Hesperaloe Has Properties That Interest Papermakers

The University of Arizona has been working with several companies in the pulp and paper industry to develop Hesperaloe *as a new source of fibers for papermaking.* Hesperaloe *fibers are unusually long and thin, similar to those of abaca and sisal. Such nonwood fibers have important uses in high-value specialty papers. While abaca and sisal fibers are imported,* Hesperaloe *could be produced in the southwestern United States.*

Most papermakers in the United States, Canada, and Europe use trees as their source of fibers. In the pulping process, the wood is broken down, either chemically or mechanically, into individual fiber cells that are then suspended in an aqueous slurry and reformed into sheets on high-speed papermaking machines. Evergreen conifers (softwoods), such as pine, spruce, and Douglas fir, produce comparatively long fiber cells that form strong paper. Broad-leaved trees (hardwoods), like poplar and aspen, have shorter, broader cells that produce a smoother paper with less strength. Many papers, such as newsprint, are a mixture of softwood and hardwood pulps. Because the stronger softwood pulps command a higher price than hardwood pulps, papermakers blend these pulps to optimize paper quality while minimizing their use of higher cost fibers.

Nonwood fibers, such as cereal straws, bamboo, and sugarcane bagasse, are also used in the pulp and paper industry. In 1993, world nonwood pulping capacity was 21 million metric tons, 10.6 percent of world paper pulping capacity (*1*). Nonwood fibers are an important source of papermaking materials in developing countries that have limited forest resources. China and India account for about 80 percent of the world's nonwood pulping capacity.

There have been efforts in the United States over the past 30 years to develop kenaf, an annual fiber crop, as a nonwood fiber for papermaking, and more recent work in Europe has emphasized fiber hemp. Given that almost any plant is suitable for making some type of paper, a new crop developed specifically for papermaking must have significant advantages in both quality and price to justify the commercialization effort.

Hesperaloe *a Possibility*

The University of Arizona has been working with several companies in the pulp and paper industry to develop two species of *Hesperaloe (H. funifera* and *H. nocturna*, desert plants native to northern Mexico) as a new source of fibers for papermaking. This 10-year project is about to move from the exploratory research and development stage toward full-scale commercialization. [1]

[1] Some of the research was funded by USDA's Alternative Agricultural Research and Commercialization Corporation under Agreement 93AARC20030 and USDA's Cooperative State Research, Extension, and Education Service under Cooperative Agreement 94-COOP-1-0036.

The greatest market opportunity for *Hesperaloe* fibers may be as a blend for strengthening various grades of paper (*2*), such as recycled paper. Fiber cells lose considerable strength in the deinking and repulping processes. Some amount of virgin fiber, usually softwood, must be added to recycled fibers to provide strength. Using a nonwood fiber, such as *Hesperaloe*, in recycled papers could be an attractive feature to consumers.

The fiber cells of these *Hesperaloe* species are unusually long and thin (table 8). They range between 3 and 4 millimeters in length, comparable to the softwood fibers. However, they are much narrower, only 14 to 17 microns in width. The ratio of length to width, called the aspect ratio, is a good indicator of paper strength. This ratio for *Hesperaloe* is very high, about 240. In other words, *Hesperaloe* fibers combine the length of softwoods with the narrowness of straw fibers, an unusual property found only in abaca, sisal, and a few other specialty fibers.

Pulps with special properties, such as a high aspect ratio, command a relatively high price. Some specialty nonwood pulps cost two to four times that of softwood pulps (table 9). Abaca and sisal pulps, in particular, may cost $2,500 to $3,000 per metric ton. Both abaca and sisal are tropical crops that are harvested by hand and processed in small batch facilities, which account for the high cost of their fibers. Sisal production and processing, however, may change in the future if production is geared toward paper applications instead of twine and cordage.

Because of their high cost, use of abaca and sisal pulps is restricted to certain small specialty markets, such as tea

Table 8--Dimensions of papermaking fibers

Fiber	Mean length	Mean width	Length to width ratio
	Millimeters	Microns	
Abaca	6.00	20	300:1
Hesperaloe funifera	3.60	15	240:1
Sisal	3.03	17	180:1
Cotton linters	3.50	21	165:1
Kenaf bast fiber	2.74	20	135:1
Wheat straw	1.48	13	110:1
Softwoods	3.00	30	100:1
Jute	2.00	20	100:1
Hardwoods	1.25	25	50:1

Source for fibers other than Hesperaloe: Alfred M. Hurter, "Utilization of Annual Plants and Agricultural Residues for the Production of Pulp and Paper," Nonwood Plant Fiber Pulping Progress Report 19, TAPPI Press, Atlanta, Georgia, 1991.

Table 9--Prices for different pulps, 1991

Pulp type	Price
	Dol./metric ton
Well-cleaned, bleached nonwood fiber pulps 1/	$1,800-2,400
Not so well-cleaned, unbleached nonwood fiber pulps 1/	$1,200-1,800
Special softwood pulps	$750-850
Normal softwood pulps	$550-750
Normal hardwood pulps	$450-550

1/ Abaca, sisal, flax, and hemp.

Source: Manfred Judt, "Non-Wood Plant Fibres, Will There Be a Come-Back in Paper-Making?," Industrial Crops and Products, Vol. 2 No 1, 1993, pp. 51-57.

bags, certain filters, and sausage skins (*2*), with stringent requirements for high strength and fine texture (*1*). According to Census Bureau data, imports of raw or processed abaca fiber averaged 990 metric tons per year during 1989-94, while imports of raw or processed sisal fiber averaged 500 kilograms during the same period. Some imports of abaca and sisal cordage may also be used by the pulp and paper industry. Imports of abaca and sisal twine and cordage averaged 6,700 and 78,800 metric tons, respectively, during 1989-94.

The James River Corporation has investigated using *Hesperaloe* fibers in several types of paper. Its patent on the use of *Hesperaloe* in tissue and towel papers (*3*) provides some information on the performance of these fibers. With these types of sanitary papers, it is difficult to simultaneously improve both softness and strength. However, using *Hesperaloe* fibers in the blend enhances both strength and softness, while increasing bulk and absorbency. An unpublished study, conducted by the Herty Foundation of Savannah, Georgia, for the University of Arizona, compared papers made from *Hesperaloe* (unbleached hand sheets) with papers made from softwood kraft, abaca, and sisal. According to this study, the *Hesperaloe* papers had superior breaking length and burst index over a range of refining intensities. Thus, papers made from *Hesperaloe* fibers are as good as those made from high-cost, specialty pulps.

Hesperaloe *Production Is Under Investigation*

The compact growth habits of *Hesperaloe funifera* and *H. nocturna* suggest that they could be grown at a high stand density. These perennial plants are very water-efficient, and their leaves are spineless and thornless, which facilitates handling. All these traits suggest that *Hesperaloe* species might do well under irrigated production in the arid southwestern United States.

Test plantings of *Hesperaloe funifera* have been growing at Tucson, Arizona, for more than 8 years. Initial growth of transplanted stands was very slow, but high biomass yields were obtained after 5 years (table 10). Stands harvested at 5 years regrew to produce a second harvest after another 3 years. A third harvest may be possible after another 2 years, since each plant now consists of a larger base from which more regrowth can occur. It is unknown how many harvests could be made from a single stand before plants expand to fill the rows and interfere with machine operations. Larger plantings have been established recently at the Maricopa Agricultural Center at Maricopa, Arizona.

Table 10--Biomass production by Hesperaloe funifera

Stand density	First harvest (year 5)	Second harvest (year 8)
Plants/acre	Fresh weight metric tons/acre	
2,750	43.4	41.5
5,500	68.2	71.3
11,000	97.8	99.7

Because seeds of these species are extremely scarce, and because planted seeds are slow to germinate and emerge, commercial production of *Hesperaloe* will have to use transplants for stand establishment. Weed control will also be costly in the beginning, since *Hesperaloe* is not competitive during its first few years when growth rates are low.

Hesperaloe has a low-irrigation requirement because it possesses the crassulacean acid metabolism (CAM) pathway for photosynthesis. CAM plants take up carbon dioxide and transpire water at night rather than during the day, as is the case with most plants. Since the rate of transpiration is much lower during the night than during the day, CAM plants have a very high water-use efficiency. Grown throughout the year, *Hesperaloe* only requires about 24 inches of water annually. In comparison, wheat, which is grown in the winter in Arizona, requires about 36 inches of irrigation water and cotton, a summer crop, requires about 48 inches.

The projected crop cycle for *Hesperaloe* consists of stand establishment with transplants during year 1, first harvest at year 5, second harvest at year 8, and third harvest at year 10 or 11. Fresh-weight leaf yields from the three harvests obtained over the 10 or 11 years are projected to total about 250 metric tons per acre (based on a planting density of 8,700 plants per acre). For commercial production, flower stalks would be removed at an early stage of growth. The effects of this on subsequent leaf growth has yet to be investigated. Because dry fibrous raw material represents approximately 30 percent of the leaf fresh weight and pulp yield is 40 percent of the raw material, 1 acre of *Hesperaloe funifera* could probably produce sufficient biomass to yield 30 metric tons of pulp. This is equivalent to a 10- to 12-percent pulp yield based on the original fresh weight. Like abaca and sisal fibers, *Hesperaloe* fibers can be pulped by the kraft, soda, or sulfite processes (*2*, *3*).

In addition to its possible use in specialty papers, *Hesperaloe* could also potentially replace some softwood uses. For instance, in some applications, half as much sisal pulp can be used when substituted for softwood pulp (*2*), but market prices for sisal and softwood pulps do not favor such substitution. However, *Hesperaloe* pulp is superior to that of sisal and probably can be produced for less than twice the average price of softwood pulp. (Softwood pulp prices vary greatly in 3- to 5-year cycles.) This potential for substituting *Hesperaloe* pulp for softwood pulp would greatly expand its market opportunities beyond that of the premium specialty papers. Additional markets would be necessary to justify the development of a new fiber crop, given the small size of the specialty papers market.

Research on *Hesperaloe* will continue. Acreage at the Maricopa Agricultural Center is being expanded, primarily to increase seed production. The private sector is conducting pilot-scale pulping and papermaking trials. [Steven McLaughlin, University of Arizona, Office of Arid Lands Studies, (602) 621-8577, spmcl@ag.arizona.edu]

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2. Hurter, Alfred. M. "Utilization of Annual Plants and Agricultural Residues for the Production of Pulp and Paper." *Nonwood Plant Fiber Pulping Progress Report 19*, TAPPI Press, Atlanta, GA, 1991.

3. Reeves, R.H., J.D. Plantikow, L.J. Smith, T.P. Oriaran, A.O. Awofeso, and G.L. Worry. "Soft High Strength Tissue Using Long-Low Coarseness *Hesperaloe* Fibers." U.S. Patent No. 5320710, 1994.