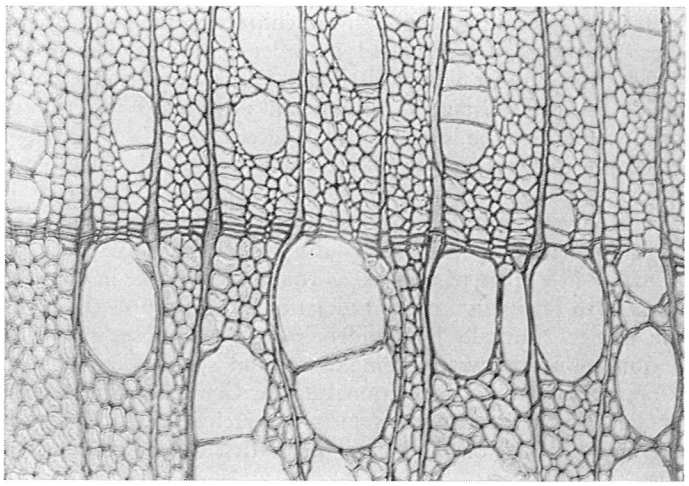
zochte cultivars een belangrijk hoger vochtgehalte heeft dan het spinthout. Er is een zeer sterke vochtgradiënt bij de overgang van kern naar spint; in één geval bedroeg het verschil zelfs 165 %. Het vochtgehalte neemt af van de voet naar de top van de boom, waarbij de verschillen in het kernhout groter zijn dan in het spinthout. Eveneens treden er soms grote vochtverschillen in horizontale richting op. Het natste spinthout bevindt zich aan de buitenzijde, terwijl het vochtgehalte van het kernhout het laagst is vlak bij het hart. Enkele cijfers mogen dit illustreren. Het gemiddelde vochtgehalte van het spinthout vlak aan de grens van het kernhout bedroeg bij P. 'Gelrica' op 1 meter hoogte van de grond 183 % (berekend op het geheel droge hout), op 11 meter hoogte was dit 110 %.
Voor het kernhout vlak aan de grens van het spint waren deze waarden resp. 246 en 177 %. Van buiten naar binnen gerekend verliep het vochtgehalte op 1 meter hoogte in het spint van 130 naar 110 % en in het kernhout van 177 naar 157 %.
Voor de andere cultivars werden soortgelijke resultaten verkregen.
Wat de volumedichtheid en het volumegewicht betreft, werden eveneens grote verschillen gevonden in het hout op verschillende plaatsen. Zoals bekend geeft de volumedichtheid aan het gewicht van de geheel droge stof per volume-eenheid in natte toestand, terwijl het volumegewicht aangeeft de verhouding van het gewicht tot het volume, beide onder dezelfde omstandigheden bepaald (hier bij ca. 15 % vochtgehalte).
De volumedichtheid van het hout neemt toe van de voet naar de top; dit is vooral uitgesproken bij P. 'Gelrica' en P. 'Robusta'. Voor het spint van P. 'Gelrica' op 1 meter hoogte in de stam werd een gemiddelde van 285 kg/m³ gevonden, terwijl dit op 19 meter hoogte 364 kg/m³ was. Voor P. 'Robusta' waren deze cijfers resp. 399 en 477 kg/m³. Hetzelfde beeld toonde ook de andere onderzochte cultivars.
Bij P. 'Robusta' werd een duidelijke afneming van de volumedichtheid gevonden van buiten naar binnen; bij P. 'Gelrica' was dit niet het geval.
Voor het volumegewicht gold in alle gevallen hetzelfde als voor de volumedichtheid.
Voor de gemiddelde waarden van de volumedichtheid van de drie onderzochte stammen werd bij P. 'Robusta' gevonden 378 kg/m³, voor P. 'Oxford' 369 kg/m³, voor P. 'Dorskamp' 331 kg/m³ en voor P. 'Gelrica' 297 kg/m³. Het hout van P. 'Robusta' was dus ca. 25 % zwaarder dan dat van P. 'Gelrica'.
De volumekrimp van het hout bleek bij toenemende hoogte in de boom af te nemen. Het hout van P. 'Gelrica' vertoonde de laagste cijfers.

c *Juveniel hout*
Uit de hier besproken onderzoekingen en een diepgaande anatomische studie van P. 'Gelrica' en P. 'Oxford' konden interessante gegevens worden ontleend voor de aanwezigheid van juveniel hout in populieren. Dit hout, dat in de jeugdperiode van de boom is gevormd, verschilt vrij sterk van het volgroeide hout. In het algemeen zijn de belangrijkste kenmerken van juveniel hout: lagere volumedichtheid en de daaruit voortvloeiende minder goede sterkte-eigenschappen, kortere vezellengte, grotere lengtekrimp en afwijkende chemische samenstelling. Allerlei industrieën die populieren verwerken, hebben dus belang bij de kennis over juveniel hout.
Het bleek uit de gegevens, verkregen uit het onderzoek, dat de juveniele periode voor P. 'Gelrica' op ca. 10–12 jaar kan worden gesteld en die voor P. 'Oxford' op 8–10 jaar. Ten naaste bij geldt eenzelfde periode voor P. 'Robusta', P. 'Dorskamp' en ook andere populieresoorten.

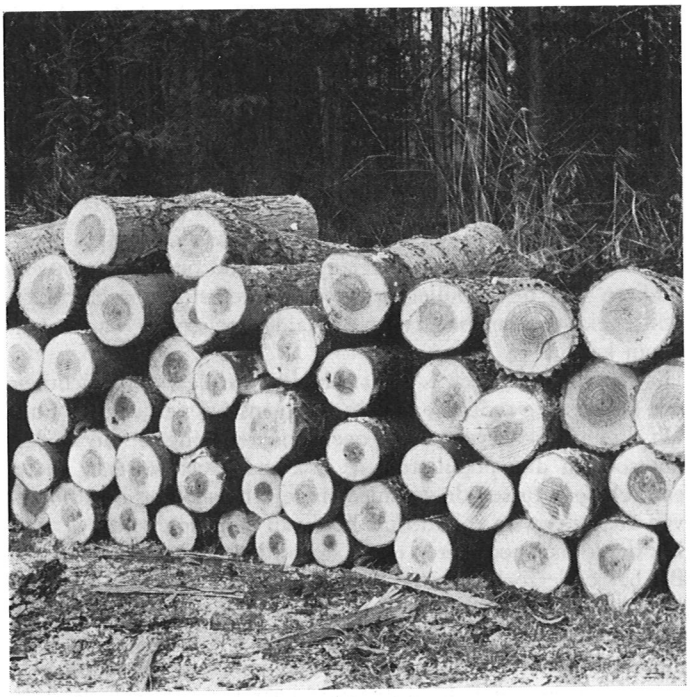
d *Niet-destructieve bepaling van de volumedichtheid*
In de inleiding is reeds het belang genoemd om in een jeugdig stadium van de populier gegevens te verkrijgen over de geschiktheid van het hout voor bepaalde doeleinden wanneer de boom kaprijp is.
Uit vroeger onderzoek is reeds gebleken dat de volumedichtheid een belangrijke indicatie is voor de eigenschappen van het hout. Uit literatuurgegevens, vnl. over onderzoekingen van andere houtsoorten dan populierehout, is komen vast te staan dat er een relatie is tussen de volumedichtheid bepaald op borsthoogte van de stam en de volumedichtheid van de gehele stam.
Dit dient voor populieren nader te worden onderzocht.
Bij het onderzoek naar de volumedichtheid van het hout van jonge bomen kon men zich het beste bedienen van een niet-destructieve bepalingsmethode. Hiervoor wordt de zg. boorkernmethode aanbevolen, waarbij met een holle boor monsters worden genomen vanaf de buitenzijde naar het hart van de stam. De boormonsters, in de vorm van cylindervormige dunne staafjes, kunnen gemakkelijk worden gebruikt voor de bepaling van de volumedichtheid.
Het Houtinstituut TNO zal in samenwerking met het Bosbouwproefstation te Wageningen dit onderzoek gaan uitvoeren.
Meer uitvoerige gegevens zijn te vinden in het tijdschrift „Populier" 2 (nr. 4) 1965; 5 (nr. 4) 1968; 9 (nr. 1 en 2) 1972, benevens in vele TNO rapporten aan de Nationale Populieren Commissie.



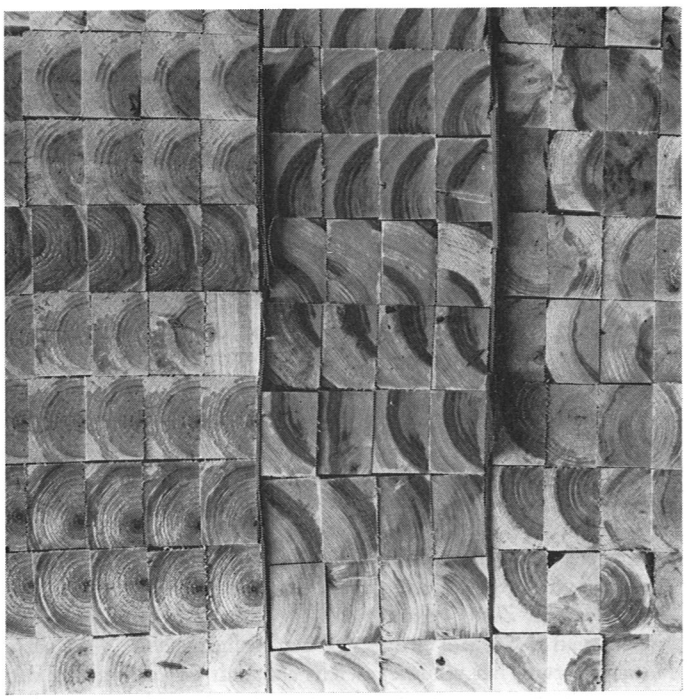
Microscopische opname van de dwarse doorsnede van hout van Populus species. De afbeelding toont het houtweefsel nabij de groeiringgrens (vergr. ca. 100 x).
*Microscopic view of the cross section of wood pf Populus species. The picture shows the wood tissue near the growth ring boundary (enlarged about 100 x).*
Foto: Houtinstituut

K. Griffioen / **Investigation on the properties of poplar wood**
Forest Products Research Institute TNO, Delft

**Introduction**
After the establishment of the Netherlands National Poplar Commission in 1948 it was soon recognized that in addition to the sylvicultural research on poplar it was very necessary to dispose also of technological data of this wood species. For in a country deficient in timber, like the Netherlands, poplar wood could supply a not unimportant share in the provision of the need for timber, already depending for far the greater part on



Papierhout.
*Pulp wood.* Foto: H. A. van der Meiden



Klossen van populierehout voor het vervaardigen van pallets.
*Poplar blocks for pallets.* Foto: Smolders, Borkel en Schaft

import. In this connection the fact that the poplar is a very fast-growing tree played an important part of course. Already after some decennia the tree can procure suitable wood for the industry.
Besides the fields of application already known, it would be useful to search for further purposes for this wood.
In later years still another point came to the fore. With the increasing sylvicultural research the cultivation of more various species of poplar was started in order to find those species which would grow very well under Dutch conditions, which would be very resistant to diseases and pests and which, moreover, would give the highest yield of wood.
From the industrial point of view this would only have sense if the wood is suitable for industrial purposes. Therefore it would be very significant to know the technological properties of the relevant species. Of course this knowledge must be available in a stage of the tree as young as possible, in order to be able to take this into consideration at the future choice of the species. Naturally it is evident that in most cases it will be a compromise between technological and sylvicultural factors.
From the beginning the National Poplar Commission has called in the help of the Forest Products Research Institute TNO for the investigations on poplar wood; the first order already dated back to 1949.

**Properties of poplar wood**

In general the anatomical, physical, mechanical and chemical properties of the wood of poplar are favourable for many purposes as solid wood as well as in the form of veneer (plywood) and as raw material for boards and for paper products. It is, however, very striking that in the Netherlands (and also in several other countries) poplar wood is not or hardly used in certain fields, e.g. the building industry, notwithstanding its suitable properties in this respect.
When, as in the following table, the properties of poplar and of spruce (being an important building wood species) are put side by side, we can state a very great similarity. (See table 1 in Dutch text)

This pleads for an intensification of the research on the properties of poplar wood and its further possibilities of application.

**Investigations carried out at the Forest Products Research Institute TNO**

In 1949 and following years the wood of several poplar varieties was investigated on physical, mechanical and technical properties. The technical properties were tested in co-operation with the woodworking industry (paper, clog, match and saw industry). Populus 'Robusta' was one of the six investigated varieties, a poplar with no love from the industry at that time. P. 'Robusta' was also involved in more recent research work.
Into the studies mentioned above also the influence of the various growing sites on the properties of the wood was drawn. The wood of some poplar varieties originating from certain growing sites had a low basic density with lower strength properties in agreement with this, while those from other sites had a high basic density with corresponding higher strength figures. This came to the fore very clearly with an extensive research on Populus 'Serotina' of two different growing sites, whereby in the one case the strength values were about 15 to 20 per cent lower than in the other case. In this connection not only the growing site but also a complex of other factors play a part, that can not be unraveled very easily.
In those years also extensive studies have been carried out on the presence of tension wood in poplars. This reaction wood has abnormal properties and is a nuisance for the wood working industry.
In the period from 1961 till 1965 an extensive and interesting research has been carried out on the industrial output of some poplar varieties in the match and in the clog industry. A part of the work was done in factories in co-operation with the industry. From those studies with 4 varieties (P. 'Marilandica', P. 'Robusta', P. 'Gelrica' and P. 'Regenerata') it appeared that there was no mutual variation in the output of clogs. This output, however, amounted to only 14 to 15 per cent, thus giving a loss of 85 per cent of waste!
In the match factory the yield of boxes together with sticks was

about 60 per cent for all varieties, however the ratio boxes to sticks varied considerably, being 22 to 49 per cent for the boxes and 11 to 39 per cent for the sticks. The need of poplar for the match industry is decreasing in consequence of the introduction of more and more cardboard for the boxes.
From 1968 an extensive anatomical, physical and mechanical research has been executed on the wood of Populus 'Robusta', P. 'Gelrica', P. 'Dorskamp' (3 Aigeiros clones) and P. 'Oxford' (a balsam hybrid). The investigated stems of P. 'Robusta' and of P. 'Gelrica' came from 22 years old trees grown in the North East Polder and those of P. 'Dorskamp' and P. 'Oxford' from 12 years old trees grown in East Flevoland. From each cultivar the stems of 3 trees have been studied.

a *Anatomical studies*
The microscopic investigation concerned the wood fibres of which the length, the diameter of the lumen and the thickness of the wall have been measured.
All the investigations showed that the length of the fibres increased from the heart to the periphery of the stem and decreased from the foot to the top of the stem. The same was valid for the thickness of the fibre wall. The diameter of the fibre lumen hardly increased from heart to periphery, but dropped a little from foot to top.
The longest fibres of P. 'Robusta' were about 1500 $\mu$m and the shortest about 650 $\mu$m. The fibre dimensions of P. 'Gelrica' varied from 1300 to 600 $\mu$m, of P. 'Dorskamp' from 1150 to 700 $\mu$m and of P. 'Oxford' from 1100 to 600 $\mu$m.
The diameter of the lumen (a measure for the thickness of the fibre) varied in P. 'Robusta' from 10 to 15 $\mu$m, in P. 'Gelrica' from 16 to 24 $\mu$m, in P. 'Dorskamp' from 13 to 20 $\mu$m and in P. 'Oxford' from 12 to 17 $\mu$m. It is evident that P. 'Gelrica' had rather thick fibres and P. 'Robusta' rather thin ones. The thickness of the fibre walls varied from about 2.4 to about 3.5 $\mu$m.

b *Physical investigations*
From the physical characteristics of the poplar wood the moisture content, the basic density, the specific gravity and the volumetric shrinkage have been determined.
It appeared that the heartwood of the four cultivars in green conditions had a considerably higher moisture content than the sapwood. There is a very steep moisture gradient at the transition zone from heartwood to sapwood; in one case the difference was even 165 per cent. The moisture content decreased from the foot to the top of the stem, the differences in the heartwood being greater than in the sapwood.
In some cases there were also great differences in the horizontal directions. The wettest sapwood was present near the periphery of the stem while the moisture content of the heartwood was lowest near the centre of the stem. Some figures may illustrate this. The average moisture content of the sapwood of P. 'Gelrica' near the transition zone of the heartwood was 185 per cent (calculated on the oven dry wood) at 1 meter height of the stem and at 11 meter it was 110 per cent.
For the heartwood near the transition zone to the sapwood these figures were 246 and 177 per cent respectively. At 11 meter height the moisture content in the sapwood dropped from 130 to 110 per cent from the periphery to the inside and in the heartwood from 177 to 157 per cent from the transition zone to the centre of the stem. Similar results were obtained for the other poplars investigated on moisture content.
With regard to the density and the specific gravity also considerable differences have been found at various places in the wood. As is known the basic density stands for the weight of the oven dry solid matter per volume-unity of the green wood and the specific gravity stands for the ratio of the weight to the volume, both under the same condition (in this case about 15 per cent moisture content).
The basic density of the wood increased from the foot to the top of the stem; especially in P. 'Robusta' and P. 'Gelrica' this was strongly marked. At 1 meter height the sapwood of P. 'Gelrica' had an average basic density of 285 kg/m$^3$ and at 19 meter height of 364 kg/m$^3$.
In P. 'Robusta' these figures were 399 and 477 kg/m$^3$ respectively. A similar tendency was present in P. 'Oxford' and P. 'Dorskamp'.
In P. 'Robusta' we found a clear drop of the basic density from the periphery to the heart of the stem; this was not the case in P. 'Gelrica'.
The average basic density of the 3 stems involved in these investigations was 378 kg/m$^3$ for P. 'Robusta', 369 kg/m$^3$ for P. 'Oxford', 331 kg/m$^3$ for P. 'Dorskamp' and 297 kg/m$^3$ for P. 'Gelrica'. The wood of P. 'Robusta' was about 25 per cent heavier than that of P. 'Gelrica'.
The results of the determination of the specific gravity showed in all cases the same tendency as the basic density.
Measurements of the volumetric shrinkage of the wood showed a decrease at increasing height in the tree. The wood of P. 'Gelrica' had the lowest shrinkage figures.

c *Juvenile wood*
From the investigations discussed above and from a more profound anatomical study on P. 'Gelrica' and P. 'Oxford' interesting data could be derived for the presence of juvenile wood in poplars. This wood formed in the youth period of the tree varies rather considerably from the adult wood. In general the most important characteristics of juvenile wood are: lower basic density and the corresponding lower strength properties, shorter fibres, greater longitudinal shrinkage and a different chemical composition. Many industries using poplar wood must be interested in the knowledge of juvenile wood.
From the data obtained from the investigations it appeared that the juvenile period for P. 'Gelrica' can be fixed on about 10 to 12 years and that for P. 'Oxford' on 8 to 10 years. Nearly the same period is valid for P. 'Robusta', P. 'Dorskamp' and also other poplar species.

d *Non destructive determination of the basic density*
In the introduction the importance is stressed to obtain in a young stage of the poplar tree data on the suitability of the mature wood for specific purposes.
From earlier research work it appeared that the basic density is a significant indication for the properties of the wood.
From literature data, especially of investigations on other wood species than poplar, it is evident that there exists a relation between the basic density at breast height of the stem and that of the whole stem. This must also be searched thoroughly for poplar wood. Investigating the basic density of the wood of young trees it is necessary to use a non-destructive method of evaluation.
In this case the so-called increment borer method can be recommended. With a hollow borer samples can be taken from the periphery to the heart of the tree. These borer cores, thin cylindrical sticks, can be used very easily for the determination of the basic density. The Forest Products Research Institute TNO will perform this investigation in co-operation with the Forest Research Station at Wageningen.
More extensive data can be found in the Netherlands periodical "Populier" 2 (nr. 4) 1965; 5 (nr. 4) 1968; 9 (nr. 1 and 2) 1972 and in many reports of the institute to the National Poplar Commission.