Variety trial and pyrolysis potential on kenaf grown in Iowa

Marie Bourguignon [1], Ken J. Moore[1], Robert Brown[2], Roger Hintz[1], Brian Baldwin[3], Kwang H. Kim[2].

[1] Dept of Agronomy, Iowa State University
[2] Bioeconomy Institute, Iowa State University
[3] Plant & Soil Sciences, Mississippi State University

Objectives:

1) How do kenaf varieties perform in Iowa for yield?
2) How does fiber morphology and quality differ among varieties and among core and bast fiber?
3) What potential does kenaf (bast or core) have for producing fuel using fast pyrolysis?

1 BACKGROUND

- **Kenaf** (*Hibiscus cannabinus* L.) is an annual, dicot herbaceous crop, originally grown in Africa. It is a fiber-crop used for bio-products such as rope, paper pulp, textile, or biocomposite.
- Kenaf could be a source of lignocellulosic biomass for energy production due to its unusual stem anatomy (Fig. 1).

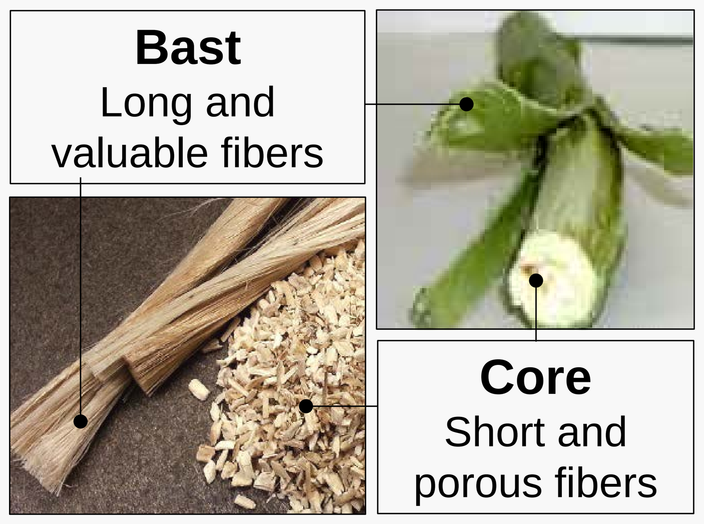

Figure 1: Anatomy of kenaf fibers.

- Kenaf can yield 10 to 20 Mg ha^{-1} in 5 to 7 months with low input.
- India and China are the leaders in kenaf production. In the U.S., kenaf is mostly grown in Southern U.S.
- **Midwest studies on growth and use of kenaf have been scant; however, kenaf may have potential as an alternative crop for Iowa and the Midwest.**

2 METHODS

Seven kenaf varieties were grown at the Iowa State University Agronomy and Agricultural Engineering Research Farm in Boone County, IA between 2004 and 2007.

Table 1: Experimental design, measurements, and statistical analysis.

Experimental design	RCDB, 4 replications
Row spacing	38 cm
Seeding density	247,105 seed.ha^{-1}
N	168 kg.ha^{-1}
Biomass (2004 – 2007)	Wet/dry weight
Morphology (2004 – 2005)	Leaf:stem ratio, stem height, diameter, core:bast ratio
Fiber and ash (2004 – 2005)	ANKOM procedure for NDF, ADF, ADL and insoluble ash
Ash composition (2004 – 2005)	ICP-OES
Micro fast pyrolysis (2004 – 2005)	Pyrolyzer (30 sec at 500 °C), gas chromatography and flame ionization detector.
Statistical analysis	ANOVA, 5% level of significance

3 RESULTS

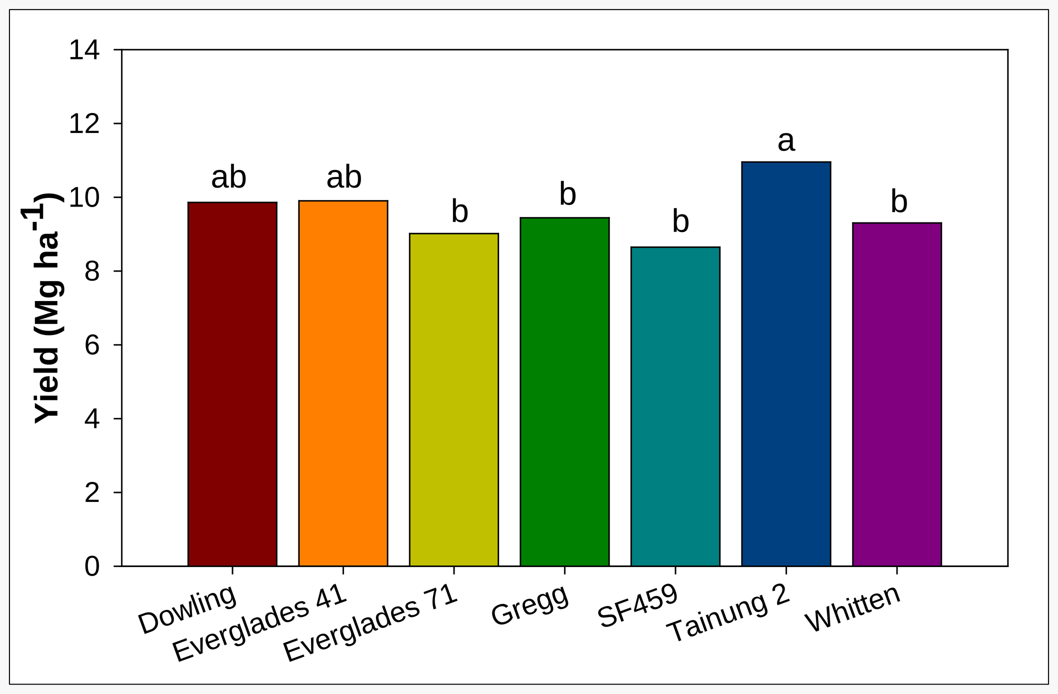

Figure 2: Average yield per kenaf variety over 2004 – 2007 (letters denote differences between varieties).

Objective 1: Field performance in Iowa

The crop yield and population were higher in 2005 with 11 Mg ha^{-1} and 163,000 plants ha^{-1}, respectively.

Yield (Fig. 2) and population varied among varieties but in different ways.

In general, kenaf yields were slightly lower than what has been shown in the literature. Also, final population was approximately half of the initial seeding density.

Objective 2: Fiber quantity and quality

Plants grown and processed in 2004 had 10% more leaves, were 16% thicker but had 9% less core than in 2005.

Stem height, core:bast ratio (Fig. 3) and fiber composition (Fig. 4) presented diversity among varieties, providing choice for intended fiber purposes.

On average, the bast contained 9% more cellulose, 23% less hemicellulose, 41% less lignin and 18% less insoluble ash but 63% more total ash than the core. Bast had higher concentration of Ca, Fe, Mg and S in its ash than in the core. Ca, K, Mg and S concentrations, however, depended on the variety (Fig. 5).

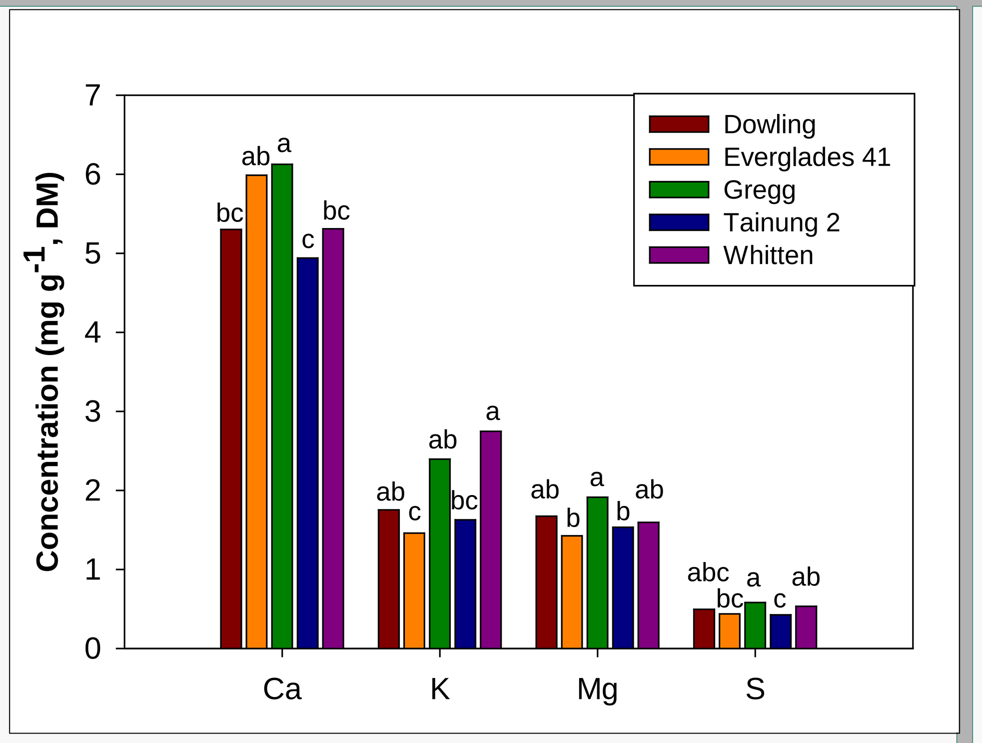

Figure 5: Ca, K, Mg and S (DM %) that were significantly influenced by the variety (letters denote differences between varieties for each element).

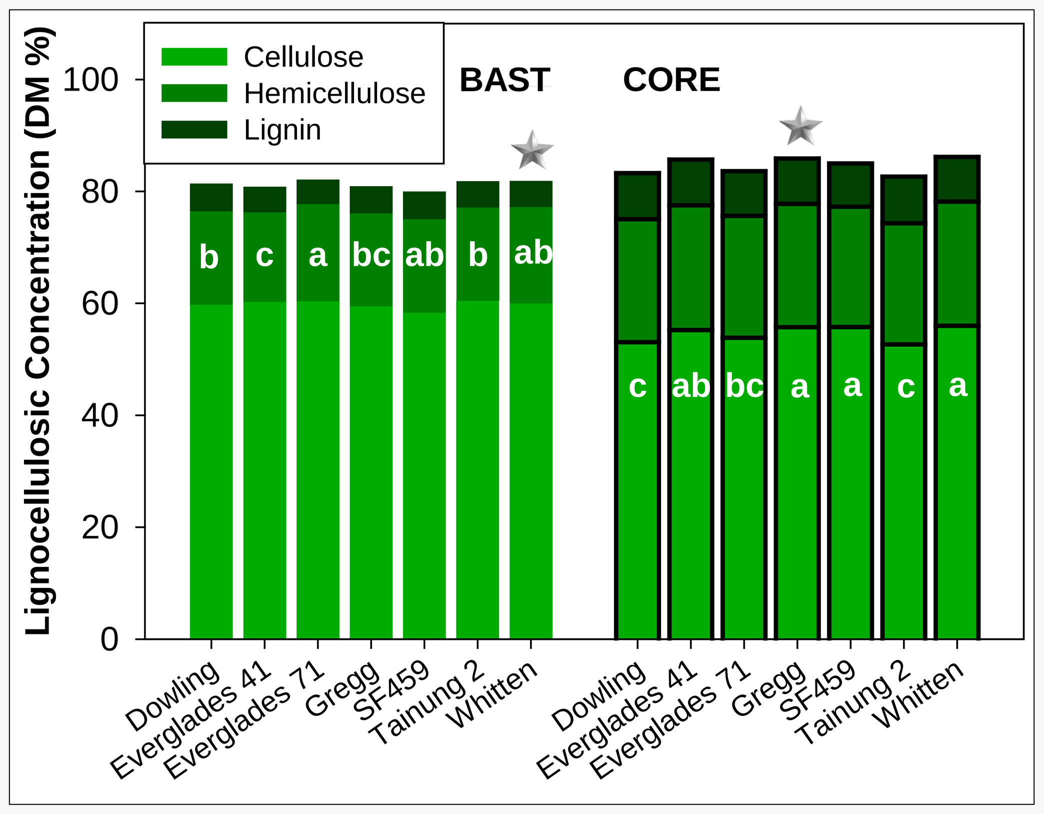

Figure 4: Cellulose, hemicellulose and lignin concentration in bast and core of each variety, over 2004 and 2005 (letters denote differences between varieties). Stars indicate the dominance of the variety for total ash.

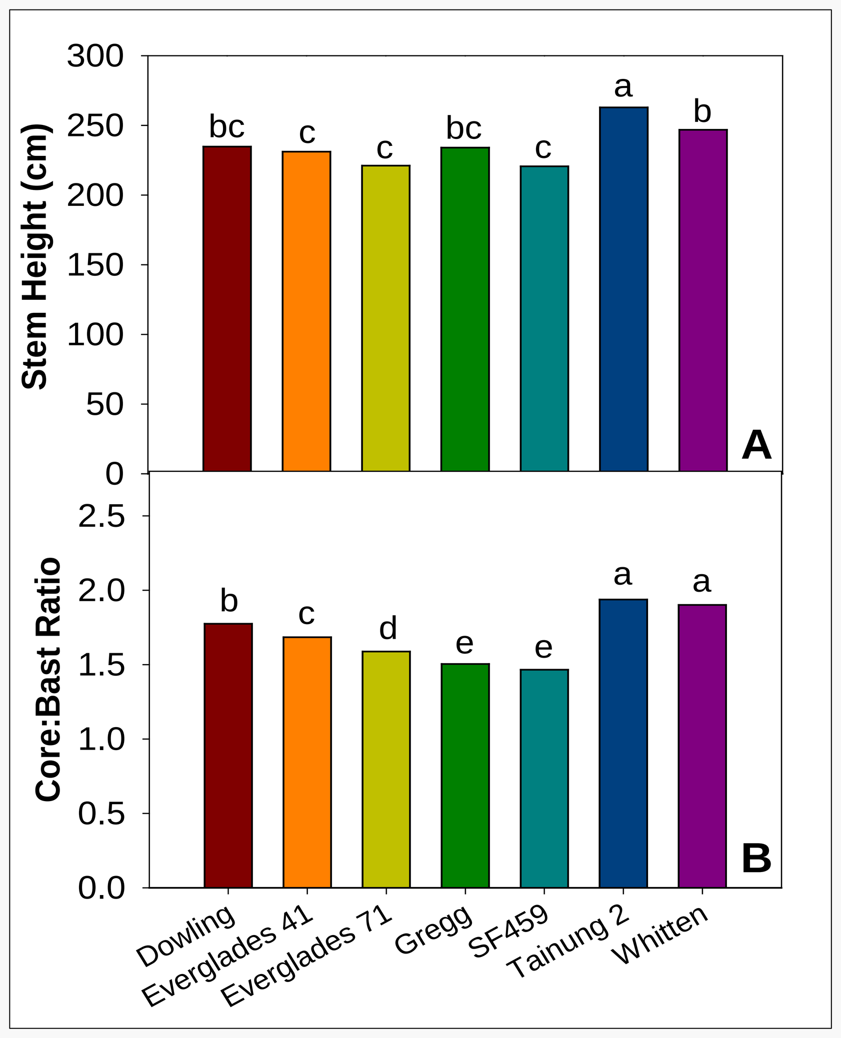

Figure 3: Average stem height (A) and average core:bast ratio (B) per kenaf variety over 2004 – 2007 (letters denote differences).

Objective 3: Fast pyrolysis potential

Kenaf could be also used for chemical production. The chemical analysis showed that there were some "pollutants" due to ash content (Table 1).

There was a tradeoff between levoglucosan and hydroxyacetone.

Table 1: List of hemicellulose (gray), cellulose (white) and lignin (light gray) pyrolysis products, influenced by year (Y), fiber category (F) and/or variety (V), and their yield.

Pyrolysis product	Effect	Yield (wt %)
acetic acid	Y*F	1.95
furfural	Y*F*V	0.13
hydroxy acetone	Y*F, F*V	0.86
methyl cyclopentelonone	F, Y*V	0.03
5-HMF	Y*F*V	0.33
levoglucosan	Y*F*V	1.25
4-ethylphenol	Y*F*V	0.01
4-vinylphenol	Y*F*V	0.18
2-methoxy-4-vinylphenol	Y*F*V	0.32
2,6-dimethoxyphenol	Y*F*V	0.07
vanillin	Y*F	0.02
4-hydroxy-3-methoxyacetophenone	F	0.02
2,6-dimethoxy-4-(1-propenyl) phenol	Y*F	0.02

4 CONCLUSION

Overall:

- Tainung 2 was the most productive variety in Central Iowa from 2004 to 2007.
- There were variations among varieties regarding the lignocellulosic composition, providing choice for intended fiber purposes.
- Depending on the variety and/or the fiber category, the pyrolysis compounds could be produced in different quantity.
- In general, bast and core could be used for fuel or chemical production but further work is needed.

Acknowledgements

I would like to thank my major professor, my committee members, the Department, the lab and the field research assistants.