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Pulping and Papermaking Properties of Fertilized Wood

Introduction

In 1971, the total capacity of global pulp manufacture was nearly 110 million tons. Forecasts made by the FAO indicate that the demand is growing continuously, and will amount to about 176 million tons of pulp in 1980 (1). Most of this pulp is made from different types of wood raw material. As wood generally grows rather slowly at high latitudes, attempts have been to promote more rapid growth in the forests by such measures as the application of special fertilizers. This is one means of meeting the rising demand for wood.

Many important questions are connected with the fertilization of forests. Although wood density is regarded as an important criterion of wood quality. it will not be discussed here, as density in itself is of minor importance in the pulping process. Nevertheless, it is necessary to know the kind of pulp quality that is obtainable from fertilized wood material, and what its pulping yield is. As a result of fertilization, a tree begins to grow more intensively, at least if the forest type is originally poor; this means that a greater output of wood is obtained, evaluated as volume. However, more wood per hectare, according to weight, should be produced to ensure an adequate profit from the capital investment in fertilizing operations, and furthermore a corresponding output of pulp from the pulp mill.

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Fertilization can in principle be effected in two different ways. The first of these is the method normally applied in practice, in which forests almost ready for harvesting are fertilized. In the second method the forest is constantly fertilized, from the time the plantation is started. This method may seem expensive, but it can of course be utilized when very poor soil needs to be changed into wood-producing land. In this case, harvesting should be carried out when the trees attain the age of those normally cut for fibre production.

1. Previous investigations

The fertilization of forest land is not new. In Finland, the first fertilization experiments were begun about 60 years ago. By means of a charge of 1.500 kg of lime fertilizer per hectare, the annual wood growth could be raised by a mean value of about 0.7 solid cubic metres per hectare. In general, it is estimated that fertilization increases the annual growth by 1.5—3 solid cubic metres per hectare, particularly on the fertilization of a well-wooded forest almost ready for cutting (7).

The Finnish Pulp and Paper Research Institute has earlier made investigations into the papermaking properties of fertilized, wood raw materials (3, 4). These studies were concerned with the sulphate-pulping of wood grown on swamps. In the earlier study, the growing area was a treeless bog of Eriophorum vaginatum type. The sample wood was cut 11 to 15 years after the fertilization treatment, and put through a mill chipper. The material was screened, and cooked to sulphate pulp on a laboratory scale. The results obtained indicated that fertilization with only fine phosphates, as compared with wood ash fertilization, exerted an unfavourable effect upon both the tensile and burst strength values of the pulp, and the screened yield, but rendered the pulp easier to beat. The wood ash contained potassium, and also phosphorus (4).

Later research work related to nitrogen, phosphorus and potassium and their effect upon the pulp and papermaking properties of wood raw material from swamp pines 40-70 years of age that had been treated with these fertilizer chemicals. The results obtained were compared with those from wood grown before the fertilizing action. It was found that the fertilization slightly increased wood density, but as far as the extractive-free yield and strength properties of the sulphate pulps were concerned, no noteworthy effect was observable (3).

The main basis for this paper is provided by the results obtained in two different studies (5, 6). In the earlier, an investigation was made of the pulp and papermaking properties of pine and spruce grown on moraine soil; the fertilizing procedure was a two-step treatment with nitrogen—containing chemicals. In the atter study, young swamp-grown pines were cooked; in this case, the wood raw material had been grown under the effect of fertilizers containing phosphorus, potassium and nitrogen.

2. Experimental

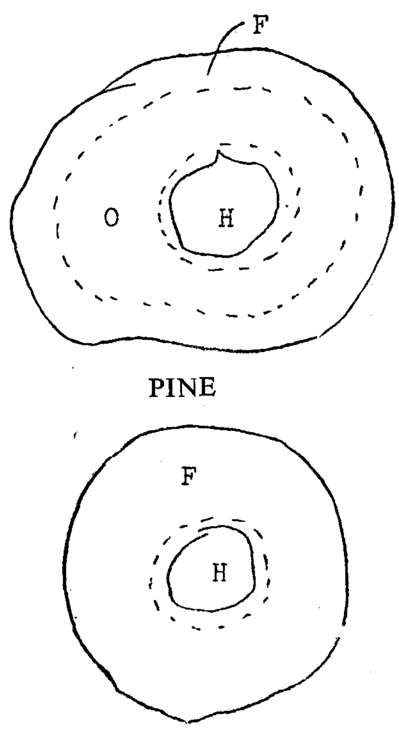
2.1. *Fertilization*

Table 1 illustrates that the pine and spruce trees grown on the moraine were fertilized on two different occasions, with a five-year period between the treatments. On the first occasion, ammonium nitrate was utilized, and on the second, urea; the first of these had a nitrogen content of almost 21%, and the second approximately 46%. The swamp-grown young pines were fertilized with varying dosages of fine phosphates, potassium salt and calcium-ammonium nitrate, with respective fertilizing values of 33% P_2O_5, 50% K_2O and 25% N.

2.2 *Forest soil and chipping*

The moraine soil was of Vaccinium type for the pines, and of a "fatter" Oxalis-Myrthillus type for the spruce. The situation is illustrated in Table 2, from which it is observed that no real reference samples could be taken from the swamp land concerned, since in practice no growth occurs on a swamp of this type unless the soil is fertilized. Consequently, tree samples for this purpose were taken from an unfertilized, but rich soil swamp; it was borne in mind that these trees should be of the same diameter and age. The swamp pines grew on a bog of Eriophorum type, from which the living soil surface had been removed; initially, after ditching, it functioned as a drying site. The swamp had inferior soil for growth (pH 4) before fertilization, and was poor in potassium, and particularly in phosphorus, as are bogs in general. Before fertilization, the location had practically no growth (2).

Three pine trees from the moraine soil were sampled both from unfertilized and fertilized areas; 5 and 6 spruce sample trees were correspondingly taken. Swamp pines were sampled by cutting 10 trees from every fertilizer combination. The logs were debarked, sawn into discs, and chipped in a laboratory chipper. The wood samples taken from the moraine were handled as illustrated in Figure 1, since it was necessary to separate the wood material grown during the 'fat years', as well as what had grown during the same time in the outer sapwood of the unfertilized reference samples. In the spruce discs, it was impracticable to separate the unfertilized sapwood without the risk of getting hartwood in the test material, as such sapwood is very small in quantity. Of course, no need existed for separation of the inner and outer parts of the sapwood of the swamp pines, which were fertilized at the age of two years, and thus produced only fertilized wood. They contained almost no hartwood.



F=(fertilized) sapwood
O=non-fertilized sapwood
H=hartwood

Figure 1. Chipping of fertilized and non-fertilized sapwood.

2.3. *Cooking methods*

All the pine and spruce samples were cooked in 15 cubic-decimetre tumbling, electric-heated digesters, according to the sulphate method, and under the following conditions:

charge of chips	2200 g.o.d. pine or spruce
active alkali	16 and 18% Na_2O of the wood
sulphidity of white liquor	30%
liquid-to-wood ratio	3.5:1
time of rise	(20°) 0.5 h 80°1.5h 170°C
time at 170°C	1.5 h

In autoclaves of the same type, the spruce wood was digested into sulphite pulps as follows:

charge of chips	2200 g.o.d. spruce
evacuation of air	final pressure 0.5m H_2O
liquor	1.2% CaO and 7% total SO_2
impregnation	3 kp/cm², 30 min
time of rise	(20°) 0.5 h 60°2.0 h 100° (3.5:1) 1.75 h 130°C
time at 130°C	3 and 4 h

The acid-to-wood ratio was adjusted to the final value at a temperature of 100°C.

The cooking was followed by washing with water, disintegration for 15 minutes in a rod opener, and final screening as a diluted slurry in a slot screen, with 0.3 mm slot width. The screened pulp was then analysed for chemical and physical properties.

3. Results

3.1. *Growth*

The pine grown on moraine soil improved its annual growth by 2.0-2.8 solid cubic metres a hectare as a result of fertilization. It was obvious that growth improved slightly after the second fertilization step. The mean wood amount was about 120 solid cubic metres per hectare, and the dominant tree height was correspondingly about 15 metres. The comparison of spruce growth was complicated by the great difference in the numbers of cubic metres per hectare of the tree stand.—The mean annual growth of the swamp pine was 1.8 solid cubic metres per hectare; this can be considered profitable growth. In this case the mean tree height was about 4 metres, and the frequency of stems was 2500 a hectare.

Table 3 illustrates the effect of fertilization upon the radial growth and density of a tree. In practice, the fertilization had not changed the wood density, although the density of outer sapwood in a slow-growing tree is normally observed to be higher than that of inner sapwood. Consequently, the wood density of fast-growing outer sapwood is of the same order as that of inner sapwood. The annual extra growth for moraine pine would thus be about 1.2 tons of dry wood per hectare as a mean value, with the wood density taken into account. Furthermore, mention is due that the corresponding value for young swamp pine is 0.6 tons at a mean wood density of 0.36 kg/dm^3.

3.2 *Yield*

Naturally, a pulp mill is interested in whether the extra growth of wood reported is comparable with normal wood grown under unfertilized conditions as far as pulping yield and pulp properties are concerned. Table 4 indicates that fertilization may diminish the pulp yield, calculated as extractive free pulp from extractive free wood material. However, the wood consumption of pine in cooking does not change by reason of compensation for higher wood density, as given in the table, when variation within the sample is taken into account.

The mean yield of the swamp pine was no higher than about 45% at a Kappa number of 35; this is obviously attributable to the low age of the trees. Potassium fertilization was found to be of great importance to the yield, as can be seen from Table 5. Fertilization with large amounts of potassium resulted in superior yield, whereas an increased charge of phosphorus simultaneously slightly diminished the yield. The yield can be returned to values as low as 44% if potassium is totally excluded, even if large quantities of phosphorus are applied at the same time.

3.3 *Fibre weight*

Spring-wood fibre has thinner walls than summer-wood fibre, and is thus more flexible. It is to be expected that fibre material grown under fertilization conditions is also of spring-wood fibre type, in view of its rapid growth. The analysis showed that fibres grown during the fertile period had in fact a clearly lower specific fibre weight than that of normal fibres. Figures in respect of fibre weight by length are listed in Table 5; in many cases, differences in papermaking properties are partially explicable by low fibre weight of the fertilized wood.

3.4 *Papermaking properties*

Table 6 contains details of some papermaking properties. In general, it can be said that the differences are rather small, but if the wood material grows continuously under fertilized conditions the pulp obtained will certainly possess exceptional properties. The results obtained with the fertilized swamp pine point in this direction, the fertilization vary clearly reduced the beating time, the tensile strength seems to be constant, but the tearing strength was diminined.

Summary

The observation that fertilization, from an economic standpoint, is mostly suitable for forests of high tree-volume content, which are at the same time ready for end-harvesting, leads to the conclusion that the relative amount of wood grown during a 10-year period is rather low, and consequently this part of the tree cannot to a great extent influence the pulp quality. This becomes even more evident when thought is given to the relatively small changes in quality resulting from fertilization.

The situation naturally differs when the trees are fertilized for the entire period, beginning at plantation; the results obtained with swamp pine make this evident. A slightly lower tear may thus be expected. The results obtained make it clear that the yield is inferior, although this is partly dependent upon the low tree age. For this reason, investigations of swamp pine should be repeated after say 20 years; this might enable a more adequate answer to be given to the questions raised.

REFERENCES

1. FAO Outlook for Pulp and Paper Consumption, Production and Trade to 1985, 1972, 66 p.
2. Huikari, O. — Paarlahti, K. Kivisuon metsänlannoituskokeet Kenttäopas, Helsinki 1966, 43 s.
3. Jensen, W.—Huikari, O.—Palenius, I. Lannoituksen vaikutus suolla kasvavan suomalaisen havupuun massan saantoon ja massan laatuun, Colloquium on Forest Fertilization, August 22nd — 26th, 1971, Jyväskylä, Finland
4. Jensen, W.—Virkola, N-E.—Huikari, O.—Paarlahti, K. Wood Grown in Fertilized Forests as a Raw Material for Pulp Manufacture Paper and Timber 46 (1964): 8, 443-452
5. Lönnberg, B. Oy Keskuslaboratorio — Centrallaboratorium Ab, Internal Report, 1972
6. Lonnberg, B.—Palenius, I. Oy Keskuslaboratorio — Centrallaboratorium Ab, Internal Report, 1970
7. Salonen, K. Metsänlannoituksen kehityksestä ja tuloksista Suomen Puutalous (1968): 3, 72, 75, 83

TABLE 1. Fertilization procedures

Fertilization	N	PKN
Forest	moraine	swamp
Fertilization year	n	n
Fine phosphates, kg/ha	—	200, 400, 600
Potassium salt, kg/ha	—	100, 200, 400
Calcium ammonium nitrate, kg/ha	—	200, 400, 800
Ammonium nitrate, kg/ha	400	—
Fertilization year	n+5	—
Urea, kg/ha	200	—
Wood samples cut	n+10	n+13
Fertilized years	11	12
Age of trees, years	30—40	15

TABLE 2 Fertilized forest types

Wood species	Fertilized	Fertilized with	Forest type
pine	no	—	VT
,,	yes	N	,,
spruce	no	—	OMT
,,	yes	N	,,
pine	no	—(rich soil)	swamp
,,	yes	P, K, N (poor soil)	,,

TABLE 3. Effect of Fertilization on wood density and radial growth

Wood species	Part of log	Fertilized	Density kg/dm	Radial growth mm/year
pine	O	no	0.44	1.6
,,	F	,,	0.48	1.5
,,	,,	yes	0.49	1.9
spruce	O	no	0.35	1.4
,,	F	,,	0.36	3.5
,,	,,	yes	0.34	3.7