

Papermaking potential of congress grass: pulpability and fiber characteristics

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ABSTRACT: *Parthenium hysterophorus* L., a weed commonly known as congress grass, is presently known only for its adverse and negative characteristics. This paper evaluates the possible use of congress grass as a papermaking raw material.

The raw material was tested for its proximate chemical analysis and pulpability by the soda and soda anthraquinone process. The results revealed the suitability of congress grass for chemical pulping. The ash content was found to be slightly on the high side. The pulp yield ranged from 40% to 45% and the kappa number varied between 24 to 34. Unbleached brightness was low, ranging from 21 to 25.5. The α -cellulose content of the pulps varied between 77% to 88.5%.

Examination of the pulp under light and electron microscopes showed a variety of cell types indicating similarities with hardwood and nonwood species. The fibers are thin and slender with pointed ends. The weighted average fiber length by weight was determined as 1.01 mm. Zero-span breaking length of 5.4 km was moderate. Physical and strength properties of test handsheets were similar to hardwoods and nonwoods.

Application: This study provides initial indications that congress grass, a weed that has spread through much of India, may be useful as a fiber source for papermaking.

Faced with the challenge of meeting the ever-increasing demand for quality paper and paperboard products, the industry worldwide is in search of new and hitherto unexploited sources of cellulosic fibers. Traditionally, forest based woody raw materials have been the principal source of paper making fibers, and the paper industry is considered to be the highest consumer of forest based cellulosic materials (1). However, this situation is fast changing, thanks to a growing concern for the environment in general and the alarming rates of deforestation in particular. In India, the share of forest-based raw materials in the total production of paper has declined from a peak of 84% in 1970 to 42% in the mid-1990s (2). The acute shortage and high cost of wood based raw materials is considered to be the most important factor restricting the growth of the Indian paper industry and its development into a globally competitive industry (3). The conditions are similar in many other regions of the world.

The search for new fiber crops as alternatives has been underway for a long time (4). Many fast growing annual and perennial plants have been identified, cultivated and studied for their suitability for pulp and paper manufacture (5). Pulping of depithed kans grass (*Saccharum spontaneum*) has been reported (6). Mixed pulping of bamboo with *Neyrandia reynaudiana* (khagra reed) (7) and



1. Photograph of a mature congress grass plant

Sesbania aculeate and *Tephrosia candida* (8) has been studied. Another study reported the use of spent citronella grass (*Cymbopogon winterianus* jouritt) for paperboard manufacture (9). Among other non-conventional raw materials, switch grass (*Panicum virgatum*) (10), giant reed (*Arundo donax*) (11), olive

wood trimmings (12), and oil palm empty fruit bunches (13) have been studied and evaluated for their paper-making potential.

Parthenium hysterophorus L., a weed commonly known as congress grass (Figure 1), belongs to the dicot family of flowering plants-composite (*Asteraceae*) which include ornamentals like dahlia and chrysanthemum and oilseed crop plants like sunflower and safflower. This weed, growing to a height of 1-1.5 m in its mature state, is an aggressive and highly colonizing species that seems to thrive under all kinds of habitats and survive through all seasons. The weed populations can easily be found growing along the roadsides, railway tracks, riverbanks, waste places, construction sites, and peripheries of agricultural fields and parks. Since its arrival from the United States of America with wheat imports in the 1950s (14), it has spread throughout most of the Indian subcontinent and has become the principal terrestrial weed in India (15). Today it is best known as an obstinate usurper of every piece of marginal land (16, 17, 18, 19). Its disease causing potential and possible remedies have been studied and reported (20, 21, 22). Research efforts notwithstanding, effective management and eradication of congress grass seems to be eluding the scientific community and administrators (23, 24, 25).

		SPECIES									
		CONGRESS GRASS	EUCALYPTUS TERETICORNIS	POPULUS DELTOIDES	WHITE BIRCH	RED MAPLE	WHEAT STRAW	BAGASSE	BAMBOO	ESPARTO GRASS	SWITCH GRASS
PARAMETERS	Hot water solubility (%)	1.75	—	—	—	—	7.5-12.5 ⁽²⁸⁾	3-10 ⁽³¹⁾	5-6.5 ⁽³¹⁾	—	—
	1% NaOH solubility (%)	36.43	—	—	—	—	—	—	24-25 ⁽³¹⁾	—	—
	Alcohol-benzene solubility (%)	4.07	2.8 ⁽²⁶⁾	2.01 ⁽²⁶⁾	—	—	0.5 ⁽¹⁰⁾ ; 2.1 ⁽²⁹⁾	2-10 ⁽³¹⁾	3-3.5 ⁽³¹⁾	—	1.6 ⁽¹⁰⁾
	Lignin (%)	18.80	25.52 ⁽²⁶⁾	24 ⁽²⁶⁾ ; 21.6 ⁽¹⁰⁾	18.9 ⁽²⁷⁾	24 ⁽²⁷⁾	24 ⁽¹⁰⁾ ; 16-21 ⁽³⁰⁾	18-21 ⁽³⁰⁾	21-31 ⁽³⁰⁾	17-19 ⁽³⁰⁾	21.8 ⁽¹⁰⁾
	Holocellulose (%)	68.78	70.1 ⁽²⁶⁾	75.12 ⁽²⁶⁾ ; 78.4 ⁽¹⁰⁾	—	—	73-74 ⁽²⁸⁾	—	67-72 ⁽³¹⁾	—	79.3 ⁽¹⁰⁾
	α-Cellulose (%)	41.84	—	39.7 ⁽¹⁰⁾	44.5 ⁽²⁷⁾	44.8 ⁽²⁷⁾	29-35 ⁽³⁰⁾	30-35 ⁽³⁰⁾	26-43 ⁽³⁰⁾	33-38 ⁽³⁰⁾	43.4 ⁽¹⁰⁾
	β-Cellulose(%)	11.05	—	—	—	—	—	—	—	—	—
	γ-Cellulose (%)	15.89	—	—	—	—	—	—	—	—	—
	Ash (%)	5.78	—	1.1 ⁽¹⁰⁾	0.2 ⁽²⁷⁾	0.2 ⁽²⁷⁾	11.1 ⁽¹⁰⁾ ; 4.5-9.0 ⁽³⁰⁾	2-5 ⁽³⁰⁾	1.7-4.8 ⁽³⁰⁾	6-8 ⁽³⁰⁾	1.5 ⁽¹⁰⁾

I. Proximate analysis of congress grass and some known papermaking raw materials

Can this seemingly useless material be put to some useful end? This paper attempts to highlight the possible use of congress grass as a papermaking raw material. The study includes pulping trials and examination of the fundamental fiber characteristics.

MATERIALS AND METHODS

For this study, we collected congress grass manually from within the institute itself. The collected grass was allowed to air dry and the leaves and flowers were removed by stroking on a hard surface. The roots were then cut and removed using a sharp knife. We chopped the remaining part of the plant into 10-20 mm long pieces in a fodder cutter.

For proximate chemical analysis, the congress grass pieces were washed thoroughly with water and allowed to air dry. These were then ground into fine powder and screened. We used a 40/60 fraction of this powder for analyses in accordance with relevant TAPPI test methods. Those included T 203 om-93 for α, β, and γ cellulose, T 244 om-93 for ash content, T 222 om-88 for acid insoluble lignin, T 207 om-81 for hot water solubility, T 212 om-76 for 1% NaOH solubility, and T 204 om-76 for alcohol benzene solubility.

Soda (sodium hydroxide, NaOH) and soda anthraquinone (AQ) pulps were prepared in the laboratory at different pulping conditions in 2 l reaction bombs immersed in a 20 l externally heated laboratory digester filled with water as the heating medium. At the end of each pulping, the digester was relieved to atmospheric pressure, the bombs removed, opened and the contents washed on a 400-mesh screen with sufficient amounts

of water. The pulps were then screened through a 24-mesh screen to remove uncooked materials, if any. Pulps were analyzed for their kappa number (TAPPI test method T 236 cm-85) and α, β, and γ cellulose. For the purpose of α, β, and γ cellulose determination of the pulps, as well as of the raw material earlier described, we first delignified the samples using a 1% solution of sodium chlorite with a few drops of glacial acetic acid at 70°C in a water bath. The delignified samples were then tested for their α, β, and γ cellulose content. Samples were further examined under optical and scanning electron microscopes. Fiber length and fiber coarseness were determined according to TAPPI test methods T 232 cm-85 for fiber length of pulp by projection and T 234 cm-84 for coarseness of pulp fibers.

For the preparation of laboratory handsheets, pulp was disintegrated in a standard pulp disintegrator at 3000 rpm for 25 min. (unbeaten strength point according to TAPPI T 200 sp-96). Handsheets were then prepared in accordance with TAPPI method T 205 sp-95 for the determination of various physical and strength properties (T 220 sp-96 for physical testing of pulp handsheets).

RESULTS AND DISCUSSION

Proximate analysis

The proximate analysis of congress grass, along with some common as well as non-conventional raw materials, is shown in Table I. It has a marginally lower holocellulose content than the common hardwoods and nonwood raw materials. But the α-cellulose content is comparable to the hardwoods and is higher than those

of most of the nonwood species. A low lignin content is always desirable for chemical pulping. It is evident from Table I that the lignin content of congress grass is distinctly lower than common hardwoods except white birch. Among nonwoods, wheat straw, bagasse and esparto grass have lignin contents similar to congress grass while bamboo and switch grass have a higher lignin content. Congress grass has a slightly higher amount of extractives as reflected in its 4.07% alcohol-benzene solubility. At 5.78% the ash content of congress grass is higher than the hardwoods, but it is comparable to most of the nonwood species except wheat straw, which has a much higher ash content.

Soda and soda anthraquinone pulping of congress grass

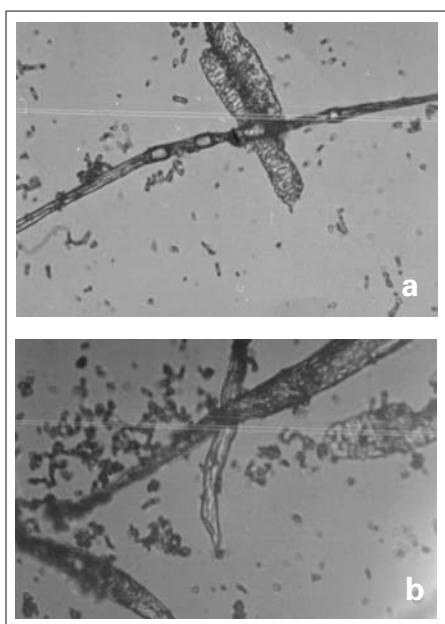
Congress grass can be converted into acceptable quality pulp by both soda and soda anthraquinone process. Table II shows the results of the pulping experiments conducted. All the pulps were produced with a bath ratio of 6:1. Initial trials were made with NaOH charges of 9.5% and 12% but the pulps produced were not satisfactory with very high amounts of rejects and incomplete defibration. An acceptable pulp was produced at 14.3 % NaOH charge with 42.23% screened yield, 0.08% rejects and 33.56 kappa number. Screened yield as well as rejects reduced to 38.43% and 0.03% respectively when the alkali charge was increased to 16.7% with kappa number dropping to 31.9.

At each alkali charge of 14.3% and 16.7% respectively, addition of anthraquinone improved both the screened yield and residual lignin con-

NONWOOD FIBER

CHEMICALS CHARGED												
(% OF O.D. WT OF RM)			TEMP	MAX. TEMP.	TIME TO	TIME AT	REJECTS	KAPPA	α , β , & γ			BRIGHT-NESS
S.N.	NaOH as	AQ							TEMP.	YIELD	CELLULOSE (%)	
	Na ₂ O		(°C)	(MIN.)	(MIN.)	(%)	(%)	NO.	α	β	γ	(ISO)
1.	14.3	0.00	175	90	120	42.23	0.08	33.56	83.52	10.50	1.62	22.25
2.	14.3	0.06	175	90	120	43.16	0.05	32.95	85.20	9.56	0.96	23.11
3.	14.3	0.09	175	90	120	45.70	0.05	28.73	88.54	6.83	0.90	23.55
4.	16.7	0.00	175	90	120	38.43	0.03	31.90	80.89	13.20	1.77	22.52
5.	16.7	0.06	175	90	120	40.64	0.03	27.88	81.27	13.43	1.19	23.48
6.	16.7	0.09	175	90	120	43.43	0.00	25.86	83.46	10.96	2.22	23.60
7.	16.7	0.09	175	90	135	39.05	0.00	24.46	77.28	13.73	5.81	24.65
8.	16.7	0.12	175	90	135	39.12	0.00	24.22	77.30	13.81	5.74	25.59
9.	18.4	0.09	170	90	120	43.30	0.00	28.16	81.46	12.60	2.27	25.14
10.	14.9	0.08	170	90	150	53.13	4.50	38.53	84.38	11.98	3.64	21.01

II. Pulping conditions, yield, and pulp properties of congress grass pulps



2. Photomicrographs of congress grass soda anthraquinone pulp

tent of the pulp. At 16.7% NaOH and 0.09% AQ charge the screened yield was 43.43% with no rejects and the kappa No. was 25.86.

Addition of anthraquinone also improved the total carbohydrate yield and the α -cellulose content of the pulps. Increasing alkali charge, however, had an adverse effect on the carbohydrate yield. A nominal improvement in the unbleached pulp brightness was also achieved by increasing the alkali charge from 14.3% to 16.7%. Similarly, at a constant alkali charge increasing the anthraquinone dose gave a marginal improvement in brightness.

When at an alkali charge and anthraquinone charge of 16.7% and 0.09% respectively, the time at maximum temperature was increased by 15 min., from 120 to 135 min. That resulted in a

sharp decrease in the pulp yield from 43.43% to 39.05% with only a small drop in kappa number from 25.86 to 24.46. The yield loss can be attributed mainly to an increased carbohydrate loss; α -cellulose content dropping from 83.46% to 77.28%. There was not much improvement even when the anthraquinone dose was increased to 0.12%, with the yield increasing only marginally to 39.12%, kappa number dropping to 24.22, and α -cellulose increasing by only 0.02% to 77.30%. There was, however, a small improvement in the unbleached pulp brightness.

Two experimental runs were made at a reduced maximum temperature of 170°C. At this temperature an alkali charge of 14.9% and anthraquinone charge of 0.08% could only produce a very coarse pulp with high rejects even when the pulping time was increased to 150 min. The kappa number was very high at 38.53. Increasing the alkali charge to 18.4% with anthraquinone charge at 0.09% and 120 min. reaction time at maximum temperature resulted in a yield of 43.30% with no rejects and a kappa number of 28.16. However, the unbleached pulp brightness was higher at 25.14.

It is imperative to note that the experimental results do not fully optimize the pulping parameters. The main aim of these experiments were to test and evaluate the pulpability of the new raw material.

Fiber characteristics of soda anthraquinone pulp

Figure 2 (a and b) shows photomicrographs of the congress grass soda anthraquinone pulp. A variety of characteristic cell types are visible in the micrographs. Figure 2 (a) shows the vessel elements. Figures 2 (a) and 2 (b) also illustrates a large number of epidermal and parenchyma cells characterized by their irregular shapes and small and varying

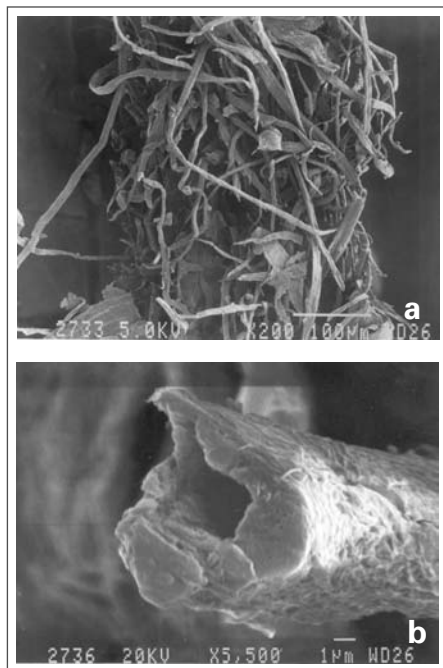
sizes. The fibers (only a few are visible in the micrographs) are thin with pointed ends. The single fiber visible in Figure 2 (a) shows the nodes and other irregularities along the length of the fiber.

Figures 3 (a) and 3 (b) are the scanning electron micrographs of the cross section of an air dried congress grass soda anthraquinone pulp handsheet and a magnified view of a single fiber from the same cross section respectively. Fibers have 8-12 μ diameter. It would be more appropriate to call this fiber width rather than diameter as the fibers are essentially flattened during pulping and sheet-making). They have a weighted average fiber length by weight of 1.01 mm and a decigrex of 6.06 mg/100 m. These fiber dimensions and those of some known raw materials are given in Table III for comparison. The fiber length of congress grass is comparable to most of the hardwood and nonwood species. However, the fiber diameter is smaller. Fiber coarseness of hardwoods has been reported to be 7-16 mg/100 m (34). Thus, the congress grass fibers are thin and slender. Table IV shows the physical and strength properties of the congress grass soda anthraquinone pulp handsheets. Pulp has a moderate intrinsic fiber strength depicted by the zero-span breaking length of 5.4 km. Other properties are typically similar to hardwood and nonwood pulps.

CONCLUSION

Proximate analysis of congress grass primarily suggested its suitability for paper-making; the revealing features being the lignin content comparable to most of the nonwoods but lower than the hardwoods with acceptable amounts of holocellulose and α -cellulose. The ash content was somewhat on the higher side.

The raw material was successfully converted into an acceptable quality



3. Scanning electron micrographs of cross section of congress grass soda anthraquinone pulp handsheet

pulp by both soda and soda anthraquinone process; the later giving both yield and kappa No. benefits. Pulps obtained were dark in color. Pulping parameters, especially the time temperature schedule, however, needs to be further optimized.

Congress grass fibers were found to be thin and slender. The average fiber length was comparable to most of the hardwood and nonwood species. It had a moderate intrinsic fiber strength. In addition to the fibers, the pulp contained a variety of other cell types, i.e., vessel elements, parenchyma and epidermal cells which revealed its similarity to hardwood and nonwood species. This similarity was further exemplified by the physical and strength properties of the test handsheets.

Fully establishing the papermaking potential of congress grass will require studies of the bleachability and beating response of the pulp. Efforts in this direction are currently in progress. **TJ**

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	FIBER LENGTH (mm)	FIBER DIAMETER (μ)
Congress grass	1.01	8-12
Eucalyptus	0.7-1.3*	20-30*
Gmelina	0.8-1.3*	25-35*
Temperate hardwoods	0.7-1.6*	20-40*
Tropical hardwoods	0.7-3.0*	20-40*
Bagasse (depithed)	1.0-1.5*	20*
Wheat straw	1.5*	15*

* Source: Ref. (30)

III. Fiber dimensions of congress grass and some known papermaking raw materials

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	$^{\circ}$ SR	22.00
	Bulk (cc/g)	1.91
Gurley Porosity (sec/100ml)		9.30
Tensile Index (N.m/g)		24.53
Bursting Index (kPa.m ² /g)		0.74
Tearing Index (mN.m ² /g)		1.96
Zero-span (km)		5.40

IV. Properties of unbeaten congress grass soda anthraquinone pulp handsheets

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