PULPING AND PAPERMAKING WITH ASIAN GRASSES--EKRA, KHAGRA, AND NAL

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PULPING AND PAPERMAKING WITH ASIAN GRASSES--EKRA, KHAGRA, AND NAL[1]

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Summary

Ekra (Erianthus ravennae), khagra (Saccharum spontaneum), and nal (Phragmites karka), grasses that grow abundantly in Pakistan, India, and other Asian countries, were pulped separately and in various mixtures with one another by the sulfate process.

Pulp yields of 44 to 47 percent were obtained from the individual grasses or mixtures of them. Digestion conditions of 170° C. for 1 hour in a liquor with 17.6 percent of active alkali were found to be most suitable for pulping a mixture of equal parts of the three grasses.

Physical tests on the individual grass pulps showed that ekra and khagra were about equal in strength properties, while in bursting strength, tearing resistance, and breaking length, nal averaged about 85 percent as high as ekra and khagra. The sulfate pulps obtained from cooking the mixture had strength properties somewhat higher than the average of the three grasses digested separately. The strength properties were in the lower range of values reported for American hardwoods.

A conventional three-stage bleach consisting of chlorination, alkaline extraction, and hypochlorite was given pulp from equal

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mixtures of ekra, khagra, and nal to brightness levels of 75 and 82 percent. Pulp strength after bleaching was 85 percent that of the original unbleached pulp, except for the tearing resistance, which was not lowered. The strengths of the bleached pulp was in the range of bleached American hardwood sulfate pulps.

Pulps made from the mixture of grasses were converted into wrapping, newsprint, book-coating base, offset, cover stock, and bond papers, using the grass pulps as partial and as complete substitutes for long-fiber woodpulps. To obtain wrapping paper with properties close to those of southern pine kraft wrapping paper, it was necessary to add 50 percent long-fibered woodpulp to the furnishes. A typical newsprint paper, made from 25 percent of bleached grass pulp and 75 percent of commercial groundwood pulp, had good tearing resistance, but it was low in bursting and tensile strengths. The addition of southern pine sulfate pulp for a portion of the grass pulp improved the strength properties. Although below the average for newsprint, the properties were still in the range obtained on commercial paper.

Cover-stock paper was made from a mixture containing 70 percent of bleached grass pulp and 30 percent of bleached southern pine sulfate pulp, and book-coating base stock of acceptable strength was made from a furnish containing 65 percent of bleached grass sulfate pulp and 35 percent of commercial groundwood pulp. Offset and bond papers with good formation were produced from 100 percent grass bleached sulfate pulps.

Introduction

Ekra (*Erianthus ravennae*), khagra (*Saccharum spontaneum*), and nal (*Phragmites karka*) are grasses of worldwide distribution. They grow abundantly in various regions of India, Pakistan, Burma, and other Asian countries. Ekra has a stout, erect, nearly solid stem attaining a height of about 16 to 18 feet and a 3/4-inch girth. The leaf sheath is longer than one internode and adheres to the stem even when mature. Khagra grows to a height of 10 to 12 feet and girth of 1 inch. The stem is solid, slender, and smooth. Nal attains a maximum height of 14 to 15 feet and has a hollow stem about 2 inches in circumference.

Among investigators of the problem of producing paper pulp from reeds and grasses, Raitt[3,4] covered a wide variety of Indian grasses in his studies, including the three species investigated in this project.

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[3]Raitt, W. Investigations of Savannah Grasses. Indian Forest Records, Vol. 5, Part III: 74-115. (1913).

[4]Raitt, W. The Digestion of Grasses and Bamboo for Papermaking. Crosby, Lockwood, and Son, London. (1931).

His work was limited to soda pulping and bleaching experiments. Raitt found that grasses contain large quantities of starch and pectic materials, and suggested that these easily soluble materials be removed with hot water or hot dilute caustic soda before proceeding with the actual digestion.

He reported that nodes required more drastic pulping conditions than did the internode sections, and conditions suitable for pulping nodes caused severe cellulose degradation in the internode sections. Crushing reduced the nodes to an easily pulped material. The lengths of the khagra and nal fibers averaged 2 millimeters, and their fiber diameters averaged 0.016 and 0.015 millimeter respectively. Raitt concluded that khagra and nal are first-class materials for papermaking, with nal slightly superior to khagra. Ekra was pronounced inferior to khagra and nal in quality, but would not be objectionable if less than 20 percent were used in any mixture.

Bhat and Virmani[5] investigated the suitability of nal for paper pulp. Sulfate and soda pulps were made and checked for papermaking properties. They reported a higher soda pulp yield than Raitt, 46 percent as compared to 39 percent, even though their cooking conditions were more drastic. The sulfate process gave lower yields of unbleached pulp than did the soda process, they found, but the yields of bleached sulfate were higher; sulfate pulps were stronger than soda pulps. They concluded that nal pulps must be mixed with longer fibered pulps in order to produce satisfactory writing and printing grade papers. Bhat reported[6] the average fiber length of nal chemical pulp as 1.2 millimeters and an average diameter of 0.012 millimeter.

It is noted that only nal has been studied extensively with regard to pulping, bleaching, and papermaking experiments. There is considerable difference in results and conclusions between Raitt and Bhat on the pulping and papermaking qualities of this grass. So far as is known, nal, ekra, and khagra grass have not been pulped in mixtures with one another.

Pulping experiments are reported here on the individual grasses and various mixtures of the three, followed by bleaching and papermaking experiments.

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[5] Bhat, R. V., and Virmani, K. C. Indigenous Cellulosic Raw Materials for the Production of Pulp, Paper, and Board. Part VII, Writing and Printing Papers from Phragmites Karka. Indian Forest Bulletin No. 157. Reprinted from the Indian Forester 78 (3): 127-137 (1952).

[6] Bhat, R. V. Pulping Tropical Woods and Other Indigenous Cellulosic Raw Materials. Tappi 35 (4): 183-190 (1952).

Raw Material

The three grasses were obtained from the Sylhet district of East Pakistan. They had matured during the month of October, but harvesting could not be started until the rainy season was over and the ground dried out. Therefore, harvesting started in early January and was completed in early February. After harvesting, the grasses were air dried and then hand-cut into 3/4-inch lengths. The dried and cut grasses were packed in double-thickness jute bags lined with waxed paper. During the drying, cutting and packaging operations, precautions were taken to prevent the grasses from getting wet, and from the information available, the grass did not get wet in transit. The material received was free from any apparent fungus attack.

Chemical Composition of Grasses

The chemical composition of ekra, khagra, and nal is given in table 1. Except for solubility in alcohol-benzene and hot water, the chemical properties of the three grasses are quite uniform. The narrow range of values for most of the individual chemical components indicates the pulping characteristics for the three species would be similar. Values for solubility in alcohol-benzene and hot water were lowest for khagra, intermediate for ekra, and highest for nal. Materials having high solubilities usually require more pulping chemical and give a lower pulp yield than those having lower solubility values.

Experimental Pulping

General

The pulping work was done in three parts. One part consisted of digestions of 3 grams of the grass in sealed glass test tubes to establish the effects of time, temperature, and cooking chemical concentration on pulp yield and permanganate number. The range of digestion conditions studied covered those commonly used in the sulfate pulping of wood and those used for pulping bamboo and grasses by the sulfate process.

The most favorable digestion condition found in the glass tube experiments were then investigated further by cooking 6 pounds of the material in 0.8-cubic-foot digesters. Pulps were made from each grass and from equal mixtures of the grasses. These cooks yielded sufficient pulp to permit a study of pulp strength properties. After digestion, the pulp was screened through a flat, vibrating screen with 0.008-inch openings (8-cut). Screened pulp yield and screening rejects were determined. TAPPI permanganate number and Valley beater tests were run on all pulps.

From the data collected, digestion conditions were selected for producing sufficient pulp for pilot-plant papermaking experiments. A 14-cubic-foot digester was used to produce the pulp used for the papermaking experiments. The resulting pulp was washed with cold water, screened, centricleaned, and screened again. Screening was done through 12- and 8-cut, vibrating, flat screens. A centri-cleaner was used to remove dirt and sheath particles in all pulps except those used for wrapping paper. The screened pulp was de-watered on a wet machine to about 25 percent dryness. Screened pulp yield, screening rejects, TAPPI permanganate number, and strength properties were determined for the pulps.

Pulping conditions and results are reported on a moisture-free grass basis throughout this report.

Cooking Liquor

The cooking liquor was prepared from technical-grade sodium hydroxide and sodium sulfide. The water content of the grasses was included when calculating the quantity of water required to give the desired volume of cooking liquor. Black liquor was not used, as in mill practice, as a diluent in the makeup of cooking liquor.

Experimental Results

Test Tube Scale Digestions

Figure 1 shows the relationship between pulp yield and cooking chemical concentration when ekra, khagra, and nal are pulped for 2 and 4 hours at 150° C. in sealed glass tubes. All demonstrate normal pulping trends for the 2-hour cooking time, but there are definitely higher pulp yields obtained when the cooking time is 4 hours. This higher yield could be due to the reprecipitation of lignin or lignin-like material. Support for this explanation can be found in figure 2, which shows that all pulps produced at the longer cooking time have higher permanganate numbers.

Ekra and nal show another interesting trend for the 4-hour cooking time. The pulp yield (fig. 1) passed through a minimum value at a chemical concentration of about 20 percent. The permanganate number also became a constant value at this point (fig. 2), although the chemical consumption continued to increase. This combination of circumstances suggests that continued consumption of alkali is involved in the destruction of cellulose. The resulting degradation products could combine with the lignin material already removed and in solution, and then be deposited on the pulp, thus causing an increase in yield.

Figure 3 shows the relationship between pulp yield and cooking chemical concentration when the three grasses are pulped for 1 hour at 170° C., and when ekra and khagra are pulped for 2 hours at 170° C. Ekra gave higher pulp yields when cooked for 2 hours rather than 1 hour. At both cooking times, the ekra pulp passes through a minimum yield value with change in initial chemical concentration. If this assumption is valid, it indicates that ekra is overcooked when the chemical concentration exceeds about 23 percent. It seems probable, then, that ekra can be pulped under relatively mild conditions. The pulp yield for khagra was lower for the 2-hour cook than for the 1-hour, a normal woodpulping trend. For the 2-hour cook, however, khagra showed evidence of being overcooked if the initial chemical concentration was greater than 23 percent, with a greater degree of cellulose destruction. Nal showed a normal pulping trend when cooked for 1 hour.

Under the same conditions of cooking, the order of decreasing pulp yield for the three grasses is: Khagra, ekra, and nal. Ekra can be pulped most easily, while khagra and nal require more drastic cooking conditions. The test-tube-scale results indicated that pulping conditions of 2 hours at 150° C. and 1 hour at 170° C. warranted further investigation.

If an acceptable upper limit of 15.0 is placed on the permanganate number, some preliminary estimates of the chemical requirements can be made. The three grasses have the following minimum chemical requirements:

At 150°C. for 2 hours, Ekra, 16.0 percent; khagra, 16.0 percent and nal, 20.0 percent. At 170° C. for 1 hour, Ekra, 18.0 percent; khagra, 20.0 percent; and nal, 23.0 percent. Since the three grasses would probably be cooked as a mixture under commercial conditions, both ekra and khagra should be pulped at conditions suitable for nal to determine the effect of the higher chemical concentration on individual pulp strength.

0.8-Cubic-Foot Scale Digestions

Pulping experiments on the three grasses were made in the 0.8-cubic-foot digester at the two levels suggested by results from the test-tube digestions. An acceptable maximum limit of 1.5 percent of screening rejects was established for all pulps. Table 2 shows that ekra, khagra, and nal gave pulps with screening rejects of 0.8, 1.3, and 2.0 percent, respectively, when cooked with 19.5 percent of active alkali at 150° C. for 2 hours. Screened pulp yields for ekra, khagra, and nal were 45.5, 48.1, and 43.1, respectively, at these cooking conditions. For the digestions at 170° C. for 1 hour with 19.5 percent of active alkali, all three grasses gave pulps with screening rejects less than 1.5 percent. Khagra and nal, however, were close to the maximum limit with 1.3 percent rejects. Screened pulp yields at these digestion conditions for ekra, khagra, and nal were 45.9, 45.0, and 43.4 percent, respectively. The screening rejects cooked for 2 hours at 170° C. with 19.5 percent of active alkali were reduced to 0.6 percent or less for khagra and nal. Screened pulp yields were lowered also. Ekra was not pulped at 170° C. for 2 hours with 19.5 percent of active alkali because screening rejects were reduced to an acceptable value with less drastic digestion conditions. The screening rejects mentioned previously consisted almost entirely of unpulped nodes, with the remainder of stones.

Strength properties for pulps from each grass species are given in table 2. For digestions with 19.5 percent of active alkali at 150° C. for 2 hours, nal was lowest in all strength properties, ekra was highest in bursting and tensile strength, while khagra was highest in tearing resistance. Ekra and khagra were equal in folding endurance. When pulped with 19.5 percent of active alkali at 170° C. for 1 hour, nal was again poorest in all strength properties, khagra was highest in tearing resistance, folding endurance, and tensile strength, while ekra and khagra were about equal in bursting strength. When pulped with 19.5 percent of active alkali at 170° C. for 2 hours, nal pulps were still lowest in strength, and khagra pulps were highest. Table 2 shows that nal strength values at the more drastic pulping conditions are even lower than those reported for the other two pulping levels. Khagra pulp, however, does not appear to be degraded by the more drastic conditions, and some strength properties increased slightly over those obtained for the milder digestion conditions. The strength values of the individual pulps reported in table 2 are lower than those reported for bamboo and fall in the lower range of U.S. hardwoods. Photomicrographs of ekra, khagra, and nal sulfate pulps are reproduced in figures 4,5, and 6.

With knowledge of the pulping characteristics and strength properties for the individual pulps, the effect of pulping the grasses in mixtures was determined. Mixtures of equal weights of ekra and khagra, ekra and nal, khagra and nal, and ekra, khagra, and nal were pulped. Results from the digestions on the individual grasses indicated that the percentage of active alkali used could be reduced to 17.6 percent without harmful effects. Digestion times of 1 and 2 hours at 170° C. were investigated.

Table 3 shows that screened pulp yields for the various grass mixtures and times of cooking ranged from 46.0 to 48.5 percent, screening rejects from 0.3 to 1.5 percent, and permanganate numbers from 9.7 to 13.0. Lowest screened pulp yields, lowest screening rejects, and highest permanganate numbers were obtained by the cooks made at 2 hours at maximum temperature.

It was expected that the mixtures of grasses would produce pulps with strength properties close to the values obtained when individual strength-property values were averaged. The mixture of khagra and nal cooked for 1 hour gave a pulp with lower strength properties than those expected (table 3). The strength values for this mixture were equal to those obtained for nal alone. Khagra and nal cooked for 2 hours did not cause a decrease in strength over that of the pulp produced in the 1-hour cook, and the 2-hour period gave results similar to those with the other three mixtures cooked for this length of time. In general, the results reported in table 3 follow the trends indicated by the pulping experiments on the individual grasses.

The pulping and strength data did not indicate that any one mixture of grasses is superior to the other three. Therefore, the most practical mixture to investigate for the papermaking experiments would be one containing all of the grasses. The pulping and strength data definitely showed that pulping conditions of 170° C. for 1 hour with 17.6 percent of active alkali would give superior pulp.

14-Cubic-Foot Digestions

All pulp used in the paper machine experiments was produced from a mixture of equal parts of ekra, khagra, and nal cooked at 170° C. for 1 hour. The average screened pulp yields, screening rejects, and permanganate numbers for the cooks with 17.6 percent of active alkali (cooks 4263, 4264, and 4266 to 4271 inclusive, table 3) were lower than similar cooks in the 0.8-cubic-foot digesters. A single digestion (cook 4265) with 15.6 percent of active alkali was made in an effort to raise the pulp yield and permanganate number to the level of the smaller digester results. The resulting screened pulp yield was less and the permanganate number was not significantly increased over that obtained with 17.6 percent of active alkali. The pulps made with 17.6 percent of active alkali were stronger than pulps made at similar conditions in the 0.8-cubic-foot digesters and were also stronger than the pulp made in the 14-cubic-foot digester using 15.6 percent of active alkali. The differences noted between the results obtained with the two sizes of digesters are similar to those obtained in cooking wood.

Preparation of Bleached Pulps

Two lots of sulfate pulp made from equal parts of ekra, khagra, and nal were cooked to about 7.0 permanganate number. Then they were cleaned by means of a centrifugal cleaner and bleached to two levels of brightness for use in papermaking experiments. A three-stage bleaching process was used, comprising chlorination, alkaline extraction, and calcium hypochlorite. By varying the amount of chlorine and hypochlorite applied, brightness levels of about 75 and 82 percent were obtained. The bleaching conditions in these treatments were in accord with those used in commercial bleaching operations and are given in table 4. The chemical requirements for bleaching these pulps were a little higher than those usually required for hardwood sulfate pulps with the same permanganate number. The bleached pulps were clean and free from discolored shives or foreign material.

Retention of pulp strength upon bleaching was normal for the process used (table 5). The average retention of bursting strength, tearing resistance, and breaking length at a Canadian Standard freeness of 250 milliliters was 90 percent at the brightness of 75 percent and 85 percent at the brightness of 82 percent. The strength of the bleached pulps was in the strength range of bleached hardwood sulfate pulps.

Papermaking

The different grades of papers were made with the fiber furnish consisting entirely of the mixed grass sulfate pulps or from blends of these pulps with North American commercial pulps. The pulp furnishes were prepared in a 50-pound-capacity beater. Some furnishes were subjected to further processing in the experimental size jordan. The papers were made on an experimental Fourdrinier paper machine that produces a sheet 12 inches wide.

The stocks were processed or blended at a consistence of about 3-1/2 percent. In those furnishes containing size or filler, the pH value of the pulp stock was adjusted to about 6.0 with sulfuric acid; then the sizing and filler were added and the pH value lowered to 5.0 with alum. The stock was dropped to the machine chest and diluted to about a 2-percent consistence with water similarly adjusted for pH. The white water returned to the stock in the headbox was maintained at this 5.0 pH value by the addition of alum solution. The water extracted by the suction boxes was discarded. The stock from the chest was diluted to a consistence ranging from 0.25 to 0.90 percent, depending upon the grade of paper. The stock was screened with 0.012-inch openings on the machine screen. The wet-web was passed through three moderately loaded wet presses. In some of the runs, a surface coating was applied to the paper at the size press located between the two dryer sections.

In most grades, only one or two trials were made from a specific pulp or pulp blend, and these did not necessarily develop the optimum operating conditions. The results should therefore be considered exploratory in this regard.

Wrapping Paper

Wrapping papers were made entirely from the unbleached grass pulps or from a combination of the grass pulp with commercial softwood sulfate pulp. For the first two runs (machine runs 5273 and 5274, table 6), the pulp was beaten to a freeness of about 520 milliliters. The pulp for the second of these runs (machine run 5274) was subjected to further processing in the jordan. In the other three runs, two (machine runs 5295 and 5296) contained 100 percent of the grass pulp, and the last run (machine run 5297) had 50 percent of long-fiber kraft pulp added for its effect on strength properties. For the last run, the grass and woodpulp components were processed separately to a 540-milliliter freeness and then blended.

A wrapping paper previously made at the Forest Products Laboratory from a commercial southern pine sulfate pulp was used as the standard of comparison.

The experimental papers had good formation and surface texture. The all-grass papers were lower in strength than the paper made from southern pine sulfate. Though jordaning the pulp improved the bursting and tensile strength of the paper, it still had properties lower than the reference paper. With the addition of 50 percent of a long-fiber woodpulp, a paper with properties more comparable to the reference paper was obtained.

Newsprint

The grass sulfate pulp was considered as a complete substitute and as a partial substitute for the long-fiber chemical pulp in a typical newsprint furnish. In the first run (machine run 5275), the furnish consisted of 25 percent of the grass pulp, bleached to a brightness of about 75 percent, and 75 percent of a commercial spruce-aspen groundwood pulp. This paper had good tearing resistance but was below the average for North American newsprint in bursting and tensile strength. The addition of 10 percent of a southern pine sulfate pulp for part of the grass sulfate pulp (machine run 5280) improved the tearing resistance but seemed to have a slightly adverse effect on the bursting strength. In the next run (machine run 5281) when the same pulp furnish was subjected to a jordan treatment, the bursting strength and tensile strength were improved, but the paper still was below the reference standard. Although the experimental newsprint papers produced with the grass pulps were below the average for newsprint in strength properties, they were within the range of properties obtained on commercial sheets.

Magazine-Book-Coating Base

A base paper for coated book, made from a furnish consisting of 65 percent of the mixed grass bleached sulfate pulp and 35 percent of a commercial groundwood pulp (machine run 5290) had strength properties approaching those obtained on a typical coating-base stock and was well-formed. For this run, that part of the furnish of grass pulp was processed in the beater to a freeness of 570 milliliters and the total furnish then subjected to further processing in the jordan. Another paper made from this pulp blend but without jordaning (machine run 5289), was low in all strength properties except tearing resistance, indicating that paper with good strength properties can be obtained with the grass pulp if the furnish is adequately processed.

One run (machine run 5288) was made using only 40 percent of the grass pulp. The remainder of the pulp furnish consisted of 60 percent of the commercial groundwood. This paper was low in strength, but it was more opaque than the other two experimental papers.

Offset Paper

A well-formed, good-appearing offset paper was made from 100 percent grass bleached sulfate pulp (machine run 5287). For this run, the pulp was beaten to about 500 milliliters and then jordaned further, resulting in a freeness in the headbox of 310 milliliters. This paper had 15 percent of clay, 3 percent of titanium dioxide, and 0.8 percent of rosin size added in the machine chest. It was surface coated with a high-viscosity starch. The opacity of the sheet was a little low, due in part to the low ash content of the sheet. Less than 50 percent of the filler added was retained in the sheet. Generally, the retention on the experimental machine for this type of paper is 60 percent or more.

Cover Stock

Two cover-stock paper runs were made from pulp furnishes consisting of 100 percent mixed grass sulfate pulp bleached to a brightness of 75 percent. Two runs also were made in which 30 percent of a southern pine bleached sulfate pulp was added for its effect on strength properties of the paper. The grass pulp and the softwood pulp were processed separately in the beater and then blended before 0.5 percent of rosin size was added.

The paper made in the first run with 100 percent grass pulp (machine run 5276) had good formation, but it was low in strength. When this furnish was subjected to a jordan treatment, bursting and tensile strength increased without adversely affecting the tearing resistance (machine run 5277).

When 30 percent of the long-fiber woodpulp was incorporated in the furnish, a substantial improvement in all strength properties was noted (machine runs 5278 and 5279). For example, the addition of this pulp increased the tearing resistance about 35 percent for both the unjordaned and jordaned furnishes and the bursting strength about 40 percent for the jordaned furnish. These papers had good brightness, oil penetration, and porosity values, all of which are desirable in printing paper.

Bond

The grass bleached pulp was used in producing a well-formed, 20-pound bond paper (machine run 5285). The pulp was beaten to a freeness of about 500 milliliters, after which 1 percent of rosin size, 5 percent of clay filler, and 2 percent of titanium dioxide were added. The paper was surface coated with a starch solution similar to that used in the offset paper. The resultant sheet was slightly low in bursting strength and would not meet the requirements of a No. 1 bond sheet. Such paper has a bursting strength value of at least "a point to the pound on a 17 by 22--500 ream basis," which is equivalent to 0.37 point per pound per ream on the 25 by 40--500 ream basis used in table 6. With a little more processing of the pulp or a different type of refining action, a sheet meeting this requirement could probably be produced.

One run of a lightweight bond paper, simulating an airmail bond, was made using the same pulp furnish as that employed in the regular bond. For this run, an additional amount of clay filler was added in the stock chest to the pulp remaining from the 20-pound bond run. This accounts for the higher ash value obtained on the sheet. The paper (machine run 5286) had good formation, surface characteristics, and strength properties.

Table 1.--Chemical composition of nal, ekra, and khagra

Species	Lignin	Alpha-cellulose	Pentosans	Solubility in--				Ash
				Alcohol benzene	Ether	1 percent sodium hydroxide	Hot water	
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Nal	19.2	50.0	22.0	10.5	1.3	34.2	14.9	2.1
Ekra	20.7	50.2	25.0	5.3	.5	32.7	8.7	2.4
Khagra	19.5	51.8	25.6	3.3	1.4	30.2	4.4	2.2

Table 2.--Sulfate Pulping experiments on ekra, khagra, and nal (intermediate scale)

Digestion No.	Cooking and yield data[1]: Chemicals charged: Concentration: Sodium hydroxide	Concentration: Sodium sulfide	Amount[3]: Total chemical	Amount[3]: Active alkali	Maximum temperature	Time at maximum temperature	Chemical consumption	Black liquor density at 15° C.	Yield of pulp: Screened pulp[3]	Yield of pulp: Screenings[3]	Permanganate number	Brightness and strength data[2]: Brightness (G. E. equivalent)	Beating time	Freeness (Canadian Standard)	Bursting strength	Tearing resistance	Folding endurance	Breaking length	Sheet density
	Gm. per l.	Gm. per l.	Percent	Percent	°C.	Hr.	Percent	°B.	Percent	Percent		Percent	Min.	Ml.	Pts. per lb. per rm.[4]	Gm. per lb. per rm.[4]	Double folds	M.	Gm. per cc.
NAL																			
3614X, 3631X	37.50	12.50	20.0	15.6	150	2.0	84.9	13.0	45.2	2.30	15.3	27.2	7	450	0.50	1.06	25	5,200	0.65
													14	250	.71	.88	155	7,000	.74
3619X, 3634X	37.50	12.50	20.0	15.6	150	4.0	88.4	10.9	43.4	2.80	16.9	25.6	7	450	.44	1.05	18	5,320	.62
													14	250	.68	.86	75	6,630	.72
3613X, 3632X	37.50	12.50	20.0	15.6	170	2.0	91.0	11.1	44.9	1.30	19.3	21.4	7	450	.42	1.04	20	5,400	.63
													14	250	.75	1.00	145	6,930	.74
3618X, 3648X	37.50	12.50	20.0	15.6	170	4.0	93.8	11.1	43.3	1.30	19.6	20.1	6	450	.42	1.10	13	5,200	.61
													13	250	.64	.90	138	7,200	.75
3622X	42.19	14.06	22.5	17.6	160	2.0	83.7	12.1	45.4	.80	14.9	26.5	6	450	.44	1.07	19	5,500	.63
													14	250	.69	1.00	98	7,340	.72
3615X	46.87	15.63	25.0	19.5	150	2.0	74.0	12.8	43.1	2.00	11.6	30.2	10	450	.46	1.03	14	5,170	.61
													19	250	.68	.92	75	6,390	.70
3623X	46.87	15.63	25.0	19.5	150	4.0	77.5	12.7	44.3	.70	12.4	29.9	8	450	.50	1.00	17	5,450	.65
													17	250	.72	.88	165	7,300	.76
3664X, 3666X	46.87	15.63	25.0	19.5	170	1.0	84.2	12.7	43.4	.50	12.6	27.5	10	450	.44	1.06	11	4,310	.62
													20	250	.69	.95	101	6,400	.75
3616X, 3640X	46.87	15.63	25.0	19.5	170	2.0	83.6	12.8	41.8	.30	12.7	27.0	5	450	.32	1.00	9	4,760	.61
													11	250	.61	1.00	42	6,290	.71
EKRA																			
3678X	37.50	12.50	20.0	15.6	150	2.0	75.6	10.9	48.5	.50	8.0								
3683X	46.87	15.63	25.0	19.5	150	2.0	65.4	13.1	45.5	.80	6.5	38.8	17	450	.68	1.13	70	6,500	.64
													29	250	.87	.98	220	7,900	.76
3679X	46.87	15.63	25.0	19.5	170	1.0	76.5	13.0	45.9	.10	8.4	33.2	15	450	.50	1.30	18	5,000	.58
													30	250	.80	1.07	150	7,500	.72
KHAGRA																			
3627X	37.50	12.50	20.0	15.6	150	2.0	71.4	11.1	51.4	1.90	9.5								
3641X	46.87	15.63	25.0	19.5	150	2.0	60.0	13.1	48.1	1.30	9.0	28.9	13	450	.54	1.24	45	5,440	.65
													22	250	.75	1.00	220	7,100	.77
3667X	46.87	15.63	25.0	19.5	170	1.0	79.2	11.4	45.0	1.30	10.2	26.5	18	450	.60	1.36	60	6,200	.66
													33	250	.82	1.23	280	7,750	.78
3682X	46.87	15.63	25.0	19.5	170	2.0	82.4	11.4	44.9	.60	9.2	26.0	25	450	.56	1.35	45	5,830	.65
													45	250	.79	1.16	320	7,850	.77

[1]Digestions were made in steam-jacketed, cylindrical, tumbling digesters of 0.8-cubic-foot capacity heated indirectly with steam. The equivalent of 5 to 8 pounds of moisture-free grass was used. Cooking conditions other than those shown were as follows: Liquor to wood ratio, 4 to 1; time to maximum temperature, 0.75 hour; sulfidity based on active alkali, 25.5 percent. Active alkali was the sodium hydroxide plus the sodium sulfide, both calculated as sodium oxide.

[2]Strength data at freeness values of 450 and 250 milliliters interpolated from beater test curve.

[3]Moisture-free grass basis.

[4]Ream size was 500 sheets, each 25 by 40 inches.

Table 3.--**Sulfate pulping experiments on mixtures of grasses**

Species[3]	Digestion No.	Weight of grass charged	Chemicals charged: Concentration amount[4]: Sodium hydroxide	Chemicals charged: Concentration amount[4]: Sodium sulfide	Chemicals charged: Total chemical	Chemicals charged: Active alkali	Time at maximum temperature	Chemical consumption	Black liquor density at 15° C.	Yield of pulp: Screened pulp	Yield of pulp: Screenings[4]	Permanganate number	Brightness (G. E. equivalent)	Beating time	Freeness (Canadian Standard)	Bursting strength	Tearing resistance	Folding endurance	Breaking length	Sheet density
		Cooking and yield data[1]											Brightness and strength data[2]							
		Lb.	Gm. per l.	Gm. per l.	Percent	Percent	Hr.	Percent	°B.	Percent	Percent		Percent	Min.	Ml.	Pts. per lb. per rm.[5]	Gm. per lb. per rm.[5]	Double folds	M.	Gm. per cc.
Ekra, khagra	3760X, 3778X	6.0	42.19	14.06	22.5	17.6	1.0	80.2	11.8	48.5	1.3	9.7	27.6	13	450	0.60	1.36	48	5,600	0.63
														21	250	.78	.96	155	7,130	.74
.....do.....	3761X, 3776X	6.0	42.19	14.06	22.5	17.6	2.0	85.3	11.7	48.0	.4	9.7	27.0	15	450	.55	1.28	26	5,760	.63
														25	250	.71	.94	123	7,260	.71
Ekra, nal	3765X, 3774X, 3790X	6.0	42.19	14.06	22.5	17.6	1.0	81.9	12.0	47.4	.3	11.2	28.7	11	450	.60	1.15	25	5,910	.62
														22	250	.84	.94	135	8,010	.74
.....do.....	3764X, 3775X, 3791X	6.0	42.19	14.06	22.5	17.6	2.0	85.5	11.9	45.9	.3	11.3	27.8	13	450	.49	1.04	13	5,020	.54
														28	250	.77	.87	92	7,480	.72
Khagra, nal	3773X, 3777X	6.0	42.19	14.06	22.5	17.6	1.0	80.5	11.9	47.8	1.5	11.8	26.9	8	450	.45	1.06	17	5,130	.65
														14	250	.67	.93	84	6,500	.75
.....do.....	3767X, 3781X	6.0	42.19	14.06	22.5	17.6	2.0	84.8	11.8	46.8	.8	13.0	24.4	9	450	.45	1.05	15	5,180	.59
														14	250	.64	.87	96	6,790	.74
Ekra, khagra, nal	3766X, 3780X	6.0	42.19	14.06	22.5	17.6	1.0	79.8	11.9	47.4	1.2	11.7	27.0	9	450	.48	1.25	16	5,180	.61
														18	250	.75	1.06	140	6,530	.73
.....do.....	3768X, 3782X	6.0	42.19	14.06	22.5	17.6	2.0	85.3	11.9	47.5	.5	11.9	24.9	13	450	.49	1.10	23	5,520	.61
														22	250	.71	.86	130	6,910	.75
.....do.....	4263, 4264, 4266-4271	140.0	42.19	14.06	22.5	17.6	1.0	79.1	11.8	44.7	.2	6.8	36.0	9	450	.59	1.29	60	5,700	.63
														21	250	.92	1.00	380	8,000	.75
.....do.....	4265	140.0	37.50	12.50	20.0	15.6	1.0	83.0	11.1	42.4	.6	7.4	30.9	14	450	.68	1.17	70	6,100	.68
														19	250	.74	1.03	170	7,100	.74

[1] Digestions were made in steam-jacketed, cylindrical, tumbling digesters, heated indirectly with steam. Cooking conditions other than those shown were as follows: Liquor to wood ratio, 4 to 1; time to maximum temperature, 0.75 hour; maximum temperature, 170° C.; sulfidity based on active alkali, 25.5 percent. Active alkali was the sodium hydroxide plus the sodium sulfide, both calculated as sodium oxide.

[2] Strength data at freeness values of 450 and 250 milliliters interpolated from beater test curve.

[3] Mixtures consisted of equal parts by weight (moisture-free) of each grass.

[4] Moisture-free grass basis.

[5] Ream size was 500 sheets, each 25 by 40 inches.

Table 4.--Bleaching of sulfate pulps made from a mixture of ekra, khagra, and nal[1]

Bleach No	4690	4691
Digestions Nos	4263, 4264, and 4266	4267, 4268, and 4269
Bleaching treatment:[2]		
Stage 1:		
Chlorine applied....percent	2.5	3.0
Chlorine consumed....percent	2.5	2.7
Temperature....°C.	25	25
Consistence....percent	3.3	3.3
Duration....hours	1.0	1.0
Stage 2:		
Caustic soda applied....percent	2.0	2.0
Temperature....°C.	70	70
Consistence....percent	11.9	11.6
Duration....hours	1.0	1.0
Alkalinity....pH	11.7-11.6	11.6-11.5
Stage 3:		
Calcium hypochlorite applied[3]....percent	1.0	0.8
Calcium hypochlorite consumed[3]....percent	1.0	0.8
Temperature....°C.	38	37
Consistence....percent	11.5	12.1
Duration....hours	1.25	1.75
Alkalinity[4]....pH	9.3-9.0	9.3-9.3
Bleached pulp: Brightness....percent	74.9	81.6

[1] Equal parts of each.

[2] Percentages are based on weight of pulp, moisture-free.

[3] Calculated as available chlorine.

[4] Maintained by adding about 0.4 percent of caustic soda.

Table 5.--Strength of sulfate pulp from ekra, khagra, and nal before and after bleaching[1]

Beating time	Freeness (Canadian Standard)	Bursting strength	Tearing resistance	Folding endurance (MIT)	Breaking length	Density
Min.	Ml.	Pts. per lb. per rm.[2]	G. per lb. per rm.[2]	Double folds	Meters	G. per cc.
			UNBLEACHED PULP			
0	605	0.31	1.51	25	3,660	0.53
1	600	.32	1.50	25	3,700	.53
9	450	.59	1.29	60	5,700	.63
21	250	.92	1.00	380	8,000	.75
			BLEACHED PULP, BRIGHTNESS 74.9, BLEACH NO. 4690			
0	560	.28	1.67	6	2,980	.57
7	450	.51	1.36	20	3,900	.65
19	250	.84	.94	300	6,800	.83
			BLEACHED PULP, BRIGHTNESS 81.6, BLEACH NO. 4691			
0	540	.31	1.13	7	2,660	.57
7	450	.48	1.12	18	3,400	.64
23	250	.75	.93	98	6,300	.76

[1]Mixture of pulps from digestions Nos. 4263 and 4264.

[2]Ream size, 500 sheets, 25 by 40 inches.

Table 6.--Properties of experimental papers containing sulfate pulps made from a mixture of ekra, khagra, and nal

Machine run No.	Fiber furnish: Sulfate pulp from mixture of grasses: Unbleached[2]	Fiber furnish: Sulfate pulp from mixture of grasses: Bleached[3]	Fiber furnish: Softwood sulfate (shipment No. 4378)	Fiber furnish: Spruce-aspen bleached groundwood (shipment No. 4493)	Fiber furnish: Southern pine bleached sulfate (shipment No. 4386)	Sheet properties: Ream weight[1]: Standard	Ream weight[1]: Trade	Thickness	Density	Bursting strength	Bursting strength	Average tearing resistance	Average tearing resistance	Average folding endurance (M.I.T.)	Average tensile strength	Air resistance (Gurley)	Castor oil penetration	Brightness (G. E. equivalent)	Opacity	Ash content
	Percent	Percent	Percent	Percent	Percent	Lb.	Lb.	Mils	Gm. per cc.	Pts.	Pts. per lb. per rm.[4]	Gm.	Gm. per lb. per rm.[4]	Double folds	Lb. per in. of width	Sec. per 100 cc.	Sec.	Percent	Percent	Percent
									WRAPPING PAPER											
5273	100					50.8	43.9	3.7	0.76	22.1	0.43	63.7	1.25	20	20.1	14				
[5]5274	100					50.9	44.0	3.7	.76	26.5	.52	54.0	1.05	44	23.9	33				
5295	100					49.2	42.4	3.7	.74	22.2	.45	55.3	1.13	22	19.2	10				
[5]5296	100					49.6	42.8	3.5	.78	26.3	.53	52.3	1.04	63	22.6	25				
5297	50		50			52.2		3.7	.78	32.2	.62	71.1	1.34	242	25.9	21				
[6]3484						50.4	43.5	3.7	.75	30.2	.60	71.0	1.41	128	22.2					
									NEWSPRINT PAPER											
5275		25		75		37.5	32.4	3.6	.58	5.5	.15	21.7	.58	2	6.0	36	53	65.7	87.8	
5280		15		75	10	37.5	32.4	3.5	.59	4.5	.12	24.6	.65	2	6.2	33	49	65.5	87.4	
[5]5281		15		75	10	37.5	32.4	3.3	.63	5.6	.15	23.0	.61	3	6.9	41	65	65.8	87.6	
(7)						38.0	32.8	3.3	.64	8.4	.22	20.5	.54		8.4	52	50	58.0	92.6	
									MAGAZINE BOOK-COATING-BASE STOCK[8]											
5289		65		35		32.0	30.4	3.0	.59	3.5	.10	24.7	.78	1	5.4	5	12	72.5	80.2	7.0
[5]5290		65		35		33.8	32.1	2.8	.67	6.2	.18	23.3	.70	3	6.7	14	23	71.9	82.0	7.8
5288		40		60		30.8	29.2	3.2	.53	3.8	.12	20.4	.65	1	5.8	14	24	69.8	85.0	7.7
(9)						33.0	31.3	2.7	.68	7.6	.23	27.0	.82	4	7.3	28		67.9	88.8	6.9
									OFFSET (PRINTING)[10,11]											
[5]5287		100				70.2	26.3	4.6	.84	21.7	.31	66.6	.96	7	19.4	17	47	80.5	89.2	8.2
									COVER STOCK[12]											
5276		100				77.6	40.4	5.8	.74	19.5	.25	76.0	.98	7	17.4	8	23	74.2	87.5	2.2
[5]5277		100				78.5	40.8	5.5	.79	24.5	.31	78.0	.99	13	21.1	15	41	73.2	88.4	2.3
5278		70			30	77.7	40.4	5.5	.78	26.9	.35	106.8	1.38	39	21.7	14	40	70.0	87.0	2.5
[5]5279		70			30	78.8	41.0	5.2	.84	33.7	.43	104.8	1.33	65	27.5	30	78	70.3	87.6	2.8
									BOND PAPER[13]											
[11]5285		100				52.9	19.8	3.8	.77	16.8	.32	49.0	.93	7	16.4	11	32	78.8	83.2	4.4
(9)						52.5	19.6	3.8	.76	23.1	.44	62.5	1.19	45	22.5	42	60	76.7	86.7	8.3
									AIRMAIL BOND[11, 12, 14]											
[5]5286		100				27.9	10.5	1.9	.81	6.4	.23	20.4	.71	5	7.5	10	28	79.2	69.4	7.2

[1] Trade ream sizes: 500 sheets of the following sizes in inches; wrapping and newsprint papers 24 by 36, magazine book 25 by 38, offset and bond papers 17 by 22, cover stock 20 by 26. The standard ream is 500 sheets, each 25 by 40 inches.

[2] Machine runs 5273 and 5274 were made from pulp from digestion No. 4265 and the remaining wrapping papers from a mixture of digestions Nos. 4270 and 4271.

[3] Pulp from bleach No. 4690 was used for newsprint and cover stock and from bleach No. 4691 for book, offset, and bond papers.

[4] Ream size, 500 sheets, 25 by 40 inches.

[5] Stock was jordaned.

[6] Made from southern pine sulfate pulp prepared commercially.

[7] Average of several commercial newsprint papers.

[8] Furnish contained 10 percent of clay filler.

[9] Commercial paper used as reference standard.

[10] Filled with 15 percent of clay and 3 percent of titanium dioxide. Sized with 0.8 percent of rosin.

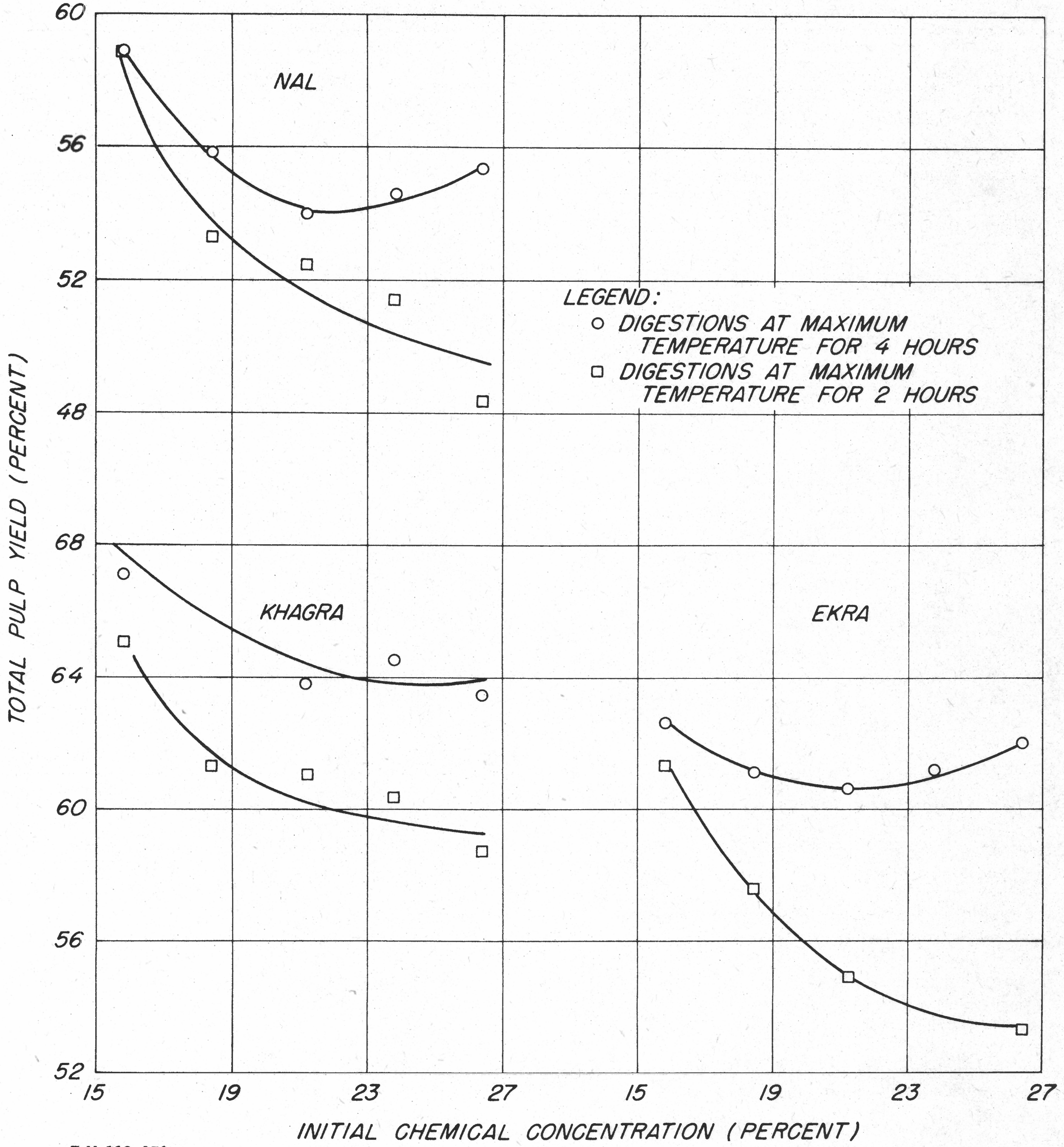
[11] Surface coated with 0.75 pound per gallon solution of Penford gum 250.

[12] Filled with 2 percent of clay. Sized with 0.5 percent of rosin.

[13] Filled with 5 percent of clay and 2 pefcent of rosin. Sized with 1 percent of rosin.

[14] An additional amount of clay was added in the stock chest.

M 115 015



Z M 118 072

Figure 1. --Sulfate pulping of ekra, khagra, and nal at 150° C. in sealed glass tubes.

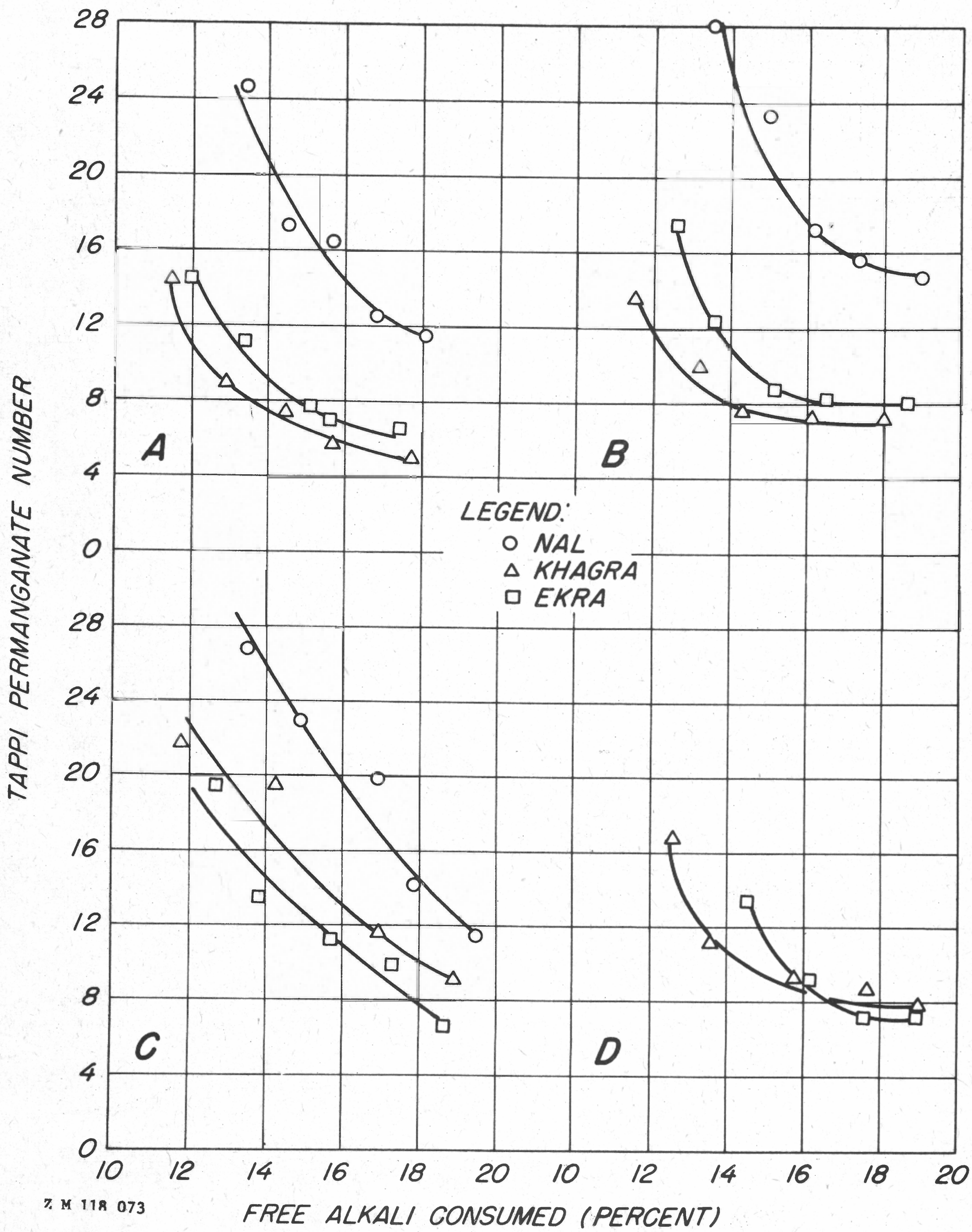
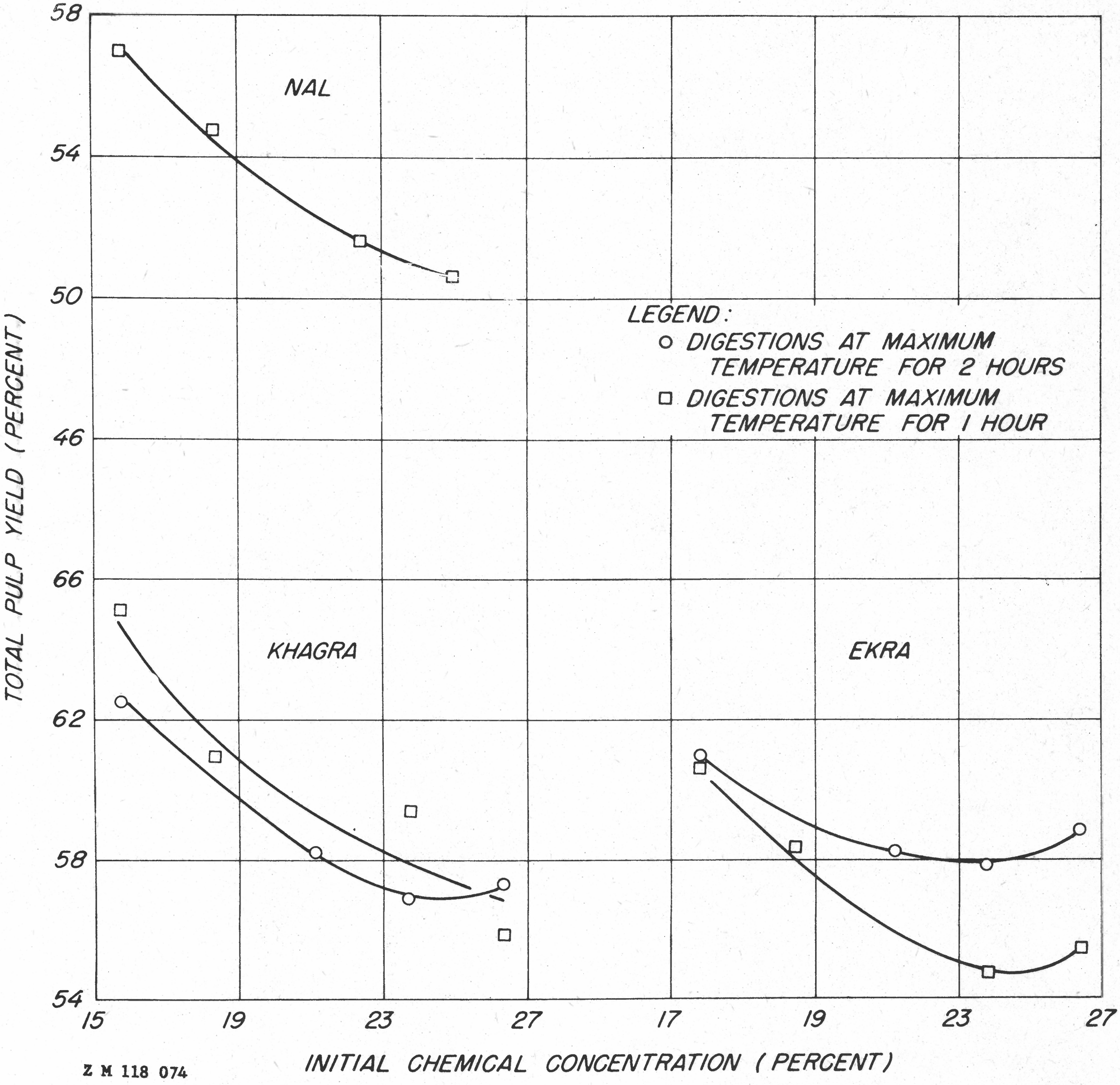


Figure 2. --Relationship between TAPPI permanganate number and chemical consumption in the sulfate pulping of the Pakistan grasses. A, digestions at maximum temperature of 150° C. for 2 hours. B, digestions at maximum temperature of 150° C. for 4 hours. C, digestions at maximum temperature of 170° C. for 1 hour. D, digestions at maximum temperature of 170° C. for 2 hours.



Z M 118 074

Figure 3. --Sulfate pulping of ekra, khagra, and nal at 170° C. in sealed glass tubes.

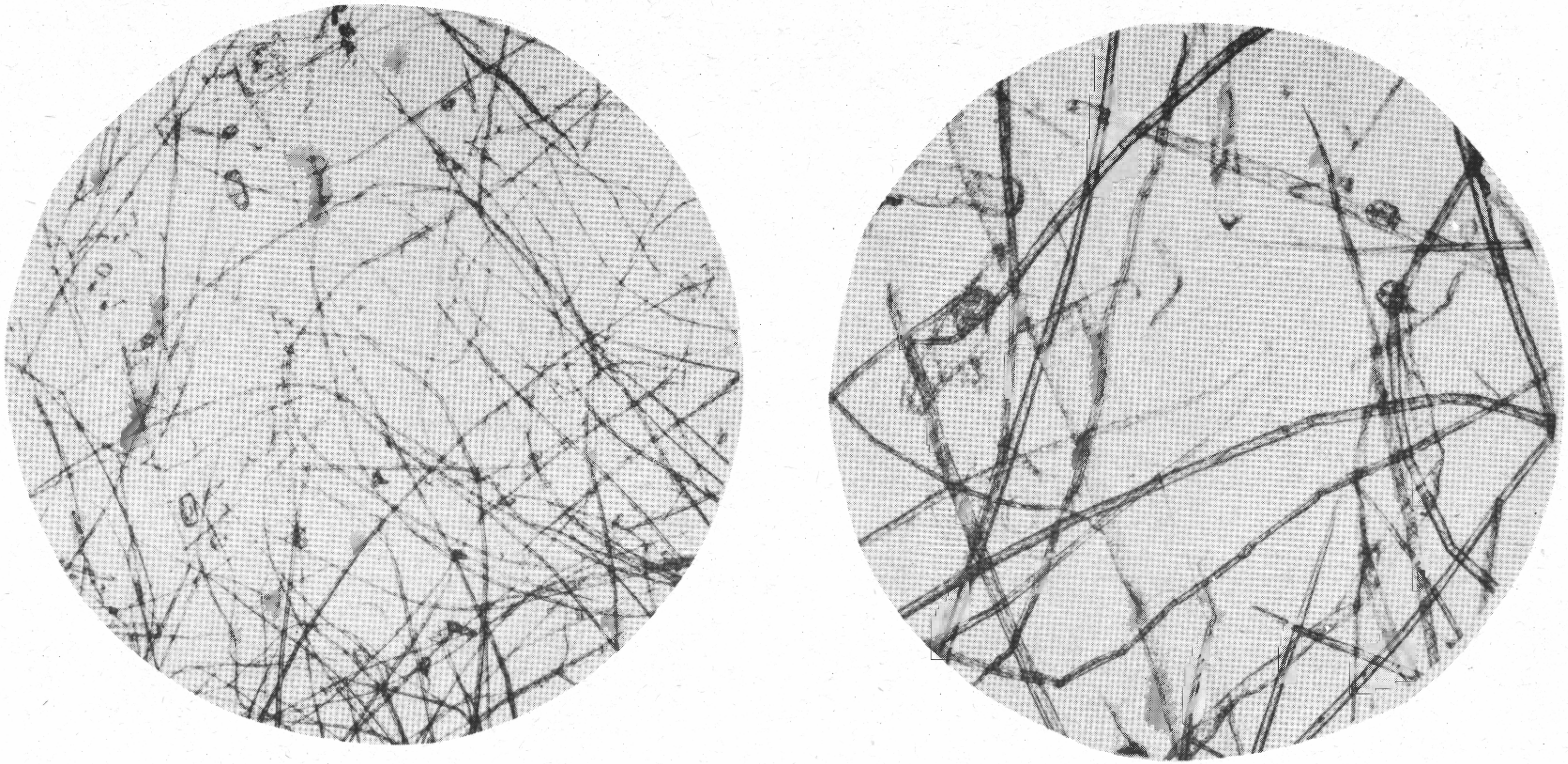


Figure 4. --Photomicrographs of ekra sulfate pulp. (Left) Photograph made at 50X magnification; (Right) made at 150X magnification.

Z M 118 075

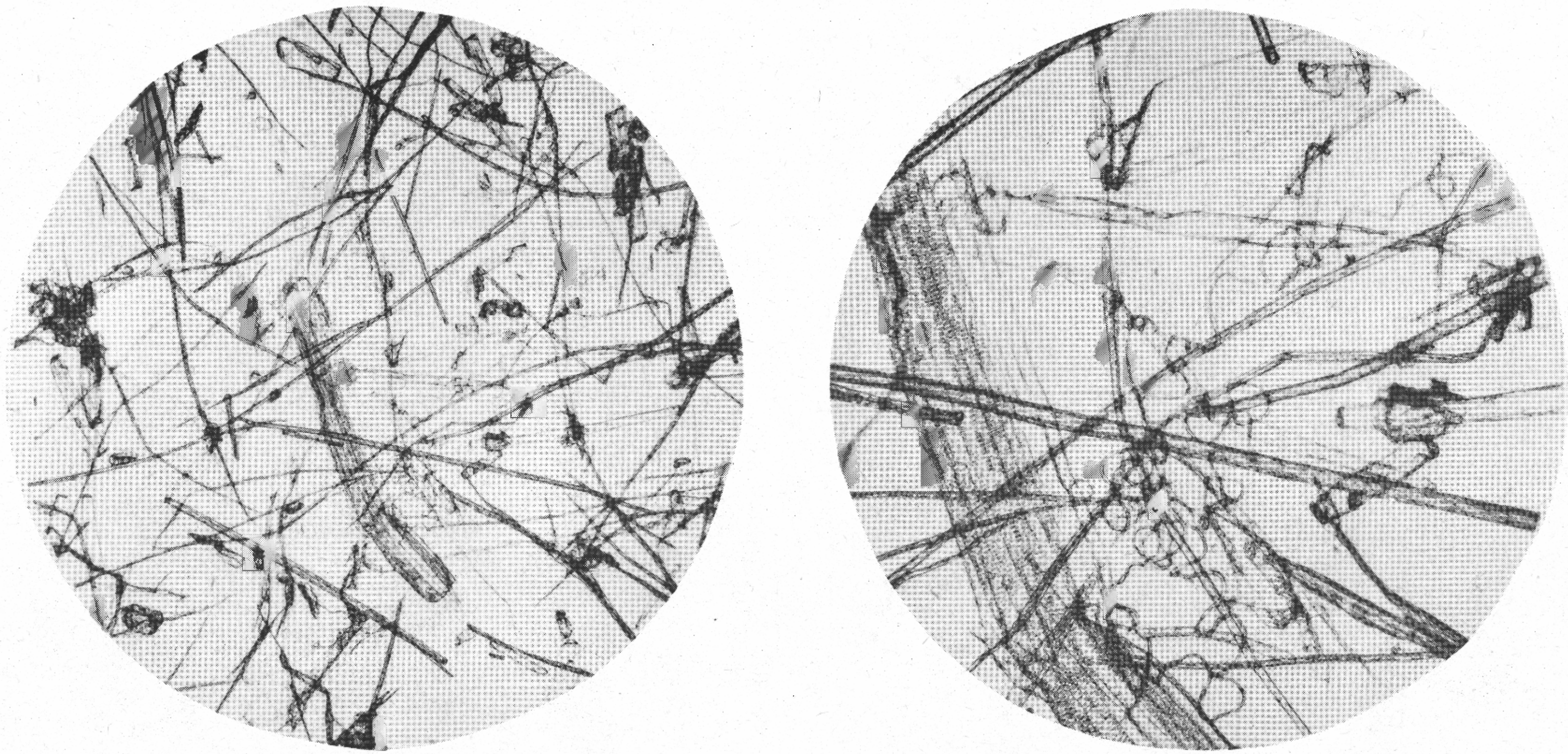


Figure 5. --Photomicrographs of khagra (Saccharum spontaneum) sulfate pulp. (Left) Photograph made at 50X magnification; (Right) made at 150X magnification.

Z M 118 077

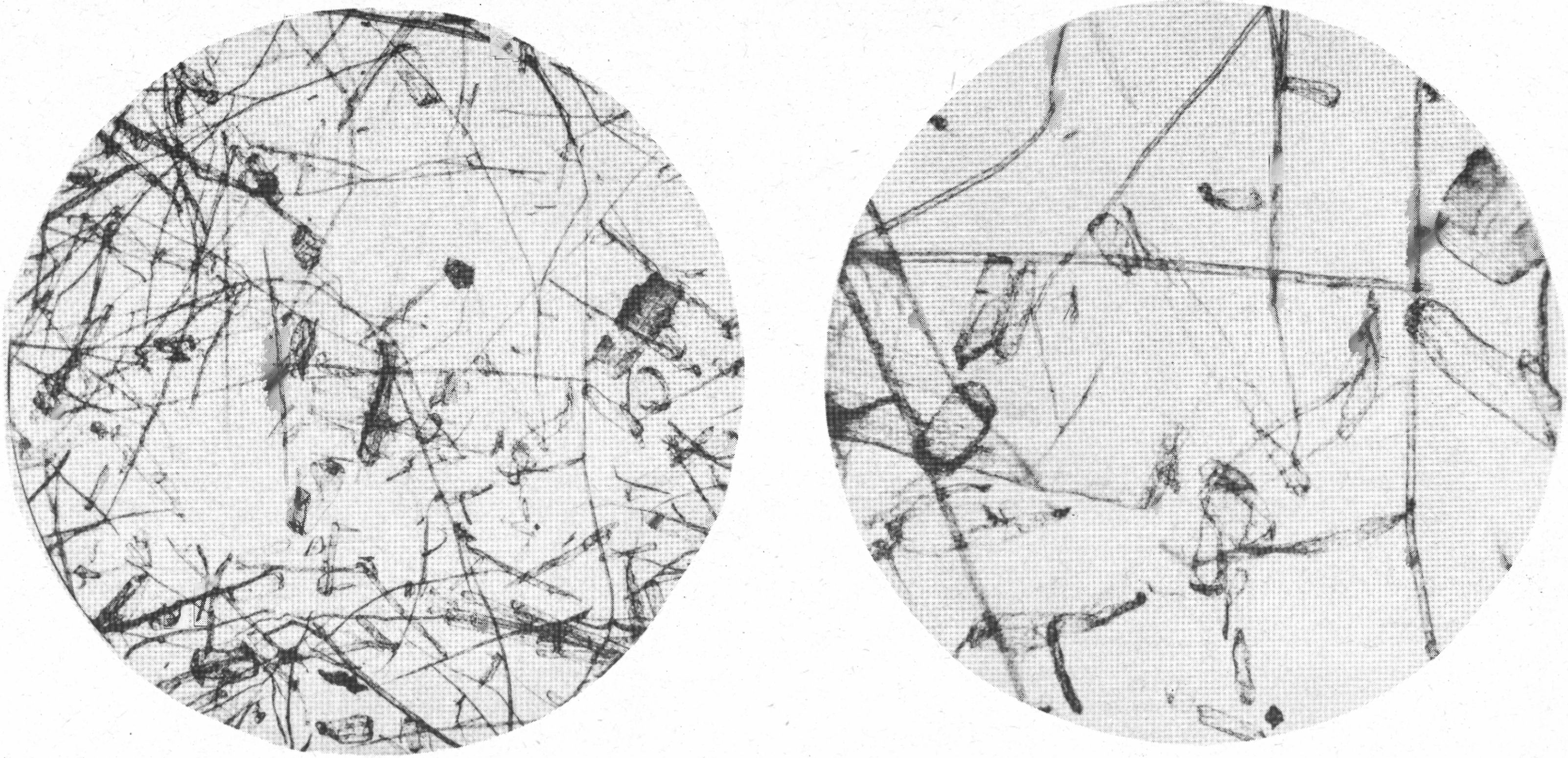


Figure 6. --Photomicrographs of nal (Phragmites karka) sulfate pulp. (Left) Photograph made at 50X magnification; (Right) made at 150X magnification.

Z M 118 076