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# THE UTILIZATION OF CROP PLANTS IN PAPER MAKING.

By CHARLES J. BRAND,

*Physiologist in Charge of Paper-Plant Investigations, Agricultural Technology,  
Bureau of Plant Industry.*

## REVIEW OF RECENT EXPERIMENTS.<sup>1</sup>

During the past ten years many crop materials have been subjected to pulping experiments by some of the more progressive paper manufacturers and by private individuals. In most cases a satisfactory quality of paper has been made, but in the end nothing practical has come of the work. The whole situation might be summarized by the statement that it has been found possible to make paper out of many crop wastes, but it has been found impossible to make money out of more than one or two.

Congress, in making appropriations for the Department of Agriculture for 1908-9, provided the sum of \$10,000 to be used in testing "such plants as may require tests to ascertain if they be suitable for paper making." One half of this fund was assigned to the Forest Service for studies of unused woods, the other half to the Bureau of Plant Industry for the investigation of crop and wild plants. Work was taken up in the summer of 1908 on the following: Cornstalks, flax and rice straw, cotton stalks, bagasse, and tules. Since that time broom-corn and hemp stalks, hemp wastes, cotton-hull fiber, stalks of saccharine and nonsaccharine sorghums, *Epicampes macroura* (a southwestern grass whose tops are a by-product of the root-brush industry), *Arundo*, *Arundinaria*, *Eulalia*, and several other plants have been added to the list. During the past year special attention has been given to practical tests in a large book-paper mill.

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## CORNSTALKS.

Cornstalks were taken up first for several reasons: (1) They represent an enormous supply of raw material—the greatest unused crop by-product. Over 100,000,000 acres are now devoted annually to Indian corn in the United States. Taking 1 ton as the yield of stalks per acre, which is a very conservative estimate, there are produced at least 100,000,000 tons of stalks each year. Certainly not more than one-third of this vast quantity is put to paying uses in present farm practice. Ignoring another third, which may be produced in scattered localities, thus adding a factor to the considerable expense that would be involved in assembling it, there remain fully 30,000,000 tons of cornstalks grown in the area known as the “corn belt.” A great addition to farm wealth would result if some of this supply of material could be made into paper and pulp products at a reasonable profit. (2) Results obtained with cornstalks would be applicable in a considerable measure to all grasses, rushes, and sedges which have a similar structure, and in less measure to dissimilar plants having some of the same cellular elements. (3) Considerable pioneering work had been done with cornstalks, the results of which were accessible to the Department.

While the cornstalk experiments have been encouraging, they have not yet produced results that justify a definite pronouncement. Paper of excellent quality has been made from eight or ten varieties of corn during the past season, but it remains to be determined whether the profit to the manufacturer will enable him to give the farmer enough for his stalks to pay for harvesting, shredding, baling, and delivering the same. All parts of the corn plant except the ears and roots are used. Under present plans it is expected that cornstalks will yield three products:

(1) Long fiber, which, on account of its strength and its good felting and other desirable qualities, is suitable for book, writing, and other papers of the better class. Bone-dry stalks will yield from 12 to 18 per cent of long fiber, varying with the variety, conditions of growth, and chemical treatment.

(2) Pith pulp, suitable for pulp and paper specialties, such as insulating material, grease-proof wrappers, pie plates, fiber boxes, and possibly bottles. The yield of pith will range from 15 to 30 per cent of moisture-free stalks. The usefulness of pith pulp for standard products is not as great as that of the long fiber, but it is a plastic material that should serve many useful purposes. The character of the fiber and pith cells is shown in figure 16.

(3) Cornstalk extract, the soluble solids of the stalks, obtained by water extraction or by saturation under pressure and subsequent expression. The method most commonly employed in obtaining this extract is to place the shredded stalks in the digester with a quantity

of water and boil for an hour under a steam pressure of from 50 to 70 pounds. The liquid containing the soluble solids is then drained off and evaporated to the desired consistency, while the extracted stalks remain in the digester ready for cooking with caustic soda.

A ton of cornstalks will yield from 200 to 300 pounds of soluble solids containing the greater part of the food value of the stalks. When made under the best conditions from 8 to 12 per cent of the extract is protein, about 25 per cent is invert and cane sugar, and about 25 per cent more is sugars of the pentose and pentosan class.

About 25 gallons of extract of molasses-like consistency were produced at a paper mill during the summer of 1910, and a month's preliminary feeding test of two animals was made in cooperation with the Bureau of Animal Industry of the Department of Agriculture. All of the food mixed with dry matter was eaten and no injurious effects were observed. It remains to make a conclusive test with a larger number and a greater variety of animals before the nutritive value of the material can be determined or whether it is injurious if fed for a long time. As broom-corn and sorghum stalks and rice straw yield a similar extract, the possibility of reclaiming the food elements will very likely be one of the factors in determining whether or not the wastes of crop plants can be put to practical use in paper making. If cornstalk extract proves valuable and the water-soluble solids can be returned to the farm, mixed with roughage, and fed, an important step in conservation will have been gained, as the removal of the raw material from the farm need not then represent a serious attack upon the soil resources. The extraction of the soluble solids from the stalks is beneficial, because it leaves them in an improved and advanced condition for chemical treatment and lessens the cost by reducing the quantity of chemicals required.

Cost estimates are incomplete, but it appears that the farmer could not afford to handle the raw material for less than \$5 a ton, air-dry. If the extract has any value it is probable that the manufacturer could afford to pay

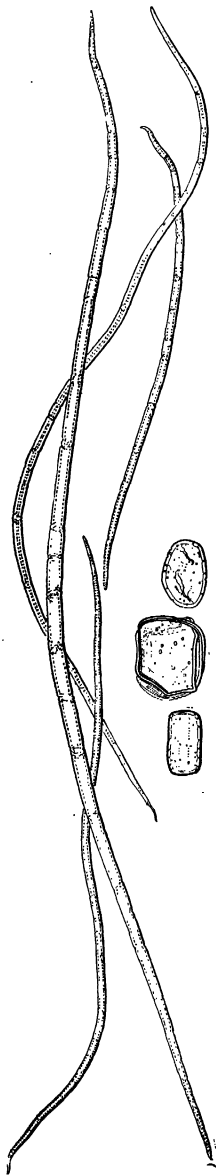


FIG. 16.—Long fiber and pith cells of Indian corn. (Enlarged 71 times.)

this, though these are matters upon which more accurate data must be secured and which must necessarily be finally decided in actual practice

#### BROOM CORN.

Both the corn and broom-corn stalks used in the Department's experiments were grown at specially selected places, and a careful record has been kept of the yield, the cost of production, the space required for storage, and the keeping quality of the materials. On the whole, the collaborators who grew broom corn had better success in the production of stalks than those who grew corn. As a consequence, broom-corn stalks have been investigated more thoroughly than other materials. As a large number of digestions or "cooks" of Indian corn were made first, much experience was gained which was of decided advantage in the tests of broom corn.

Broom corn throughout its cultural history has been selected for the production of a greater quantity and better quality of fiber in its "brush." It would be only natural if the production of fiber in one portion of the plant should be correlated to the higher fiber value of the plant as a whole. This appears actually to be the case. At any rate, broom-corn stalks contain a higher percentage of long fiber than do cornstalks. As a result of the experiments that have been made with broom-corn stalks it may be conservatively stated that this crop by-product is suitable, so far as the quality and yield of its pulp are concerned, for immediate use in paper making. Like cornstalks, it reduces readily to pulp with a comparatively low consumption of chemicals and steam. The time required for pulping is from 3 to 4 hours, as compared with 8 to 12 hours for wood. In addition, preliminary tests indicate that there will be no great difficulty in recovering the caustic soda used in digestion.

In tests on a laboratory and semicommercial basis, yields of 32 to 40 per cent of fiber were obtained. Later, a cook of  $3\frac{1}{2}$  tons was made in the largest sized rotary digester in common use for wood, on which a yield of practically 42 per cent was obtained.<sup>1</sup> It appears from this that it will be safe to expect this percentage of fiber in actual practice. It was found that the proportion of pith in broom-corn pulp is so low that it could be made directly into a fair quality of white paper, which, however, would probably be too brittle for most purposes. Experiments were also made to test the effect of combining broom-corn pulp with certain proportions of soda pulp from poplar and sulphite pulp from spruce. It was found that a combination of 50 per cent of broom-corn pulp, pith, and long fiber unseparated, together with 50 per cent of poplar, produced

<sup>1</sup> Acknowledgment is here made for much assistance and information furnished by S. D. Warren & Co., Cumberland Mills, Maine.

what was pronounced by practical paper men as a merchantable quality of book paper. In combination with sulphite fiber from spruce a stronger though somewhat harsher sheet resulted.

The results that have been secured with broom-corn stalks indicate that this material is suitable for immediate use in paper making, both on the basis of quality of fiber produced and on yield of fiber secured. Broom-corn stalks have one serious disadvantage, namely, the limited production of raw material. The figures for the recent census are not yet available, but according to the returns of the Twelfth Census 178,584 acres were devoted to broom corn in 1899. The yield of stalks to the acre will probably approximate very nearly 3 tons; hence, the quantity produced will probably be in the neighborhood of 450,000 tons. Many States grow small acreages of broom corn, but Illinois, Kansas, Oklahoma, and Missouri probably produce fully two-thirds of the total crop. It is possible that in these States there may be localities where the acreage cultivated near one central point is so large that pulp could be produced economically.

The harvesting of the stalks for pulp making does not interfere with the harvesting of the brush for brooms, nor would it in any way reduce the quality of the brush produced.

Broom-corn stalks, like cornstalks, yield a product under water extraction containing practically the whole food value of the raw material. In the case of broom corn it seems likely that the stalks could be pulped at a profit without taking into account the possible value of the food extract.

#### RICE STRAW.

Rice straw may be regarded as one of the most promising crop materials available for paper making at the present time. In China and Japan this material has been employed for many years. There has been considerable discussion about its use in the United States, but up to the present time no commercial plant has been constructed for the purpose. Private experimenters have produced excellent qualities of book and writing papers from it, more particularly in combination with sulphite pulp and cotton-hull fiber. In the experiments of the Department, yields of from approximately 32 to 40 per cent have been secured. Not less than 35 or 36 per cent could be expected in practice. The character of the long fiber of this straw is shown in figure 17. Pith cells are also present in rice straw, but not in such proportion as in cornstalks. Indeed, it has been found perfectly feasible to produce paper without attempting to remove the pith cells, but merely combining the straw pulp with a suitable quantity of sulphite, soda, or cotton-hull fiber.

Rice straw also yields a food extract which in the analyses thus far made runs rather high in protein; nevertheless, it does not seem necessary in the case of this waste to depend upon the extract in order to make the material as a whole utilizable.

Rice straw has a distinct advantage over cornstalks in that it is assembled at one place for thrashing and can be baled at once without extra cost for hauling in from the field and shredding. Although it does not promise to give as high a yield of fiber as broom-corn stalks, it has a distinct advantage over these because of the greater acreage grown. It has a further advantage over both corn and broom corn in that it is grown rather compactly in restricted areas, so that a pulp or paper mill located in any good rice-growing section could secure its supply of raw material within a comparatively small distance from the mill. Texas, Louisiana, Arkansas, and South Carolina are the great rice-producing States. At present these have a total of only four paper mills.



FIG. 17.—Rice-straw fibers. Though comparatively short, these are strong and felt well. (Enlarged 71 times.)

The number of acres of rice harvested in the United States in 1909 was 720,000. Growers state that the yield of straw will run from 2 to 2½ tons an acre. Using the lower yield, in the neighborhood of 1,500,000 tons of rice straw are produced annually. At the present time this is largely a waste product, though a small part is fed to stock. It is also baled to some extent and shipped to the larger cities for stable bedding, bringing about \$4 to \$4.50 a ton. If the price of wood continues to advance, rice straw should be one of the first crop materials put to practical use.

#### COTTON-HULL FIBER.

Cotton-hull fiber is the lint that remains adhering to the hulls after the long fiber has been removed by the gin and the shorter fiber by the ginning machines. The hulls are a by-product of the cottonseed-oil industry.

The fiber is used to some extent as a source of cellulose in the manufacture of guncotton; also as a stuffing material for pads and horse collars, and in upholstering. It may be removed from the seed before crushing or from the broken hulls after the seed has been crushed and the kernels extracted. The fiber obtained before crushing has not been tested in the writer's experiments. That obtained from the broken hulls contains a high percentage of the hull material, which is re-

moved with some difficulty. As the particles of the hull do not digest or bleach as readily as the fiber, they frequently show up in the pulp or finished paper as small brown specks, which would seriously interfere with the salability of the product.

There is some diversity of opinion among producers as to the quantity of cotton-hull fiber that could be made available. It would probably be rather small. It is not suitable for paper making in a pure state, as it is somewhat deficient in strength, and furthermore it will probably command a higher price for other purposes than paper manufacturers can afford to pay. Cooked in the same digester with corn, broom corn, or rice straw, cotton-hull fiber has been found to facilitate greatly the draining of the pulp and also to add softness to the paper. It is possible that its beneficial effect in this respect might make a market for a limited quantity of this material in connection with the others mentioned. A further possibility is that this fiber, treated by special processes, may prove suitable for particular grades of paper that command unusually high prices. At present, cotton hulls with the short lint adhering are sold for fertilizer and command \$5 to \$8 per ton at the point of production. The hulls are also mixed with the ground oil cake after expression of the oil and made into stock feeds of various grades. When used as a component of stock feed it is desirable to remove the short lint. Cotton-hull fiber will probably never be used extensively in paper making, and it is only mentioned here because it may prove a valuable adjunct in the working up of other crop by-products.

#### COTTON STALKS.

Cotton stalks tested in cooperation with the Forest Service of this Department were among the first crop wastes reduced to pulp. The aggregate quantity of these stalks produced in the United States is large. Those who have given attention to the matter estimate it at 10,000,000 tons. The yield per acre of stalks is much lower than that of any of the raw plant materials thus far discussed, and probably does not exceed 1,000 pounds per acre. Cornstalks will average more than twice this quantity; rice straw, four times as much; and broom corn, six times this total. Numerous inventors have been attracted to cotton stalks by the large quantity grown, and much has been claimed for paper said to be made from them. At the present time no paper mill is using the material.

In the experiments thus far conducted by this Department cotton stalks have been found to require harsh chemical treatment, using about 30 per cent of caustic soda, which is 5 per cent more than poplar wood requires. They required from six to nine hours, with steam pressures of from 90 to 110 pounds, for cooking. The yield of fiber



ranged from 35 to 43 per cent in various tests, but the fiber was found to be short and inferior in strength. With this yield and the low production of 1,000 pounds per acre it would require 5 acres of stalks to make a single ton of pulp. Difficulties were also encountered in connection with bleaching. The dark outer bark proved very refractory, necessitating the use of a large quantity of bleaching powder. All samples of paper made from this material which the writer has examined contain so much unbleached material as to render them unsuitable for anything except wrapping purposes. It is possible that methods may be devised which will produce a pulp sufficiently white and a fiber sufficiently strong to make cotton stalks a promising material, but the results obtained to date are not encouraging.

#### BAGASSE.

Bagasse is the refuse of the sugar cane after the juice has been expressed. It is susceptible to the treatment given to the stalks of corn and broom corn and some of the other materials that have been discussed. When treated by the caustic-soda process in the ordinary manner the yield of pulp has been comparatively low. The individual fibers, while rather short, are slender, so that a moderately strong sheet of paper can be produced. The pulp bleaches easily, especially if it has first been extracted by the method described for cornstalks. A large percentage of pith is present, which, in practice, would have to be dealt with as in the case of corn. Several small plants have been built with a view to making various forms of pulp board and the rougher grades of paper from bagasse, but so far as the writer knows none of these has been permanently successful. The fact that the material is all assembled at the sugar mill and thoroughly broken up in the process of crushing should favor the utilization of this waste. On the other hand, the fuel value of bagasse must be carefully considered in any plan to utilize the material. The sugar industry, as now organized, counts on the refuse to furnish a very large proportion of the fuel required for the boilers. Its value for this purpose has been variously estimated at from \$1.50 to \$3 per ton. Both figures are probably too high.

#### FLAX STRAW.

In the United States flax is grown almost exclusively for seed, the annual production amounting to something more than 25,000,000 bushels. The number of acres harvested is about 2,500,000. On an average, between 2,000 and 2,500 pounds of straw are produced to the acre. At the present time not more than 250,000 or 300,000 tons of the total product of approximately 3,000,000 tons are used.

Recent years have seen considerable development in the use of flax straw, but much remains to be desired, considering the generally promising nature of the material. Many extravagant claims have been made and much promoting has been done, some of it of an extremely questionable character, on the basis of the supposed value of the straw of seed flax for textile and other purposes. At the present time its profitable use is confined almost wholly to the manufacture of binding twine, upholstery tow, and insulating material for refrigerator cars and cold-storage houses. The waste straw of the flaxseed industry is a totally different product from the carefully handled and prepared fiber from which linen fabrics are made. Even for twine-making purposes the straw must be harvested and thrashed in a particular way in order to produce a satisfactorily smooth quality of twine.

When cooked by the caustic-soda process the straw produces a material decidedly strong and in many respects promising. The yield of pulp to raw material has not run much over 30 per cent. Much private capital has been spent in attempts to make paper from flax straw, but as yet there is no mill in the United States that uses the material. Recently private agencies have conducted extensive experiments with a view to producing paper suitable for cement bags and the like. The requirement is an extremely difficult one, as paper for such purposes must have extraordinary strength. Some of the papers produced came up to the requirement, and the results as a whole were encouraging. In these tests tow was used and not the flax straw as it comes from the thrashing machine. If this method were followed in practice there would be a considerable addition to the expense for raw material. It requires from 3 to 4 tons of straw to make 1 ton of tow, and medium tow is worth over \$20 per ton at the tow mills. Flax straw must be regarded as one of the most promising materials, but extreme caution should be used in its exploitation. Straw from different sources differs in strength and quantity of fiber; climatic conditions appear to have a profound effect upon its fiber value.

#### MISCELLANEOUS CROP MATERIALS.

In addition to the crop by-products that have been discussed there are other materials that may prove of value. Among these are the common grain straws, the wastes of hemp, jute, flax, manila, and other fiber crops, and the stalks of the grain sorghums which are now being cultivated on considerable areas and whose culture is being extended rapidly. *Epicampes macroura*, a southwestern grass, which is especially plentiful in Mexico, may prove useful, as it has an excellent fiber. This plant, which is known as "zacaton," furnishes the so-called "rice roots" so extensively used in the making of brushes.

In the brush industry only the roots are used, and the tall-growing stems and leaves with their fine fiber are a waste product.

Two points should be borne in mind in all attempts to make pulp from crop wastes: That not all materials are suitable for making expensive products and that it not infrequently happens that there is as much profit, because of lessened cost of production and greater demand, in making cheaper products for which the material may be better adapted, as in making the higher priced articles.

#### PLANTS THAT MAY BE GROWN AS PAPER CROPS.

In addition to the waste materials that are available, evidence has been gathered that certain crops can probably be grown at a profit to both the grower and manufacturer, solely for paper-making purposes. One of the most promising of these is hemp. Hemp grows well in most parts of the country and produces very high yields of raw material. The average production of "hay-dry" hemp stalks per acre will reach very nearly 5 tons. Of retted stalks, an average of from  $2\frac{1}{2}$  to 3 tons can be expected. When dew-retted, as is the common practice, the tax on the soil of growing the crop is very light—an exceedingly important point in farm economics. According to careful estimates by Prof. L. H. Dewey, hemp can be grown through the retting stage at a cost of about \$14 an acre. With an average yield of  $2\frac{1}{2}$  to 3 tons of retted stalks, it seems very likely that hemp can be grown profitably solely for paper stock.

Hemp produces a paper of great durability and great strength in thin sheets. The retted stalks will yield from 40 to 45 per cent of cellulose. The fiber (fig. 18) is of such a nature and length as to fit it for the manufacture of numerous special papers that will command better prices than the ordinary grades. Should retted hemp come into use as a paper-making material it will effect a considerable saving in certain years to the hemp-fiber industry, as it frequently happens that hundreds of tons of hemp stalks are over-retted, making them unfit for textile use. These could be worked into paper to advantage.

Another plant from which excellent paper has been produced is the well-known Japanese grass *Eulalia japonica*, which is much used in this country for ornamental purposes. This plant thrives luxuriantly in the latitude of Washington on some of the poorest soils. It yields a fiber similar to that of esparto in its behavior. A large paper-manufacturing company has grown this grass as far north as Maine and has produced some excellent varieties of paper from it. Preliminary observations on a plat of the grass growing near Washington, D. C., on very poor soil, indicate that an average yield of at least 2 tons to the acre may be secured.

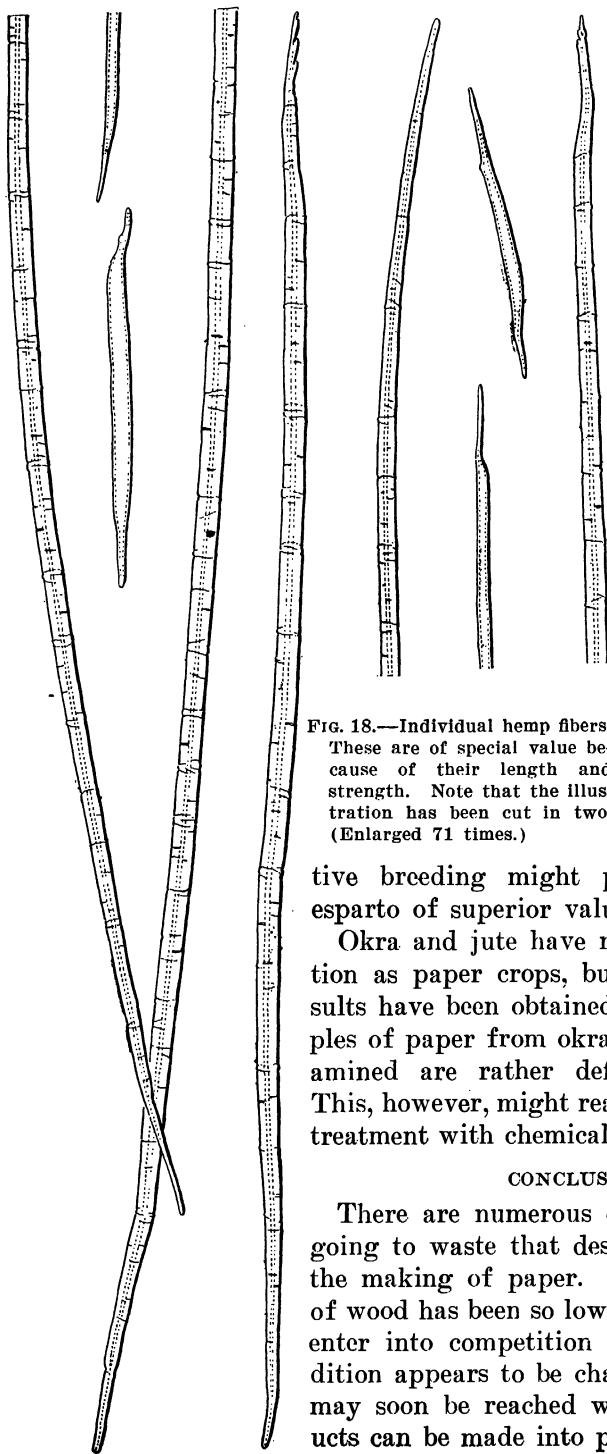


FIG. 18.—Individual hemp fibers. These are of special value because of their length and strength. Note that the illustration has been cut in two. (Enlarged 71 times.)

Esparto, which is one of the most highly prized sources of paper in the Old World, may be useful in some parts of the Southwest where there are extensive areas of unused dry land. This grass is one of the important sources of paper in Europe. The present supply is obtained from the dry regions of Algeria, Tunis, Tripoli, and Spain, where it grows wild and is harvested by hand.

It seems likely, furthermore, that the application of methods of selective breeding might produce strains of esparto of superior value.

Okra and jute have received some attention as paper crops, but no conclusive results have been obtained with them. Samples of paper from okra that have been examined are rather deficient in strength. This, however, might readily be due to over-treatment with chemicals.

#### CONCLUSION.

There are numerous crop materials now going to waste that deserve utilization for the making of paper. Hitherto, the price of wood has been so low that they could not enter into competition with it. This condition appears to be changing, and a point may soon be reached where crop by-products can be made into pulp and paper at a

profit to both the farmer and the manufacturer. There does not seem to be any reasonable hope at the present time of producing paper stock from crop wastes that will be cheap enough to use for printing newspapers. This is due chiefly to two causes—the low cost at which such paper can be produced from ground wood and the striking adaptability of ground wood pulp to the newspaper printing industry.

Not only is the grinding process the cheapest method of obtaining print paper of any character, but it also produces the highest proportion of pulp to raw material. While the two chemical processes which have been discussed produce on an average only about 1,000 pounds of pulp per cord of wood, the yield of ground wood pulp per cord is considerably over 2,000 pounds. Although lacking in durability, ground wood fiber, with the addition of a small proportion of stronger and better chemical fibers, answers its intended purpose admirably. It is light, reducing freight cost on the unprinted paper and postage on the printed. It is opaque, printing readily on both sides of moderately thin sheets, and, finally, it has excellent ink-absorbing qualities, fitting it unusually well for use on the high-speed presses of the present day.

Wood will probably be used for making news paper long after other materials have acquired importance in many branches of the chemical pulp industry. It should be added that chemical pulp papers, such as books and magazines are printed upon, consume over 1,000,000 cords more wood each year than that consumed by the ground-wood industry.

There is some skepticism as to the failure of the pulp-wood supplies, but this is certainly poorly grounded. During 1909 the quantity of spruce used was less by 40,000 cords than in 1907, but the cost was \$2,000,000 greater. Present efforts in connection with the reforestation of spruce and poplar are not extensive enough to produce any noteworthy effect upon the available supply within a generation. At the present rate of increase in consumption, it will require between 15,000,000 and 20,000,000 cords of wood to satisfy the demand for pulp and paper fiber in 1950. It will certainly be impossible to furnish this from the forests. If every acre cut over each year were reforested it would be twenty-five or thirty years, or possibly even longer, before the trees could attain sufficient size to warrant cutting. The forests can not recover from the overdrafts continually being made upon them; hence it is only a question of a limited number of years until paper fiber must be grown as a crop, as are practically all other plant materials entering into the economy of man. While the conservation of only a few of the by-products of the farms yielding paper fiber can be accomplished profitably in the near future and only a few plants promise to be money-makers immediately if grown solely for paper production, it seems very probable that raw products now scarcely considered may in a few years play an important part in the paper and pulp industry.