rainfall are highly variable in semi-arid savannas, both seasonally and inter-annually, and exert a dominant influence on amounts of organic carbon. This is apparent from the linear relationship between primary biomass and annual rainfall established for the semi-arid savannas (Coe, Cumming & Phillipson, 1976), and hence larger trees and seeds from the northwest of the country. Given the high spatial variability of rainfall and the wide spacing between meteorological stations in Botswana, rainfall records for some of the more remote seed provenances may be less accurate.

The larger and denser trees of north-western Botswana were associated with higher levels of soil organic carbon, implying that higher rainfall in these areas results in larger and denser trees that produce high levels of primary biomass, which is subsequently assimilated into the soil as organic carbon. Environmental variables Ca, Mg, K, P and Na were not significant in the determination of seed weight patterns, implying that most of the selected edaphic factors were irrelevant or are generally similar (low values) throughout the country. This is consistent with suggestions that soil nutrient content has little influence on vegetation communities in Botswana, given the extremely low nutrient and organic matter content of sand soils (Moore & Attwell, 1999). Similar correlations have been found between seed weight and rainfall for other species (Vakshasya, Rajora & Rawat, 1992; Harfouche *et al.*, 2003), but this is the first time a relationship between seed weight and soil organic carbon has been reported. Although more work is required to establish the relationship between seed weight and germination rates for *A. tortilis*, this research suggests that seed collection should focus on sites with high levels of rainfall and soil organic carbon.

**Table 2** Ranges of seed weights and seed diameters for *A. tortilis* from the seven Provenances

Provenance	Seed weight ranges (g)	Seed diameter ranges (cm)
Masunga	0.022–0.042	0.02–0.037
Tuli Block	0.022–0.042	0.019–0.030
Serowe/Palapye	0.019–0.043	0.022–0.031
Mochudi	0.032–0.040	0.026–0.027
Chobe	0.037–0.067	0.023–0.173
Okavango	0.033–0.049	0.022–0.295
Makgadikgadi	0.034–0.047	0.022–0.184



**Fig 2** Average *A. tortilis* heights and densities of other species from the seven provenances

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