# NUTRITIVE QUALITY OF BAMBOO BROWSE FOR LIVESTOCK

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## Introduction:

If able to survive Appalachian conditions, cold-hardy bamboo species may be a useful source of animal feed and other products that diversify small-farm income opportunities and improve ecosystem integrity. These other products might include building materials, fiber, flooring, ornamental nursery stock, human food (shoots), high quality charcoal, biofuels, wildlife habitat, stream bank stabilization, erosion control and carbon sequestration. However, we know little about bamboo survival, growth requirements, productivity or their nutritive value under hill-land Appalachian conditions.

We established plantings of several species of cold-hardy temperate bamboo, including one species native to West Virginia, in order to determine persistence under hill-land Appalachian pasture conditions and potential nutritive value for goats.

## Materials & Methods

- We collected clones from plantings of non-native cold-hardy species including *Phyllostachys aureosulcata, P. bambusoides, P. bissetii, P. dulcis, P. flexuosa, P. mannii, P. nuda, P. rubromarginata,* and *Semiarundinaria fastuosa* from the USDA-ARS temperate bamboo germplasm center at Byron, GA in 2001 or from commercial nurseries in 2002, and collected specimens of native bamboo, *Arundinaria gigantea* from several locations in West Virginia in 2002 (Table 1).
- Clones were propagated in a greenhouse and then planted and maintained at three field locations (two in Bragg, WV, and one in Alderson, WV).
- Live bamboo leaves were harvested in April, July, and Sept. 2003, and in Feb. 2004, and analyzed for fiber constituents and total Carbon and Nitrogen. The July sampling represented the youngest leaves.
- Fiber constituents were determined with ANKOM$^{200}$ Fiber Analyzer.
- Total C and N was determined with a Carlo-Erba 1108 CNS Elemental Analyzer. Crude protein was estimated as 6.25 x % N.
- Data were analyzed with SAS using a mixed model (PROC MIXED) with field location as a random block effect and date as a repeated measure. Tukey-Kramer adjusted differences among means are denoted by letters ( P≤0.05 unless noted).

**Table 1**. Temperate bamboo species used in this study include *Arundinaria gigantea,* a bamboo species native to the U.S. *Arundinaria* grows from Georgia and Texas to Maryland and Ohio including West Virginia and is known to have some potential as an animal fodder. Less is known about the potential of other cold-hardy bamboos. A useful species source list can be accessed from the American Bamboo Society, http://www.americanbamboo.org/.

| Bamboo Species | Height (m) | Max. diameter (cm) | Min. Temp. (C ) | Light |
|---|---|---|---|---|
| *Arundinaria gigantea* (ArGi) | 6.1 | 2.5 | -23 | Full Sun |
| *Phyllostachys aureosulcata* (PhAu) | 13.7 | 5.6 | -23 | Full Sun |
| *P. bambusoides* (PhBa) | 21.9 | 15.2 | -15 | Full Sun |
| *P. bissetii* (PhBi) | 12.2 | 5.1 | -27 | Full Sun |
| *P. dulcis* (PhDu) | 12.2 | 7.0 | -18 | Full Sun |
| *P. flexuosa* (PhFl) | 9.4 | 7.0 | -18 | Full Sun |
| *P. mannii* (PhMa) | 9.1 | 4.4 | -21 | Full Sun |
| *P. nuda* (PhNu) | 10.4 | 4.4 | -29 | Full Sun |
| *P. rubromarginata* (PhRu) | 16.8 | 7.0 | -21 | Full Sun |
| *Semiarundinaria fastuosa* (SeFa) | 9.1 | 3.8 | -21 | Full Sun |

**Fig. 1.** Almost all of the species of bamboo persist at each location after 3 growing seasons, having survived air temperatures of less than -18 degrees C and soil temperatures (at 5 cm depth) below -1 degrees C. Most bamboos retain some green leaves in sheltered areas near the base of the plants even in late-winter.

Photo: D. Ruckle

## Results & Discussion:

Sample date, associated with leaf-age, comprised the largest component of the variance analysis for crude protein (CP), acid detergent fiber (ADF), cellulose, and acid detergent lignin (ADL), while species had greater impact on variance of total ash and % carbon. Small but significant differences among species were found for all composition measures (Table 2). The pattern of composition change across harvest dates was consistent for all species (species x date interaction not significantly different, P > 0.05).

Bamboo leaves contained higher concentrations of CP in July than September, but values for February 2004 were nearly the same as average concentrations of CP observed the previous April (Fig. 3). The range of average CP among bamboo species was narrow, about 2.4%. The highest overall concentration of CP was observed in *P. dulcis,* a species reputed to produce high quality shoots favored for human consumption, while the lowest concentration of CP was observed for *P. mannii,* a species used in construction (Table 2). Bamboo leaf CP concentration was on the low side of the range reported for other browse species (Nastis and Malechek, 1981; Addlestone et al., 1999; Turner and Foster, 2000; Mueller et al., 2001; Moore et al., 2003), but was sufficient to meet the maintenance or growth needs of goats (NRC, 1981) at all harvest dates and for all bamboo species.

Harvest date affected cell wall components to a greater extent than CP. Concentrations of ADF (Fig. 4), cellulose (Fig. 5), and lignin (Fig. 6) were generally lowest for the youngest leaves harvested in July, and highest for over-wintered leaves harvested in April 2003 or February 2004. Concentrations of ADF (Fig. 4) increased linearly [ADF = 26.01 + 0.03(julian day), $r^2$ = 0.86, P < 0.08] with age of leaf, consistent with the increase in cell wall concentration expected in forages as leaves age or mature. As with CP, the most desirable (low) ADF was found for *P. dulcis*, while another species prized for its wood quality, *P. rubromarginata,* had the highest ADF (Table 2).

Similar changes in cell wall and protein concentration with age were reported for oak leaves (Nastis and Malechek, 1981). Concentrations of ADF, cellulose, and lignin were higher in these bamboos than in leaves of *Paulownia* (Mueller et al., 2001), locust, mimosa (Addlestone et al., 1999), autumn olive, multiflora rose, or honeysuckle (Turner and Foster, 2000), but were similar to concentrations reported for leaves of oak (Nastis and Malechek, 1981) and willow (Moore et al., 2003). Perhaps most importantly, bamboo retained nutritional value well through the winter at the test sites, a time when few other green fodder options are available. The upright growth habit of bamboo makes this fodder accessible to livestock even under snow conditions. Therefore, bamboo may have potential as a winter browse in central Appalachia.

An additional management consideration relates to the effects of bamboo litter inputs on nutrient cycling in pasture ecosystems. Bioavailability of traditional forage quality components can be related to the decomposition rates of bamboo litter in the ground with rates for soluble cell components > hemicellulose > cellulose > lignin. The average bamboo C/N ratio of about 19 is similar to other forages like alfalfa or Kentucky bluegrass and suggests bamboo leaves will mineralize in soil to provide inorganic nitrogen like ammonium and nitrate available for uptake by other plants. Substantially higher C/N ratios might result in immobilization whereby soil microorganisms would compete for N making it temporarily less available for plant uptake. Conversely, C/N ratios substantially lower than 20 might result in rapid mineralization of organic matter in excess of plant demands and the possible loss of N from the soil due to leaching.

**Table 2. Average forage value constituents of cold-hardy bamboo species.** Within each column, significant Tukey-Kramer adjusted differences among species are denoted by superscript letters. Significance for all constituents is P≤0.05 except % N and its derivative crude protein, which are P≤0.10.

| Bamboo Species | Ash (%) | ADF (%) | Cellulose (%) | ADL (%) | Protein (%) | N (%) | C (%) | C/N ratio |
|---|---|---|---|---|---|---|---|---|
| *Arundinaria gigantea* | $5.3^{AB}$ | $35.1^{AB}$ | $27.4^{A}$ | $5.2^{AB}$ | $15.0^{AB}$ | $2.4^{AB}$ | $45.8^{ABC}$ | 19.4 |
| *Phyllostachys aureosulcata* | $6.3^{AB}$ | $34.6^{AB}$ | $25.5^{AB}$ | $6.6^{A}$ | $15.1^{AB}$ | $2.4^{AB}$ | $46.3^{AB}$ | 19.3 |
| *P. bambusoides* | $6.2^{AB}$ | $34.0^{B}$ | $25.0^{AB}$ | $6.0^{AB}$ | $15.5^{AB}$ | $2.5^{AB}$ | $45.7^{ABC}$ | 18.9 |
| *P. bissetii* | $7.6^{A}$ | $34.7^{AB}$ | $25.2^{AB}$ | $5.8^{AB}$ | $15.9^{AB}$ | $2.5^{AB}$ | $45.7^{ABC}$ | 18.5 |
| *P. dulcis* | $5.2^{B}$ | $31.6^{C}$ | $23.8^{B}$ | $6.1^{AB}$ | $16.5^{A}$ | $2.6^{A}$ | $46.9^{A}$ | 18.0 |
| *P. flexuosa* | $6.7^{AB}$ | $35.1^{AB}$ | $27.0^{A}$ | $4.8^{B}$ | $15.6^{AB}$ | $2.5^{AB}$ | $45.3^{BC}$ | 18.4 |
| *P. mannii* | $6.2^{AB}$ | $35.5^{AB}$ | $26.9^{A}$ | $5.7^{AB}$ | $14.1^{B}$ | $2.3^{B}$ | $45.9^{ABC}$ | 21.0 |
| *P. nuda* | $6.3^{AB}$ | $34.4^{AB}$ | $26.1^{AB}$ | $5.4^{AB}$ | $14.8^{AB}$ | $2.4^{AB}$ | $45.1^{C}$ | 19.5 |
| *P. rubromarginata* | $7.3^{AB}$ | $36.7^{A}$ | $26.7^{A}$ | $6.1^{AB}$ | $15.1^{AB}$ | $2.4^{AB}$ | $45.4^{BC}$ | 19.2 |
| *Semiarundinaria fastuosa* | $5.7^{AB}$ | $34.1^{B}$ | $26.3^{AB}$ | $5.8^{AB}$ | $16.1^{AB}$ | $2.6^{AB}$ | $46.4^{AB}$ | 18.6 |
| | | | | | | | | |
| Average of all species | 6.4 | 34.5 | 25.8 | 5.7 | 15.3 | 2.5 | 45.8 | 19.1 |

**Fig. 2.** Tall rapidly growing shoots characterize the springtime growth pattern of this *P. flexuosa* now beginning its fourth season at Alderson WV. Like others, this cold hardy bamboo responds well to fertilization and prefers full sun, but lateral growth appears to be well-controlled by periodic mowing. Other species of hardy bamboo exist that prefer partial shade and could be evaluated as part of silvopastoral pasture management.

Photo: D. Ruckle

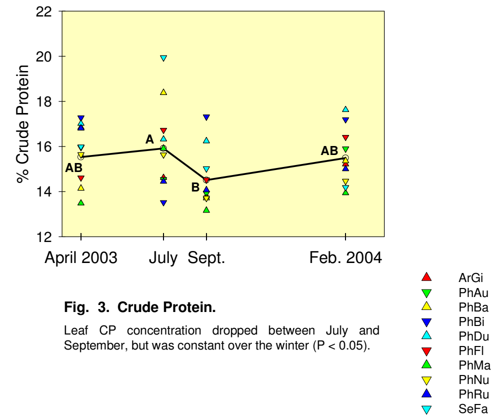


**Fig. 3. Crude Protein.**

Leaf CP concentration dropped between July and September, but was constant over the winter (P < 0.05).

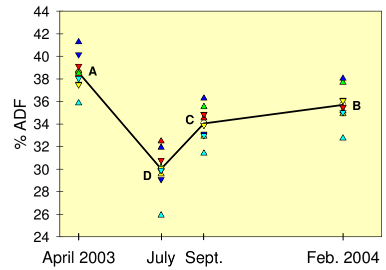


**Fig. 4. Acid Detergent Fiber.**

Concentration of ADF increased with leaf age (P≤ 0.001). July, September, February, and April harvest dates equate to leaf ages of about 2, 4, 9, and 11 months.

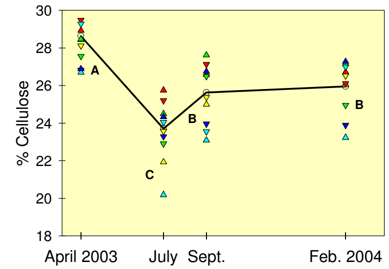


**Fig. 5. Cellulose.**

Cellulose was lowest in new leaves of July and highest in the oldest leaves in April (P < 0.05).

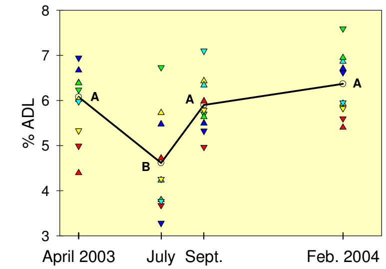


**Fig. 6. Acid Detergent Lignin.**

Concentration of lignin increased from July to September, but did not change over winter (P < 0.05).

## Summary:

Small farm systems in hill-land Appalachia need management options that diversify income opportunities; can be integrated into traditional and new livestock management strategies; and help maintain environmental integrity. Plantings of temperate bamboo, including species native to West Virginia were established to determine their ability to withstand hill-land Appalachian conditions and provide forage for goats. Most species under evaluation can withstand Appalachian winter temperatures and retain some green leaves even in late-winter. Nutritive value of bamboo species appeared generally similar to each other and showed similar trends over the season. Fibrous cell wall component concentrations were lowest in young leaves collected in July, and increased as leaves aged to reach highest concentrations in over-wintered leaves. Leaf crude protein decreased from July to September, but was relatively constant through the winter. Concentrations of fiber and protein were comparable to those reported for other browse plants and were sufficient to meet maintenance needs of goats. The ability of bamboo to remain green and maintain quality throughout the winter suggests it may have potential as a winter feed in central Appalachia. Bamboo could prove to be a valuable, multiple-use crop, suitable for Appalachian farm operations and easily adaptable to goat production systems.

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