Spiral Grain in Beech, Variability and Heredity

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(Received December 1979 / January 1980)

Summary

Spiral grain is a severe defect of beech wood (*Fagus sylvatica* L.). Over acceptable limits, it leads to uneven shrinkage and warping during drying processes. Different considerations have been studied to inform foresters and tree breeders on genetic aspects of the defect : (a) phenotypic variability between trees of one stand; (b) relationship between fiber deviation and bark aspect; (c) variation of fiber deviation along the bole; (d) evolution with tree age; (e) heredity of the defect. Material used for considerations (a), (b) and (c) consists in 40 trees chosen as representatives of the general variability for shape in a 100 year old stand. Fiber deviation was observed at height 1 m for all trees and heights 1 m, 5 m and 9 m for twenty of them. Material used for consideration (e) is part of an open pollinated progeny test: eight families from mother trees with spiral grain, eight families from mother trees with early or late flushing taken as controls with respect to spiral grain. Literature results will be given for consideration (d). The method of observation consists in measuring on a radiographic film attached about the trunk the track deviation of a radioactive potassium solution injected under the film in outer layers of the wood during vegetation period. The bark deviation was measured on photos.

Results are as follow. (a) Although a high variability exists between trees, deviations over acceptable limits, 6 degrees, occur in only 8 trees out of 40. (b) There is a close relationship between deviation of fibers and of bark anomalies when visible. But 5 of the 8 trees with an over 6 degrees deviation would have been missed with only visual observations. (c) The variation of fiber deviation between heights of observation is fairly low, 6 degrees. Highly significant correlations exist between mean angles at heights 1 m, 5 m and 9 m. (d) Fiber deviation angles increase steadily from heart rings to outer rings whichever is the direction. (e) Narrow sense heritability calculated from family means, .66, show a strong additive genetic control. The concordance between directions of mother trees and of family means permits the thought of a good parent-offspring transmission of the defect.

The variability of spiral grain offers possibilities of selection. Its genetic control gives efficiency to the selection.

Key words: Beech breeding, wood characteristics, spiral grain, variation, heritability

Zusammenfassung

Drehwuchs ist ein schwerer Holzfehler bei Buche (*Fagus sylvatica* L.). Beim Überschreiten von Grenzwerten führt er zu ungleichem Schrumpfen und Verwerfen während des Trocknungsprozesses. Verschiedene Fragen sind untersucht worden um genetische Aspekte dieses Fehlers zu klären:

a) Phänotypische Variabilität zwischen Bäumen eines Bestandes;
b) Beziehung zwischen Faserabweichung und Rindenbild;
c) Variation der Faserabweichung in unterschiedlicher Höhe;
d) Entwicklung mit dem Baumalter;
e) Erblichkeit des Drehwuchses.

Für die Fragen a), b) und c) wurde eine repräsentative Stichprobe von 40 Bäumen in einem 100-jährigen Bestand ausgewählt. Die Faserabweichung wurde in 1 m Höhe für alle Bäume und in 5 m und 9 m Höhe für 20 Bäume bestimmt. Das Material für die Frage e) ist ein Teil einer Nachkommenschaftsprüfung mit Halbgeschwisterfamilien: acht Familien von Mutterbäumen mit Drehwuchs, acht Familien von früh- und spät austreibenden Mutterbäumen als Kontrollen. Ergebnisse einer Untersuchung von Knigge und Schulz werden für die Beantwortung der Frage d) herangezogen.

Die Untersuchungsmethode besteht in der Messung eines radiographischen Films, der um den Stamm gelegt wird. Dieser zeichnet den Weg radioaktiven Kaliums 42 auf, das unterhalb des Films in den äußeren Holzmantel injiziert wird. Die im Rindenbild sichtbaren Abweichungen werden auf Fotos gemessen.

Ergebnisse: a) Obwohl zwischen Einzelbäumen eine erhebliche Variation auftritt, wird die Grenze von 6 Grad Faserabweichung nur bei 8 von 40 Bäumen überschritten. (b) Es besteht eine enge Beziehung zwischen sichtbaren Rindenanomalien und Faserabweichung. (c) Die Variation der Faserabweichung zwischen den Beobachtungshöhen ist ziemlich gering, maximal 6 Grad. Hochsignifikante Korrelationen bestehen zwischen den Faserwinkeln in 1 m, 5 m und 9 m Höhe. (d) Eine Beziehung zwischen Zweigdrehung im Alter 10 und Stärke des Drehwuchses im Alter 30 besteht nicht. Faserabweichungen nehmen vom Stammzentrum zu den äußeren Jahrringen bei allen Drehrichtungen ständig zu. (e) Die aus den Familienmitteln errechnete Heritabilität im engeren Sinn (0,66) zeigt eine starke additiv genetische Kontrolle. Die Übereinstimmung der Drehrichtung zwischen Mutterbäumen und Nachkommen weist auf eine strikte Übertragung des Fehlers auf die Nachkommen hin. Die Variabilität des Drehwuchses eröffnet Selektionsmöglichkeiten. Die genetische Kontrolle ermöglicht eine wirksame Auslese.

Résumé

La fibre torse est chez le hêtre (*Fagus sylvatica* L.) un défaut grave qui entraine des déformations du bois ou son éclatement au séchage. Diverses considérations doivent être abordées pour informer forestiers et améliorateurs sur les aspects génétiques de ce caractère: (a) variabilité phénotypique entre arbres d'un peuplement, (b) relation entre l'angle du fil du bois et les déformations de l'écorce, (c) variation de l'angle du fil du bois avec la hauteur d'observation dans l'arbre, (d) évolution de l'angle du fil du bois avec l'âge, et (e) transmission héréditaire du caractère.

Le matériel utilisé pour les points (a), (b) et (c) consiste en 40 arbres d'un même peuplement, âgés d'environ 100

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*) This paper is dedicated to Professor Dr. Wolfgang Knigge on his 60. birthday. A German translation has been published in Forstarchiv 51: 41—47 (1980)

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Photo 1. — Overbark aspect of spiral grain, deviation of wood fibers from stem axis.

ans, choisis comme représentatifs de la variabilité générale pour la forme. Les observations de la déviation de la fibre ont été réalisées à 1 m pour l'ensemble et à 5 et 9 m pour vingt arbres. Le matériel utilisé pour le point (e) est une partie d'une plantation comparative de descendances maternelles. Huit descendances proviennent de mères à fibre torse, huit descendances proviennent de mères à débourrement végétatif précoce ou tardif, sans fibre torse apparente, choisies comme témoin. Une observation sur 10 à 12 arbres par famille a été réalisée. Des résultats bibliographiques sont donnés pour (d).

La technique d'observation consiste à suivre sur un film radiographique plaqué autour du tronc la trace d'une solution de potassium radioactif injecté dans les couches externes du bois sous le film, en période d'active circulation de sève. La déviation de l'écorce a été mesurée sur des photos des troncs.

Les résultats montrent que: (a) il existe une variabilité marquée mais que des angles de déviation supérieurs à 6 degrés — limite acceptable pour l'utilisation en déroulage — n'ont été trouvés que sur 8 arbres parmi les 40 étudiés; (b) il existe une étroite corrélation entre la déviation des fibres du bois et celle des déformations de l'écorce lorsqu'elles sont visibles. Le risque est grand pourtant de manquer des arbres sans déformation de l'écorce mais à fibre torse marquée, cinq des huit arbres précédents sont dans ce cas; (c) on trouve une variation assez peu importante de la fibre torse d'un niveau à l'autre dans un arbre — 6 degrés au maximum — et des corrélations élevées entre les moyennes d'observations des différents niveaux; (d) l'angle des fibres augmente d'une façon stable du coeur vers la périphérie que ce soit vers la gauche ou vers la droite; (e) l'héritabilité calculée à partir des moyennes de descendances — 0.66 — prouve un contrôle génétique additif élevé. La concordance entre le sens de déviation des mères et des descendances permet de faire l'hypothèse d'une bonne transmissibilité héréditaire du caractère.

La variabilité de ce caractère offre des possibilités de sélection, son héritabilité démontre l'efficacité de cette sélection.

1. Introduction

Spiral grain deviation of wood fibers from stem axis *(Photo 1)* is considered as a severe defect in beech *(Fagus sylvatica* L.) when its angle reaches high values. The acceptable limits seem to be 10 degrees for saw timber and 6 degrees for veneer (KRAHL-URBAN, 1953). The consequences of spiral grain in lumber are either technological and appear during the drying processes (uneven shrinkage, warping) or economical. In France prices may be lowered by 25 % and even more in Germany (up to 40 %).

To judge the possibilities for influencing this characteristic the principal considerations are:

(a) phenotypic variability of the fiber deviation angle between trees at a given level
(b) relationship between this angle and aspect of the bark
(c) variation of this angle along the tree bole
(d) variation of this angle with the tree age
(e) heredity of the defect.

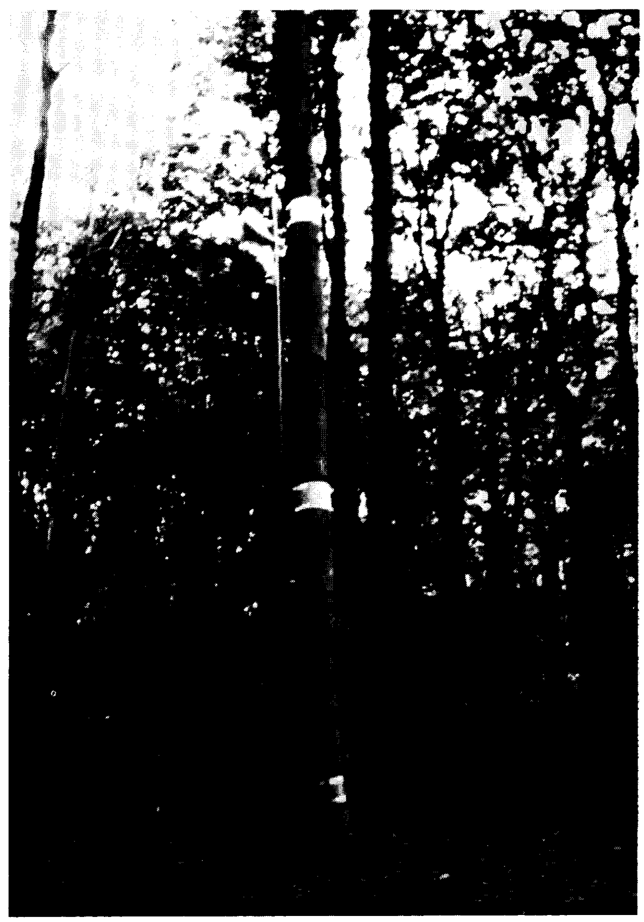


Photo 2. — Measurement of fiber angle in old beech trees at heights 1 m, 5 m and 9 m.

2. Material

Observations and measurements concerning the above mentioned points (a) (b) and (c) were made in France in a 100 years even-aged stand in Lyons State Forest, near Rouen. In this stand, on an approximately 10 ha area, 40 trees were chosen as representatives of the general variability for shape. The fiber angle has been measured for 20 of them at height 1 m, 5 m and 9 meters *(Photo 2)*; for the 20 others, at 1 meter only.

Observations and measurements concerning point (e) were made in the Federal Republic of Germany on 30 years old trees in an open pollinated progeny test established by Krahl-Urban in 1955. Krahl-Urban (1962) describes this test situated in Bramwald, Lower Saxony. The purpose was to determine if characteristics observable on standing trees, such as early or late flushing, rough bark, bole straightness, forked stem, crotch angle and spiral grain, are transmitted from one generation to the next. Selected for this comparative test, planted at a distance of 1 × 2 m, were 8 families with spiral grain and 8 families in the nearest plot which originated 4 from late and 4 from early flushing mother trees, these were considered as controls with respect to spiral grain. Each family was represented by 10 or 12 trees. The fiber deviation angle was measured at height 1 meter, approximately; any variation in this height was connected with the presence of branches or bark anomalies *(Photo 3)*.

Consideration (d) was impossible to study with the method applied. Literature results will be given.

3. Method

The method applied is non destructive. A ^{42}Potassium chloride solution is injected in the outer layers of the wood during the period of fast sap ascension. The radioactivity is tracked on autoradiographic film attached about the trunk immediately above the injection point. A detailed description of this technique is written by Keller and col. (1974). Since then it has often been utilized by Arbez and col. (1978) and Birot and col. (1979) on conifers and Birot and col. (1980) for broadleaves.

Considering the importance of high accuracy for the estimation of fiber angles, emphasis was layed on precise determination of bole generating lines. A topographic device, tacheometer, was used for the mature trees *(Figure 1)*. For younger trees, a metallic dihedron was applied on the bole. The generating line was then considered as parallel to the device's edge *(Figure 2)*.

The overbark estimation of wood fibers deviation was done from photos of the bole taken at the same levels as ^{42}K injecting points. Angles were measured on the screen projected photos. Such measurements are only possible when boles show longitudinal anomalies such as grooves, hollows or fissures. No angle transformation was applied to correct parallax resulting from photos taken at ground level to heights 5 and 9 meters; the apparent angle was decidingly similar to that which a standing observer could see from the ground.

Observations were made in France from June 21rst to June 23rd 1977 and in F. R. Germany from June 26th to June 28th 1979.

4. Results

4.1. Phenotypic variability

Angles measured on radiographs

Figure 3 gives for each observation level the number of trees per deviation angle class. The class limits are fixed by utilization criteria: less than 6 degrees in deviation angle for veneer and less than 10 degrees, for saw wood.

Among the 40 trees analysed at height 1 meter, 32 have a fiber deviation angle below or equal to 5 degrees (80 per cent); only one has an angle over 10 degrees. If individual tree values are considered, at height 1 meter, 24 trees have wood fibers spinning rightwards, 6 leftwards and 10 have no deviation at all.

Figure 4 shows the variation of mean fiber angle with height of measurement in the tree. It appears that irregardless of the population studied — leftwards deviating trees, rightwards deviating trees, all trees — mean values shift from right to left ascending from the base to the upper part of the bole. On an average, this modification is small: .9 degrees for the average tree and 2.7 degrees

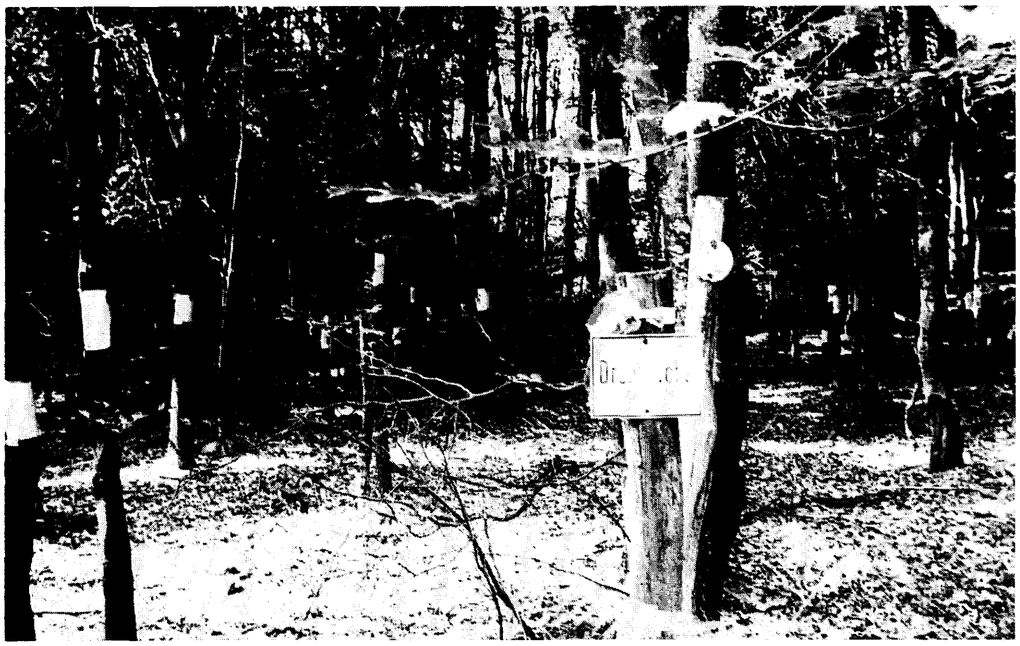


Photo 3. — Measurement of fiber angle in young beech trees at height 1 m approximately.

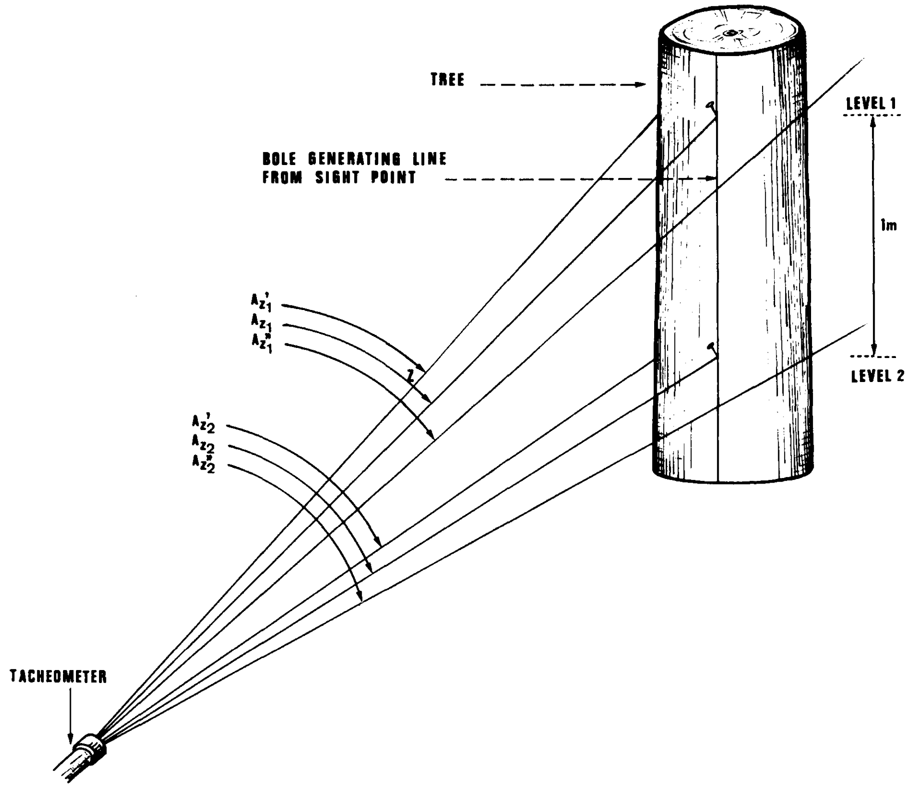


Figure 1. — Optical determination of bole generating lines.
At level 1 bearings of tangents to bole from sight point are taken: Az_1' and Az_1''. The bearing of the generating line is calculated as the arithmetic mean:

$$Az_1 = \frac{Az_1' + Az_1''}{2}$$

The sight line of the tacheometer is fixed at value Az_1. A nail is planted on the corresponding point of the bole. The same process is repeated at level 2. A rular, applied against nails, enables drawing the generating line.

for leftwards deviating trees. Variations are rather higher if individual values are considered, 6 degrees between values separated by 4 meters only.

Table 1 shows a very close relationship between values measured at different heights. It appears possible to estimate values at any height with use of the regression equation.

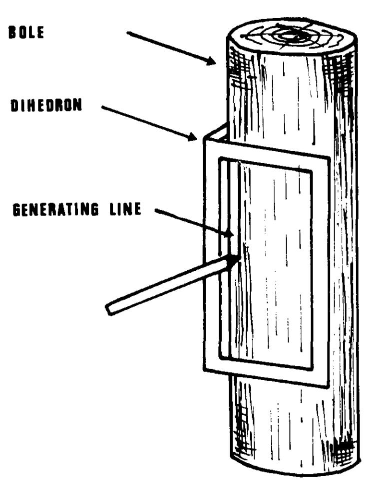


Figure 2. — Determination of bole generating line in younger trees, laying parallel to edge of dihedron.

Angles measured on photos

Photos of the boles have been taken only when bark anomalies existed: grooves, hollows or fissures. The following results are based on 29 measurements including all levels. Angles vary within the same value range as those taken from radiographs, 6 degrees leftwards to 18 degrees rightwards. In the Lyons stand, the typical case shown in photo 1, although impressive, is rare. As a matter of fact, the fiber angle deviation of that tree varied between 7 and 9 degrees according to measurement height, irregardless of measuring method used. This tree could at least be used for saw wood; but its external appearance would certainly have an unfavorable influence on potential buyers.

4.2. Validity of bark observations for wood deviation estimation

Figure 5 shows the relationship between bark deviation and fiber deviation for 29 pairs. The high values of the correlation coefficient permits the thought that elimination of trees showing a deviation of the bark will be quite efficient, at least with 100 years old trees.

Nevertheless, this appreciation is with exceptions because among the 8 trees having an over-6-degrees fiber deviation 5 had not been detected with an overbark observation; and among those 5 trees, appeared one with the most important deviation of our sample, 13 to 14 degrees according to heights of measurement.

The possibility to miss trees with high fiber deviation seems to occur quite frequently, the ^{42}K method is probably too expensive to be applied in normal forest management. But on the contrary in stands certified for seed production, where large spacing is needed for optimal fructification and where each tree takes an important part in seed production, a carefull selection should take place. Among the characteristics, spiral grain, if it is heritable, should be considered with great attention.

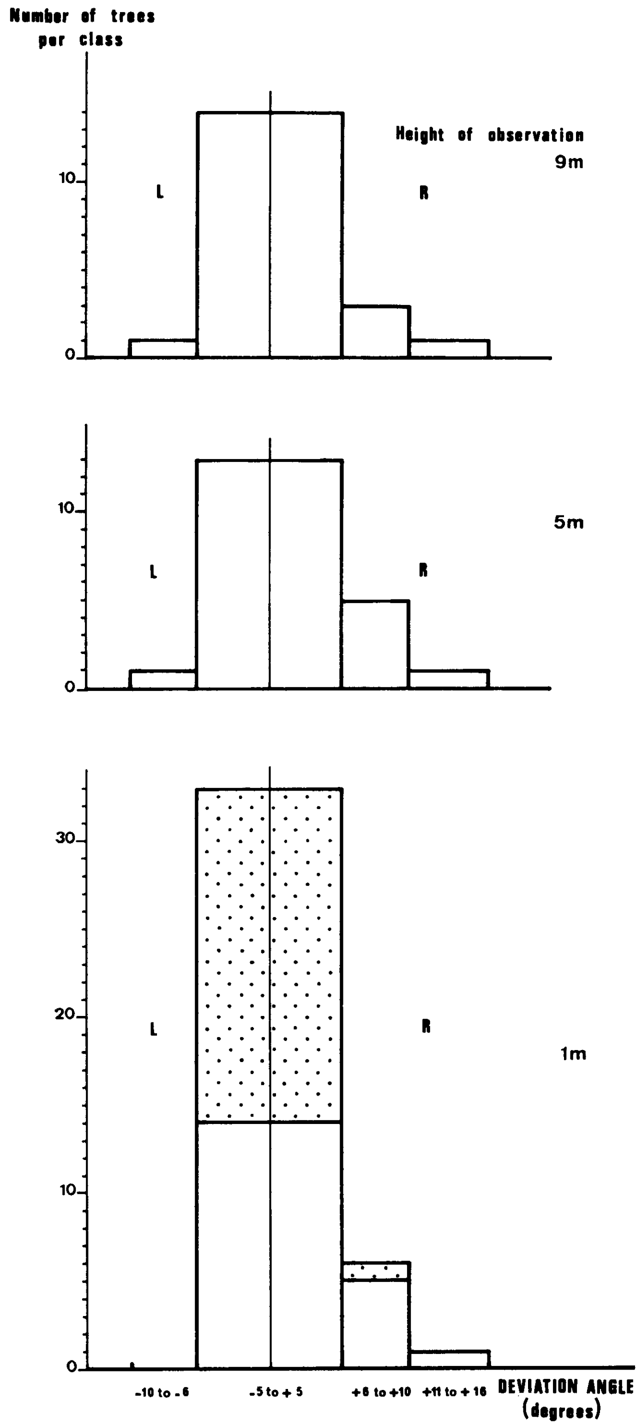


Figure 3. — Number of trees per deviation angle class. Part with dots represents trees measured at level 1 meter only. L: left; R: right.

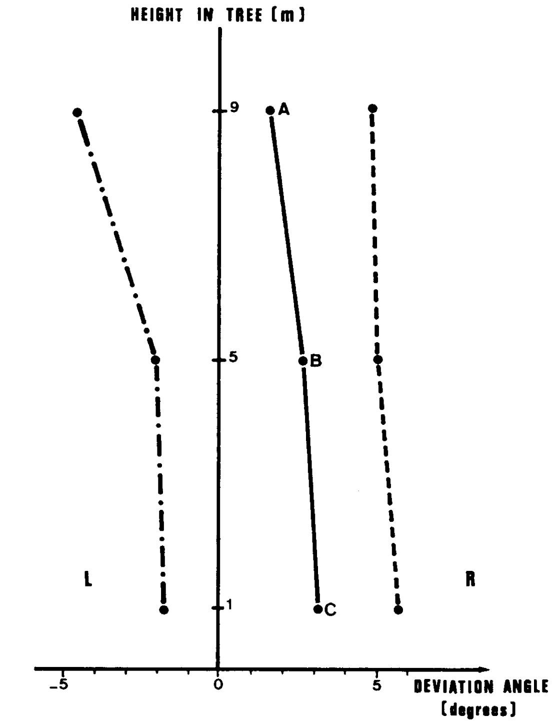


Figure 4. — Fiber deviation angle according to height of measurement on the bole. L: left; R: right. There is a statistic difference between mean values at height 9 m (A) and the two others (B and C), but none between values at heights 1 and 5 meters.
—.—.—.—.—.— 6 trees with leftward deviation
— — — — — — 14 trees with rightward deviation
——————— mean value of 20 trees.

Table 1. — Correlation coefficient between values measured at different heights

Height in tree	1 m	5 m
5 m	0,84***	
9 m	0,90***	0,93***
*** significant at 1 per cent level		

4. 3. Validity of early observations of spiral grain

Krahl-Urban (1962) published the observations of spiral grain in the 10 years old progenies. He observed the plants within a half-sib family which showed obvious branch twisting. He took this characteristic as an indication of spiral grain. It is of interest to follow this prediction in the 30 years old material. The plantation was thinned. However, since this was performed according to regular silvicultural procedure, only minor family composition influences could occur with respect to spiral grain: thus little effect upon our results can be expected.

Figure 6 gives the correlation for the family means, which is nearly zero. But if one considers the percentage of trees in each family having at least one degree fiber deviation, the correlation is highly significant, 0.68. This could mean that Krahl-Urban's method of assessing spiral grain from branch twisting is good for detection of any defect but not for an early possibility to measure it.

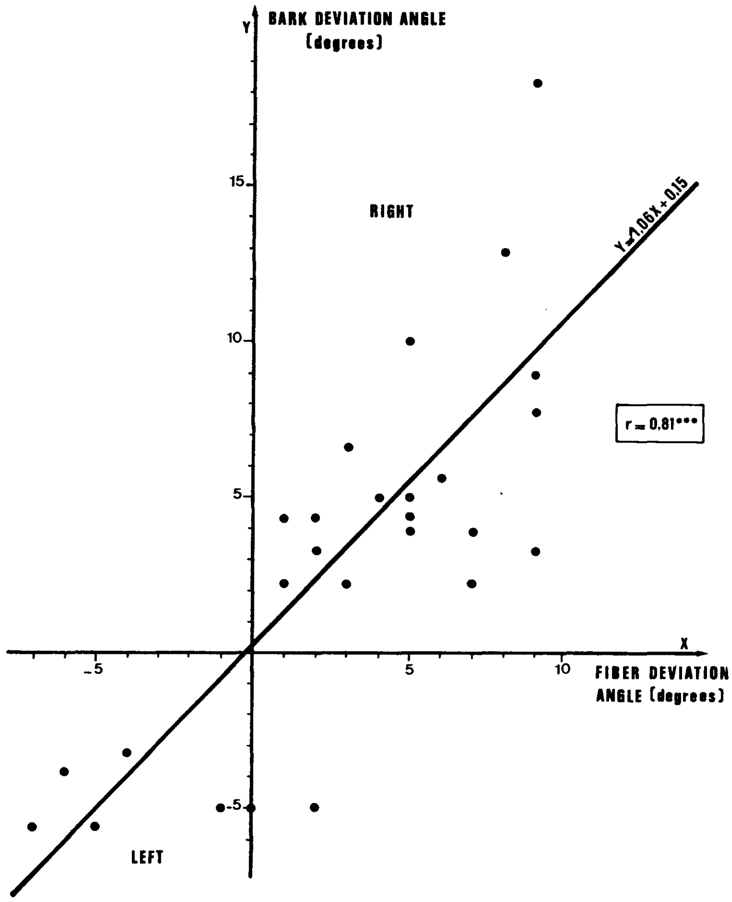


Figure 5. — Correlation coefficient and regression line between bark deviation and fiber deviation angles, including all measurements levels.

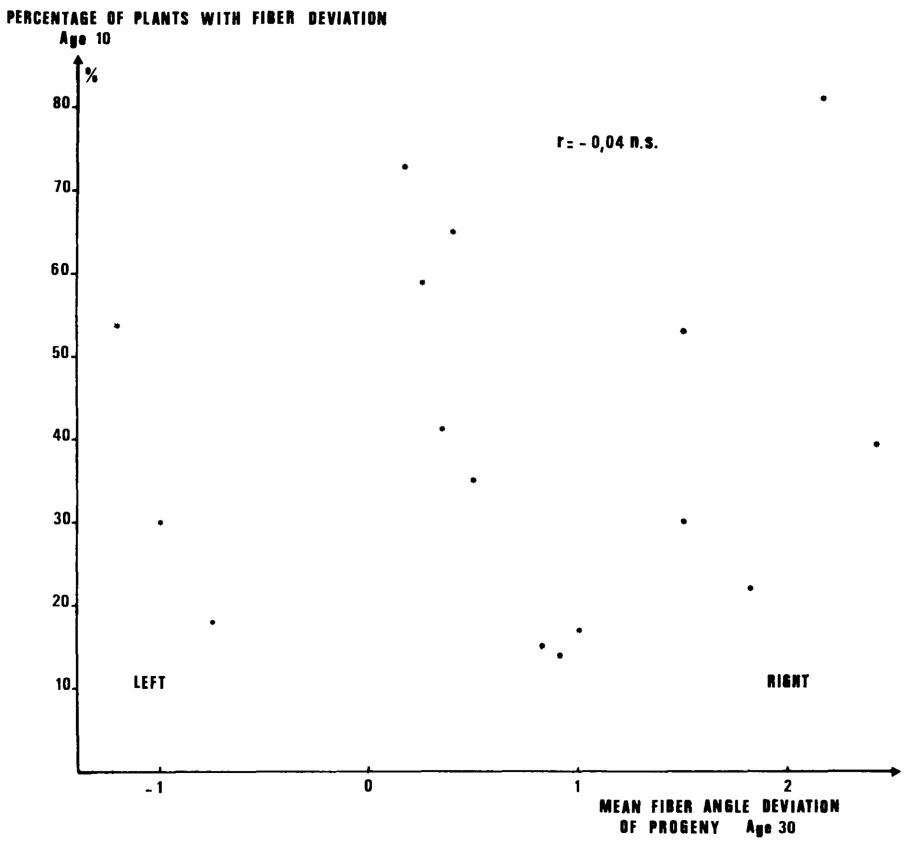


Figure 6. — Correlation of fiber deviation at age 10 with age 30.

4. 4. *Heredity of spiral grain*

In the progeny test established by Krahl-Urban, no bark deviation was noticeable. The only possible method to determine spiral grain was with ^{42}K.

Figure 7 gives mean angles for each progeny. The progeny numbers are distributed according to the direction of the fiber deviation in the mother trees (leftwards, no apparent deviation, rightwards). These numbers are the original ones given by Krahl-Urban.

Angle values. The family mean values are below 2.5 degrees. But individual values reach 7 degrees. The number of trees over or equal to 6 degrees (the outer limit for veneer) is 6 out of 188 (3 per cent). The within progeny variation is fairly high; the most important case (progeny no 42) reaches 11 degrees (from 7 leftwards to 4 rightwards). The distribution of individuals according to fiber deviation angle is as follows:

leftwards	37 (20 per cent)
no apparent deviation	81 (43 per cent)
rightwards	70 (37 per cent).

Variability between family means. The variance analysis (*Table 2*) shows variability between family means. The narrow sense heritability given by the ratio

$$h^2_{ns} = \frac{\sigma^2_A}{\sigma^2_T} = \frac{4\,\sigma^2_f}{\sigma^2_f + \sigma^2_w}$$

σ^2_A = additive genetic variance
σ^2_T = total variance

has a value of .66. This value means that in these progenies spiral grain is under strong additive genetic control.

Relationship between mother trees and progenies. The available information about individual mother trees is:

— no. 15, 4 to 5 degrees leftward fiber deviation
— no. 28, 6 to 8 degrees rightward fiber deviation
— no. 29 and 42, leftward deviation
— no. 35, 46, 79 and 90, rightward deviation

No information about spiral grain has been found in Krahl-Urban's observations about trees no. 48, 52, 64, 72, 75, 77, 80 and 94 which we considered as controls with respect to spiral grain. Since he made notes of all obvious characteristics of the mother trees included, it is sure that there were no visible and important bark deviations.

Table 2. — Analysis of variance

Source of variation	df	Mean squares (MS)	Estimations	F
Progenies	f-1	MS_f	$\sigma^2_w + k\,\sigma^2_f$	$\frac{\sigma^2_w + k\,\sigma^2_f}{\sigma^2_w}$
Error	f (k-1)	MS_w	σ^2_w	

f = number of families
k = average number of individuals per family
σ^2_f = variance between family means
σ^2_w = variance of error

Following remarks can be made from *figure 7:*

— The direction of the deviation between mother trees and their progenies is connected in 7 cases out of 8. The case of family 29 cannot really be considered as an exception, as its mean value is so low.

— The group of progenies from mother trees chosen for their rightwards fiber deviation is statisticaly different from that of mother trees with leftwards deviation.

— The progenies chosen as controls have, however, mean deviation angles distributed on just about the same range as progenies from mothers with spiral grain.

Relationship between fiber deviation and vigor. The individual tree diameters have been measured at the level of injection of ^{42}K. No correlation exists between diameter and fiber deviation. Vigor does not appear to be a factor of variation for spiral grain.

5. Discussion

The three first considerations were:

(a) Phenotypic variability of the fiber deviation angle between trees at a given level,
(b) Relationship between this angle and aspect of the bark,
(c) Variation of this angle along the tree bole.

It is now possible to reply that spiral grain is a defect which has varying importance and which does not reach extreme values in the samples studied; the range values determined lie between 7 degrees leftwards and 13 degrees rightwards. It is also interesting to note that the percentage of individuals with values over 6 degrees is low. This impression, already known by foresters, is now confirmed by the parallel connection between fiber deviation and

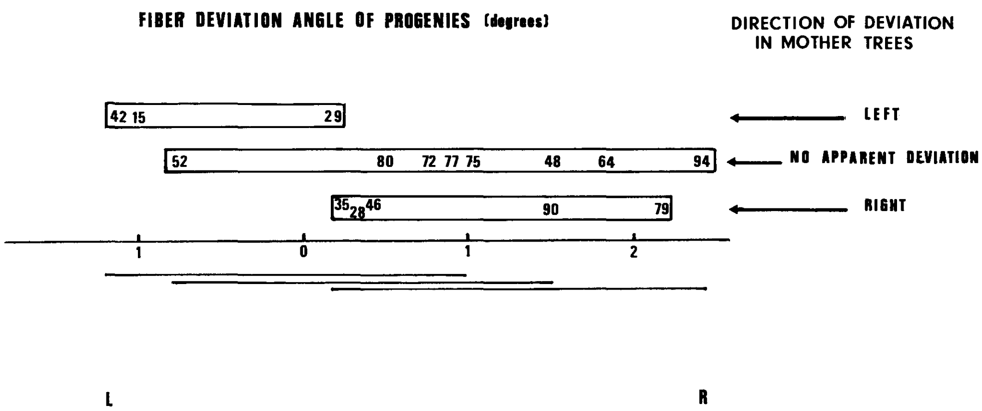


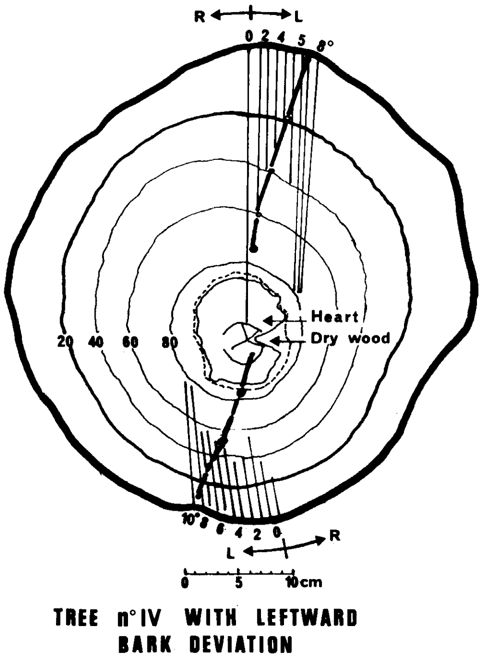
Figure 7. — Mean deviation angle for each progeny. Fisher test, F = 3.31 significant at 1 per cent level. Duncan test shows progenies differing significantly.

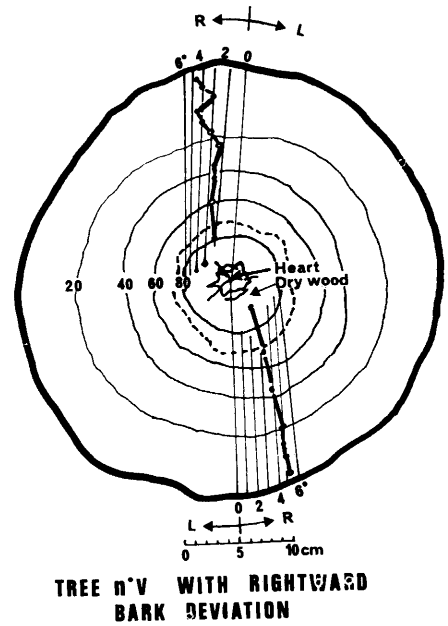
direction of bark defects when visible. Emphasis must be given to this because this connection does not exist in conifers and is without evidence in *Eucalyptus dalrympleana*. On the contrary, it exists clearly in *Quercus petraea* (Birot and col., 1980).

Finally, with the close connection present between angles measured at different levels in trees, it is possible to calculate, with good accuracy, angles at any level up to 9 meters when a measurement is possible elsewhere on the bole. This finding is important in beech where bark defects, when they exist, are not always visible along the total lenght of the bole.

To consideration (d) of fiber angle variation with tree age, these data were not obtained because of difficulties in finding a nondestructive method; additionally, it was thought that the direction of single fibers within an increment core (diameter 5 mm), a possible method, may be different to the other fibers of the bole. With this in mind, the success of the studies performed in Nancy (France) at the Station de Recherches sur la Qualité des Bois, in Centre National de Recherches Forestières, is prevalent to our research. The importance is connected to the foresters and scientists, who need a quick answer for their management based on early and accurate information. Nevertheless, the interesting work of Knigge and Schulz (1959) must be mentioned. The authors have shown that fiber deviation angle increases regularly from the center to the outer rings of the bole sections, either rightwards or leftwards when evident deviation was visible on the trees. Such a regularity does not exist in the tree without visible defect overbark (*Figure 8*). Trees IV and V studied by Knigge and Schulz show that at age 30, fiber deviation angles are somewhat near 2 degrees, a result which is in good harmony with our own observations.

The last consideration which we tried to answer is the heredity of the spiral grain.





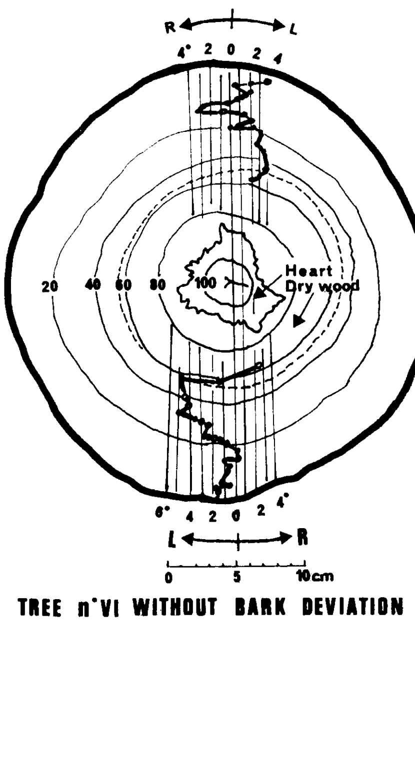


Figure 8. — Evolution of fiber deviation with age in beech. (from Knigge and Schulz 1959).

The progenies of mother trees, selected to be without spiral grain, have mean values distributed on the same range as those from mother trees chosen with spiral grain; there could be two explanations:

1. There is no strict inheritance of spiral grain.
2. Spiral grain was not detected during selection.

The answer seems to be quite clear according to the results:

— A strong additive genetic effect has been shown, 66 % of the total variance.
— The direction of the fiber deviation is the same in mother trees and in progeny means in 7 cases among 8.
— There is no overlapping between progenies from mother trees with leftwards fiber deviation and that from mother trees with rightwards fiber deviation.

Why then have mother trees, considered without spiral grain, not given progenies without spiral grain at all or at least with very low values? Two factors certainly interfere:

— The young age of the progenies correspond with low angle values (KNIGGE and SCHULZ, 1959).
— The possibility that mother trees, considered as early or late flushing by KRAHL-URBAN, included in our measurements, did have spiral grain, but not visible overbark.

To illustrate the second factor, 5 trees out of 8 with a fiber deviation angle over 6 degrees had not been visually detected in the sample of Lyons forest.

6. Conclusion

Spiral grain is a severe defect in beech. Its occurrence is impossible to detect directly in young stands. Undesirable trees will need to be eliminated because of their ability to transmit this characteristic to the next generation. In normally managed stands this selection should be made on the basis of visible bark anomalies. The efficiency of such a selection will not be 100 %. In stands selected for seed production, more accuracy is desired. The method of applying an easy to handle radioactive solution is a good detection device.

Acknowledgements

We wish to thank very much Mr. GOURLEZ and Mr. JOLY from Centre d'Etude Nucléaire, Section d'Application de la Radioactivité, for their effective help in applying 42 K, Mr. JOSEF SVOLBA from Niedersächsische Forstliche Versuchsanstalt for his help during the field work in Bramwald, Mr. PIERMANT from Centre de Recherches Forestières, Station d'Amélioration des Arbres Forestiers for his help in the field work in France and Miss BARBARA MCCUTCHAN from Niedersächsische Forstliche Versuchsanstalt for reading and correcting the manuscript.

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