Calorific value of *Prosopis africana* and *Balanites aegyptiaca* wood: relationships with tree growth, wood density and rainfall gradients in the West African Sahel

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**Introduction**

*Prosopis* africana (Guill., Perrott. and Rich.) Taub. and *Balanites aegyptiaca* (L.) Delile are native tree species in the West African Sahel and provide wood for fuel, construction and other essential products. A provenance/progeny test of each species was established on a relatively dry site in Niger, and evaluated at 13 years. Results from the tests at 13 years indicated that there was significant genetic variation in tree growth and wood density in *P. africana* but not *B. aegyptiaca*; that provenance means for tree growth of both species, and for wood density and survival of *P. africana* increased from the more humid to the drier parts of the sample region; and that the growth of trees from both species was lower in the drier zone. This paper presents additional results from the provenance/progeny tests of *P. africana* and *B. aegyptiaca* at 13 years. The major objectives were to determine (a) if tree growth and wood density were correlated with calorific value of the wood, (b) if correlations among growth and wood variables differed in strength between the drier and more humid parts of the sample regions, and (c) if calorific value was related to rainfall gradients in the sample regions.

**Materials and Methods**

The sample region for *P. africana* extends from central Burkina Faso to central Niger, covering an area ~1200 km2 from west to east, and 500–200 km2 from south to north. Mean annual rainfall in this sample region decreases from west to east (~350–350 mm) and south to north (~750–650 mm in the west, ~450–335 mm in the east). The sample region for *B. aegyptiaca* extends ~425 km2 from west to east, and ~325 km2 from south to north in central Niger. Mean annual rainfall in this sample region decreases from south to north and west to east (lattitudinal decrease ~550–350 mm in the west and ~450–350 mm in the east). Seeds were collected in 1993 from *P. africana* (275 trees from 28 provenances) and *B. aegyptiaca* (108 trees from 12 provenances). Latitude, longitude and elevation of each sampled tree was recorded using a GPS receiver. Progeny plants were established in provenance/progeny tests in 1994 at the ICRISAT Sahelian Centre in Niger (mean annual rainfall ~540 mm). Each test had eight replications. A subsample of the trees in each of the eight replications in each test was randomly selected in 2007 for this study (~30 trees per replication for *P. africana* and 10 trees per replication for *B. aegyptiaca*). The following variables were measured on each sampled tree: tree height (cm), stem diameter (cm) over bark at 1.3 m (DBH) for *P. africana* and at 30 cm (Dia30) for *B. aegyptiaca*, basic density of a disk and air-dry density of an increment core of wood (BDen and ADen, respectively, kg m−3), and calorific value (CV) of a sawdust sample. Samples for BDen, ADen and CV were obtained close to where diameter was measured. Three estimates of CV were calculated: gross and net CV (MJ kg−1) and gross CV m3 (g CVm3). Gross CV is the maximum energy available from an oven-dry sample, whereas net CV is the energy available from an air-dry sample. Mean percent ash content (AC) and moisture content (MC) were determined from the residue for a random sub-sample of the sawdust samples. These were used to calculate a fuel value index (FVI) for each species, using the following formula: FVI = [BDen(1–MC)]/[(AC)(MC)]. Pearson correlations among tree growth and wood variables were calculated using data from all sampled trees and then regressed on variations in rainfall gradients among the dry and more humid zones in the sample regions (below and above ~550 mm rainfall, respectively).

Multiple linear regression was used to investigate whether provenance means for gross CV and CVm3 varied significantly with provenance latitude, longitude and/or elevation and by implication the rainfall gradients in the sample regions. Results of this study are inconclusive with respect to this hypothesis: growth

**Results**

FVI was higher for *P. africana* than for *B. aegyptiaca* (1279 versus 1114) because AC and MC were lower for *P. africana* (0.33% and 10%, respectively) than for *B. aegyptiaca* (0.69% and 12%, respectively).

**Discussion**

Correlations between tree growth and wood density may be an adaptation to reduce bending stress produced by wind. In general, larger trees require greater strength at the base of the stem in order to reduce bending stress, and strength can be increased by producing denser wood. In general, stand densities are higher in more humid zones, and root systems and tree crowns may become intertwined to varying degrees over time, thereby allowing the stand to "collectively" reduce the bending stress. In the drier zone, this "collective" response would be less apparent because stand densities are lower. Following this argument, one would expect a stronger correlation between growth and wood density in the drier zone. This paper presents additional results from the provenance/progeny tests of *P. africana* and *B. aegyptiaca* at 13 years. The major objectives were to determine (a) if tree growth and wood density were correlated with calorific value of the wood, (b) if correlations among growth and wood variables differed in strength between the drier and more humid parts of the sample regions, and (c) if calorific value was related to rainfall gradients in the sample regions.

Correlations among all trees indicated that larger trees of both species tended to have greater BDen, ADen and gross CVm3, but correlations with gross CV were not significant. Correlations differed in magnitude between the drier and more humid zones: for *P. africana*, growth variables had stronger correlations with wood density in the more humid zone, and with gross CVm3 in the drier zone. For *B. aegyptiaca*, all correlations between growth and wood variables were stronger in the drier zone. Gross CV was weakly correlated with growth of *P. africana* only in the drier zone, but the correlation was not significant for *B. aegyptiaca* in either zone. Wood density was not significantly correlated with gross CV (not tabulated), but ADen and especially BDen were strongly correlated with gross CVm3 (e.g., r with BDen = 0.534 for *P. africana* and 0.608 for *B. aegyptiaca*, P < 0.001) because basic density was used to calculate gross CV, and the two density measurements were strongly correlated (r = 0.607 for *P. africana* and 0.759 for *B. aegyptiaca*, P < 0.001).

Regressions with provenance location (Table 2): Mean gross CV of wood of *P. africana* and *B. aegyptiaca* provenances tended to decrease in general from the more humid to the drier parts of their sample regions. For *P. africana*, it decreased from west to east and increased with elevation (Figure 1). For *B. aegyptiaca*, it decreased with latitude in the southern part of its sample region, but increased with latitude in the northern part of the sample region (Figure 2). Regressions involving gross CVm3 were not significant.

Several correlations were significant with wood density in the drier zone, whereas in the more humid zone, the correlations were not significant. In the drier zone, regression analysis showed that gross CV decreased with latitude and elevation, whereas in the more humid zones, it decreased with west to east and increased with elevation. Mean percent ash content (AC) and moisture content (MC) were determined from the residue for a random sub-sample of the sawdust samples. These were used to calculate a fuel value index (FVI) for each species, using the following formula: FVI = [BDen(1–MC)]/[(AC)(MC)]. Pearson correlations among tree growth and wood variables were calculated using data from all sampled trees and then regressed on variations in rainfall gradients among the dry and more humid zones in the sample regions (below and above ~550 mm rainfall, respectively).

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