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# Application of the Pilodyn in Forest Tree Improvement

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# APPLICATION OF THE PILODYN

# IN

# FOREST TREE IMPROVEMENT

by

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**DANIDA FOREST SEED CENTRE**

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Danida Forest Seed Centre (DFSC) is a Danish non-profit institute, which has been working with development and transfer of know-how in management of tree genetic resources since 1969. The development objective of DFSC is to contribute to improve the benefits of growing trees for the well-being of people in developing countries. The programme of DFSC is financed by the Danish Development Assistance (Danida).

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## FOREWORD

The 'Pilodyn' is an instrument for determination of wood density. This Technical Note describes the 'Pilodyn', how to use it, and discusses its application in tree improvement.

This Note is an updated version of DFSC Technical Note No.2 by E.B. Lauridsen, K. Pinyopusarerk and C. Kanchanaburagura from May 1983.

Figure 2 is used with the kind permission of the distributor of the 'Pilodyn', Kai R. Spangenberg, Hoersholm, Denmark.

Figure 1. The Pilodyn in use for evaluation of wood density in the international provenance trials of *Gmelina arborea* in Andra Pradesh, India. (Photo: H. Keiding, 1987).

# 1. INTRODUCTION

Wood density (wood specific gravity) is of key importance to the value of timber and pulpwood. It is highly correlated with major strength characteristics and with pulp and paper properties. Wood density is a complex character, determined by several factors, including cell diameter and cell wall thickness, relative properties and proportions of earlywood and latewood, cellulose and lignin content, as well as content of extractives.

Wood density is one of the more heritable and economically important traits. Therefore it is highly desirable to include this trait in tree improvement programmes in combination with other traits, e.g. growth, quality and pest resistance. Many tree improvement programmes have wood density as one of the selection criteria (Zobel and Jett 1995).

However, measurement of wood density is constrained by various factors. Firstly, measurement in standing trees is costly in terms of manpower and money because it involves extraction and processing of increment cores or discs. Secondly, the measurement inserts a time lapse from the extraction to the analysis of the samples, which delays the trial analysis and application of results. Thirdly, the determination requires what is called destructive sampling. Determination by wood discs requires felling of trees in the trial. Increment cores can be taken on living trees, but the operation involves an increased risk for pest and disease infestation. Because of the time and costs involved, destructive sampling in the trial will have to be restricted to a sample. The sample may not be representative, especially if few trees are included.

Many forest research organisations face a situation with many large trials. If wood density is to be determined, a faster and more cost-effective method is required than the conventional methods using discs and increment cores. The Pilodyn wood tester may be a good alternative as an instrument for fast and non-destructive estimate of wood density.

# 2. THE PILODYN WOOD TESTER

## 2.1 Brief description

The Pilodyn wood tester is an instrument originally developed in Switzerland for determining the degree of soft rot in wooden telephone poles. The Pilodyn drives a steel pin into the tree with a precise force. The depth to which the pin penetrates is indicated on the instrument and is inversely proportional to the density of the wood. The Pilodyn does not provide an estimate of *actual* wood density, but an estimate of the *relative* wood density, which can be used to rank various genetic 'units' (e.g. clones, families, seed lots and provenances) in regard to wood density. As individual Pilodyn instruments may vary and provide estimates at slightly different levels of density, it is very important that one and the same instrument is used for all measurements within the same trial.

Determination of actual wood density requires extraction of increment cores or sample discs.

The Pilodyn is attractive in that it is rapid, does not require the use of an increment borer (destructive sampling), and is, in principle, free of operator bias (Cown 1978).

The Pilodyn is available in three models as 6J, 12J and 18J instruments with increasing strike force, and all models can be equipped with striker pins of different diameters.

For forestry applications, the models PILODYN 6J Bark and PILODYN 6J Forest are recommended. Technical details of the two models are given in Table 1. The two models operate through the same basic principle and the precision is the same. The main difference between

the two models is a more advanced trigger mechanism on the PILODYN 6J Forest which facilitates an easy operation of the instrument. The 6J Bark model is no longer produced, and only marketed as long as in stock. The Pilodyn is produced by 'PROCEQ' in Switzerland, and distributed worldwide by 'Kai R. Spangenberg' in Denmark. Contact addresses are provided on page 12.

| Technical data | PILODYN 6J Bark | PILODYN 6J Forest |
|---|---|---|
| **Strike force** | 6J (Nm) | 6J (Nm) |
| **Penetration depth** | 0...40 mm | 0...40 mm |
| **Striker pin diameter** | 2.0 or 2.5 mm | 2.0 or 2.5 mm |
| **Dimensions:** | | |
| **Diameter** | 50 mm | 50 mm |
| **Length** | 335 mm | 420 mm |
| **Weight** | 1.550 kg | 1.250 kg |

Table 1. Technical details on PILODYN 6J Bark and Forest

### 2.2 Maintenance

Apart from regular cleaning and an occasional check to see whether the impacts have loosened the striker pin (5), the striker head (2) or the trigger (17), the Pilodyn does not require any special maintenance.

The instrument must never be oiled or greased.

The point of the striker pin (5) must be flat and sharp-edged. After about 5000 shots, the striker pin is replaced. Bent striker pins must be replaced immediately. The square locking pin (22) is used to lock the nut (6) when the striker pins are changed.

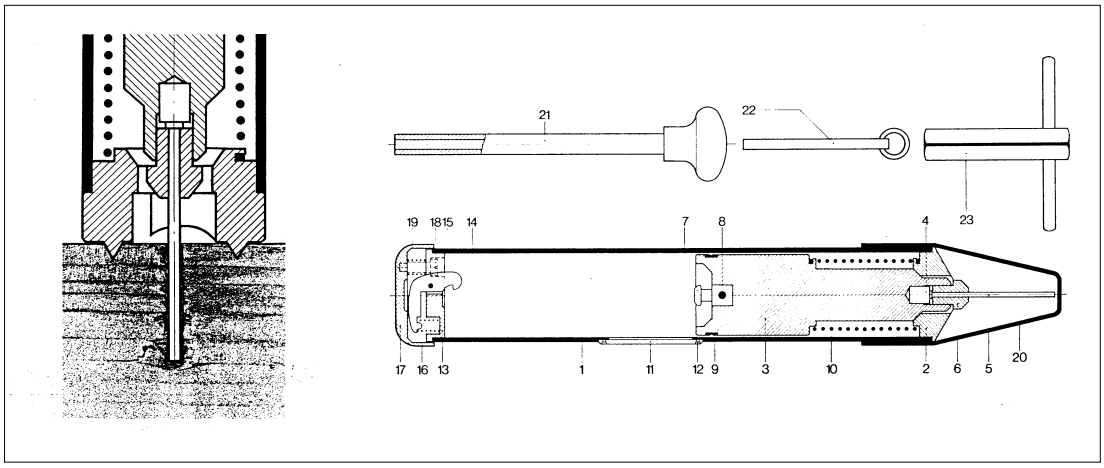


Figure 2. Technical details of the Pilodyn wood tester and parts list

1. Housing
2. Striker head
3. Striker
4. Spacer pin
5. Striker pin
6. Nut
7. Retaining pin
8. Splined pin
9. Indicator ring
10. Loading spring
11. Scale aperture
12. Cylindrical screw
13. Base
14. Pawl
15. Cylindrical pin
16. Pawl spring
17. Trigger
18. Cylindrical screw
19. Compression spring
20. Protective cap
21. Loading rod
22. Square locking pin
23. Hexagonal wrench

## 3. HOW TO USE THE PILODYN

The Pilodyn can be used with pin diameter 2.0 mm or 2.5 mm. The choice of pin diameter will depend on tree species. The 2.0 mm pin will have a deeper penetration into the wood than the 2.5 mm pin. In species with soft and low density wood, the 2.0 mm pin may not be feasible as pin penetration is maximum 40 mm on all trees. In hardwoods, the 2.5 mm pin may show only very small penetration. It is recommended that the two pin diameters are tested, and the more suitable for the species in question is chosen. Pilodyn must only be used on wood.

The operation of the Pilodyn is simple and fast.

### 3.1 Getting ready

For precise measurements, it is essential that the bark be removed from the sample spot prior to assessment because bark thickness varies considerably from tree to tree and will hence influence pin penetration. The bark is removed from the sample spot with a knife. The spot without bark should be approx. 40 mm long and a few mm wide, which is sufficient room for the two spacer pins (4) of the Pilodyn (cf. Figure 3). There is no need to make the bark free spot larger than that, as this would increase the risk for pest and disease infestation. The sample spot must be free from any visible aberration like knots or resin pockets. The sample spot is normally placed at breast height (1.3 m above ground), but in principle another position could be used. The important thing is to keep the position fixed throughout the assessment, i.e. to measure at the same height above ground on all trees.

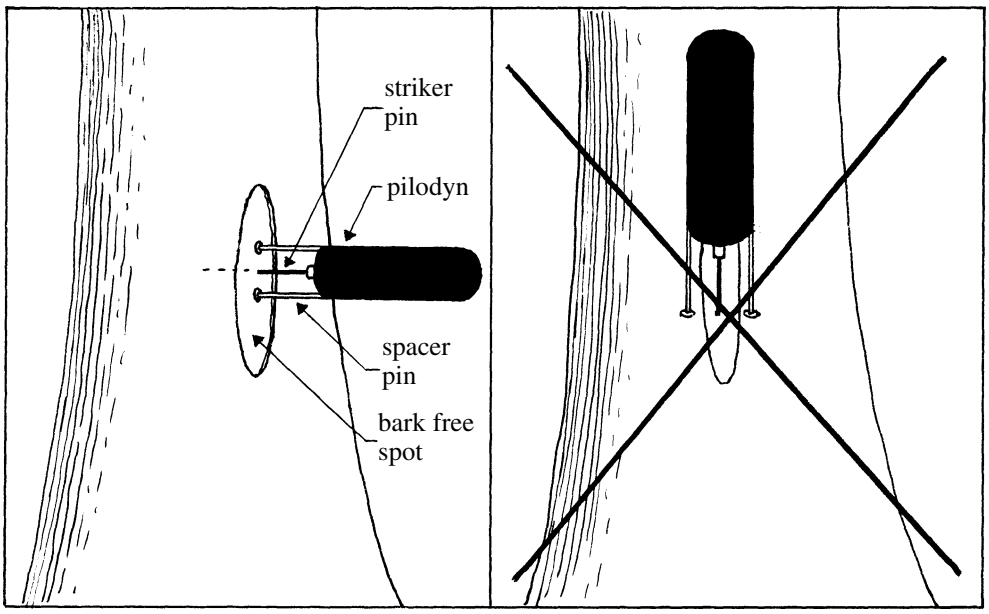


Figure 3. Positioning the Pilodyn at the sample spot. It is essential that the spacer pins are placed in the bark free area on the stem.The instrument is placed so that readings are easy to record before the instrument is withdrawn.

### 3.2 Loading

Remove the protective cap (20) and slip the loading rod (21) over the striker pin (5). Force the pin into the body of the instrument until it ‘clicks home’. Do not press against the trigger at the rear during loading, since this prevents the mechanism from ‘clicking home’. The Pilodyn is now loaded and ready for use.

Do not load the Pilodyn until immediately before use. Never transport the instrument in loaded condition or leave it unattended when it is loaded. Always point the loaded instrument towards the ground.

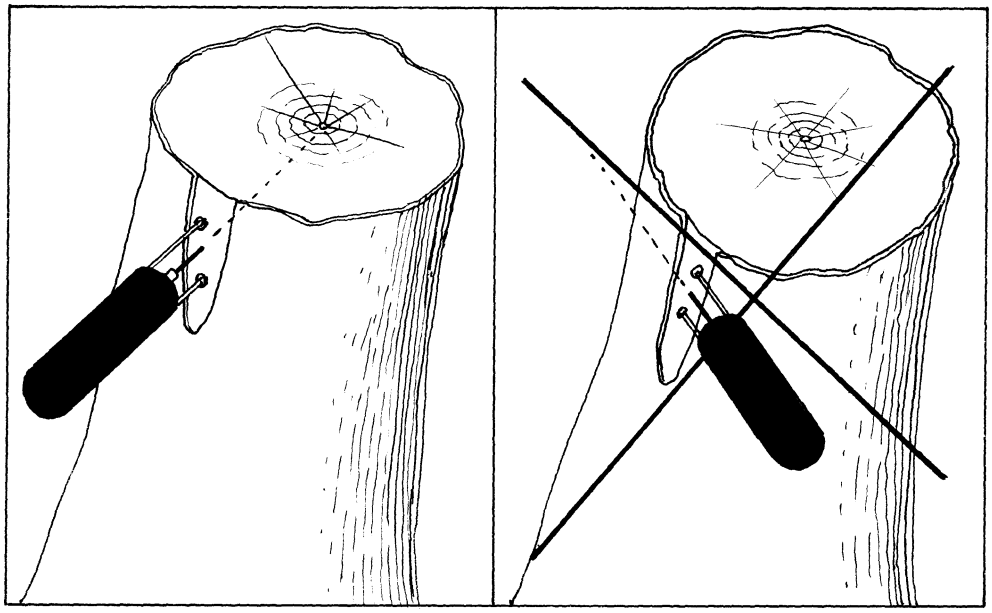

Figure 4. The Pilodyn (striker pin) should point towards the centre of the stem. The Pilodyn is used on standing trees. The cross section is shown here in order to clarify the direction to the pith.

### 3.3 Shooting

The front of the Pilodyn is pressed firmly against the stem to avoid recoil and movement of the instrument. The spacer pins (4) should be in the bark-removed spot (cf. Figure 3) and the striker pin (5) should be pointing directly towards the centre of the stem (cf. Figure 4). Be careful not to touch the trigger (17) prematurely.

Press the trigger (17). This actuates the shot and the striker pin (5) is propelled into the wood. The penetration depth of the striker pin is recorded while the Pilodyn is still pressed against the tree. The penetration is read in millimeters (0 - 40 mm, without decimals) on the scale (11) on one side of the instrument. When penetration has been recorded, the striker pin is extracted from the tree with care to avoid bending the pin. You are now ready to prepare for the next 'shot'. Normally, you will need two or more measurements of each tree (see discussion below). When measurements are completed, the protective cap is put back on the instrument.

## 4. HOW MANY MEASUREMENTS ARE REQUIRED?

Pilodyn measurements are easy to make and the main advantage of the method is that it allows measurement on all trees in the trial, whereas this is prohibitive in terms of time and costs when determining wood density by increment cores or disc segments.

At least two readings per tree are recommended in order to have reliable results, see e.g. Gough and Barnes (1984) or Greaves *et al.* (1996). In a series of provenance trials of *Pinus kesiya,* Danida Forest Seed Centre used two readings per tree, and a third measurement if the two first readings differed by more than 3 mm. If one of the three readings differed significantly from the two others, it was discarded (DFSC 1998).

The first reading should be positioned at random, i.e. no fixed orientation should be used (e.g. in relation to rows). This is to avoid a possible effect of compression/reaction wood that may have developed, for instance because of a slope or prevailing wind direction. The second reading should be at right angle to the left or right of the first one, cf. Figure 5. As mentioned earlier, the measurements should be made at a fixed height, usually 1.3 metre above ground.

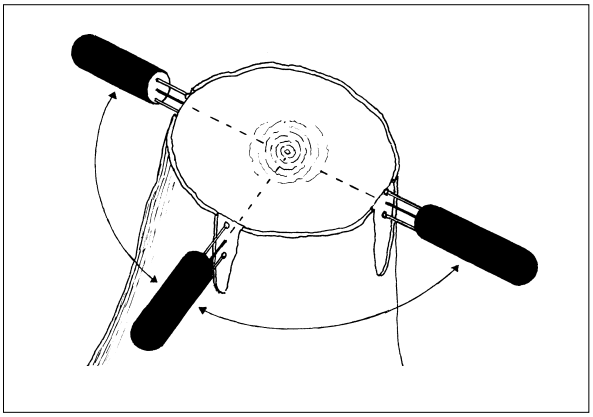

Figure 5. The first measurement should be taken at random position around the stem. The second one is taken at right angle to the first one, either to the left or right. The Pilodyn is used on standing trees. The cross section is shown here in order to clarify the direction to the pith.

## 5. APPLICATION OF THE PILODYN

The Pilodyn wood tester has been applied on a large number of forest tree species. Table 2 lists some examples, but the list is not exhaustive.

| Species | Author(s) |
|---|---|
| *Acacia aulacocarpa* | Sim and Gan (1991) |
| *A. auriculiformis* | |
| *A. crassicarpa* | |
| *A. mangium* | |
| *A. mearnsii* | |
| *Gmelina arborea* | Lauridsen *et al.* (1983); Akoun *et al*. (1985) |
| *Eucalyptus sp.* | Chapola (1994) |
| *Eucalyptus camaldulensis* | Moura *et al.* (1987) |
| *Eucalyptus globulus ssp. globulus* | MacDonald *et al.* (1997) |
| *Eucalyptus grandis* | Vale *et al.* (1995) |
| *Eucalyptus nitens* | Greaves *et al.* (1996) |
| *Eucalyptus urophylla x E. grandis* | Bouvet and Vigneron (1996) |
| *Fagus sylvatica* | Lewark and Giefing (1983) |
| *Picea abies* | Gorlacher (1987); Lewark and Giefing (1983); Piroton *et al*. (1995) |
| *Picea mariana* | Antal and Micko (1994) |
| *Picea sitchensis* | Costa E. Silva *et al*. (1994); Hansen and Roulund (1997) |
| *Pinus caribaea* | Moura and Parca (1993) |
| *Pinus engelmannii* | Yanchuk and Kiss (1993) |
| *Pinus elliottii* | Gough and Barnes (1984) |
| *Pinus glauca* | Yanchuk and Kiss (1993) |
| *Pinus oocarpa* | Wright *et al.* (1992) |
| *Pinus patula ssp. tecunumanii* | Moura and Parca (1993); Wright *et al.* (1992) |
| *Pinus pinaster* | Notivol *et al.* (1992) |
| *Pinus radiata* | Cown (1982); Watt *et al.* (1997) |
| *Pinus sylvestris* | Haapanen *et al.* (1997) |
| *Pinus taeda* | Sprague *et al.* (1983); Taylor (1981) |
| *Pseudotsuga menziesii* | King *et al.* (1988) |

Table 2. Examples of recent application of the Pilodyn wood tester in tree improvement.

A number of the studies have compared pilodyn measurements with wood density estimates using increment cores or disc segments, e.g. Cown (1978), Gough and Barnes (1984), Moura *et al.* (1987) and Sprague *et al.* (1983).

The Pilodyn, the increment cores and the disc segments measure three different density characteristics of the tree. (1) The Pilodyn pin penetrates a maximum of 40 mm into the tree and is therefore related to the density of the outer rings of the tree only. (2) The core is cylindrical and therefore there is progressively over representative sampling of the wood from bark to pith. (3) The segment is wedge-shaped and samples all rings in proportion to their volume contribution at that level in the tree, and is therefore the most accurate representation of the stem (Gough and Barnes 1984). Disc segments are thus the most reliable method for estimation of density and should preferable be used as reference when comparing Pilodyn with wood density estimates.

A number of comparative analyses have shown high correlation (often in the range 0.8-0.9) between Pilodyn estimates and wood density estimates, see e.g. Micko *et al.* (1982), Cown (1978) and Sprague *et al.* (1983). The Pilodyn results are normally compared with increment cores from the outer rings, and the correlation is therefore higher than would be expected from disc segments sampling the entire stem (Gough and Barnes 1984). Consequently, in a study of 15 full-sib families of *Pinus elliottii* in Zimbabwe a somewhat lower correlation was found between pilodyn and basic density estimates from segments at family level. The correlation was still relatively high (0.7). When density and Pilodyn were compared at single tree level, the correlation was much lower (Gough and Barnes 1984). They conclude that the Pilodyn can be safely used to rank families, but it is not a completely reliable tool for within-family selection (Gough and Barnes 1984). Other authors, e.g. Micko *et al.* (1982), found a good correlation also at single tree level. In a study of *Picea glauca* by Micko *et al.* (1982) the correlation was 0.83; the Pilodyn results were here compared with wood densities estimated from increment cores.

Wood moisture and temperature may influence the pin penetration of the Pilodyn. However, above fibre saturation point as in living trees, wood moisture content has no bearing on the test result (Micko *et al.* 1982). In a test of *Gmelina arborea,* Lauridsen *et al.* (1983) tested the Pilodyn morning and afternoon in order to check the influence of any daily fluctuations in wood moisture, but, in accordance with Micko *et al.* (1982), they found no significant differences.

Pilodyn penetration is reported not to be temperature dependent at temperatures above freezing point. Cheliak *et al.* (1984) reported that pin penetration fell rapidly between temperatures of zero and minus 10°C. They suggested that the Pilodyn wood tester should only be used at temperatures above zero degree Celcius for estimating relative wood density in standing trees.

The fact that the Pilodyn pin only penetrates the outer rings (to a maximum of 40 mm) gives a less accurate determination than disc segments. Two special cases should be mentioned in this connection:

1. Strong within-stand competition (e.g. caused by too late thinning) will result in trees with narrow outer rings with a high proportion of latewood (conifers). This again results in low Pilodyn penetration and too high density estimates (Gough and Barnes 1984).

2. Juvenile wood in conifers differs from mature wood in several ways, including lower density values, thinner cell walls, and shorter tracheids. As the Pilodyn operates by penetration of the outer rings, it will only sample the density of the outer, more mature wood, and hence overestimate the wood density of the tree, especially in older trees.

## 6. CONCLUSION

The Pilodyn is a valuable tool for quick and cost-effective assessment of relative wood density. The main advantages are associated with the speed and ease of its use and its non-destructive sampling. Large numbers of assessments can be made without recourse to laboratory analyses.

Measurements should be taken carefully. This implies at least two measurements per tree. Measurements should always be taken under bark.

Measurements of wood densities determined by increment cores or segments compared with Pilodyn measurements indicate that the Pilodyn can safely be used to rank provenances and families. Use of the Pilodyn for within-family selection for wood density (selection of single trees) is more uncertain as some studies support and other studies do not support such selection. More comparative studies are required on this issue.

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## APPENDIX 1

## AN EXAMPLE OF PRACTICAL APPLICATION OF THE PILODYN IN TREE IMPROVEMENT

This example illustrates the use of the Pilodyn in ranking provenances in a provenance trial of *Pinus kesiya*.

The provenance trial of *Pinus kesiya,* established December 1992 at Cashel in Zimbabwe was assessed in August 1998 as part of an international evaluation of provenance trials of this species. Results of the assessment are described in Hansen (2000).

The trial has 21 provenances of *P. kesiya* and there are 6 replications (blocks). 16 trees were assessed in each plot, bringing the total number of trees to 2016.

The assessment included measurement of relative wood density by Pilodyn. All trees in the trial were assessed. Two measurements were taken on each tree with a Pilodyn 6J bark model with pin diameter 2.0 mm. The same person was appointed for all Pilodyn measurements. The assessment took 4 working days.

The data was analysed on plot averages. Differences between seed lots (provenances) are tested by the model:

$$X_{jk} = \mu + provenance_j + block_k + \varepsilon_{jk}$$

where $X_{jk}$ is the mean value of the pilodyn readings in plot *jk,*
$\mu$ is the grand mean,
$provenance_j$ is the effect of seedlot number *j*,
$block_k$ is the effect of block *k* in the trial, and
$\varepsilon_{jk}$ is the residual of plot *jk* and is assumed to follow a normal distribution $N(0, \sigma_e^2)$.

Differences between provenances are tested by an F-test comparing the mean square of provenances with the residual mean square. The GLM procedure in SAS (SAS 1988) is used for the test. See Hansen (2000) for more details. In order to reduce the residual variation, various combinations of the position of the plot were tested, and significant ones were included in the statistical model.

The F-test gave the results shown in Table 3. Lsmean values together with 95% confidence intervals are shown in Figure 6.

There are significant differences among provenances. The provenances from the Philippines (Coto Mines, Benquet and Mt. Province) and the Zok Hua source from Myanmar have the highest relative wood densities (remember that a low pilodyn reading refers to a higher wood density, and vice versa). The Chinese sources Baoshan, Jingdung and Shangsi have the lowest wood densities in the trial.

| RESULTS FROM ANALYSIS OF VARIANCE | | | | |
|---|---|---|---|---|
| *Effect* | *DF* | *MS* | *F-value* | *P-value* |
| Provenance | 20 | 14.46 | 13.79 (***) | <0.0001 |
| Block | 5 | 22.53 | 21.48 (***) | <0.0001 |
| PLOTX | 1 | 11.02 | 10.50 (**) | 0.0017 |
| PLOTX2 | 1 | 4.16 | 3.97 (*) | 0.0493 |
| PLOTY2 | 1 | 12.50 | 11.92 (***) | 0.0008 |
| Error | 92 | 1.05 | | |

Table 3. Results of the statistical analysis of pilodyn data in the Cashel trial, Zimbabwe from Hansen (2000).

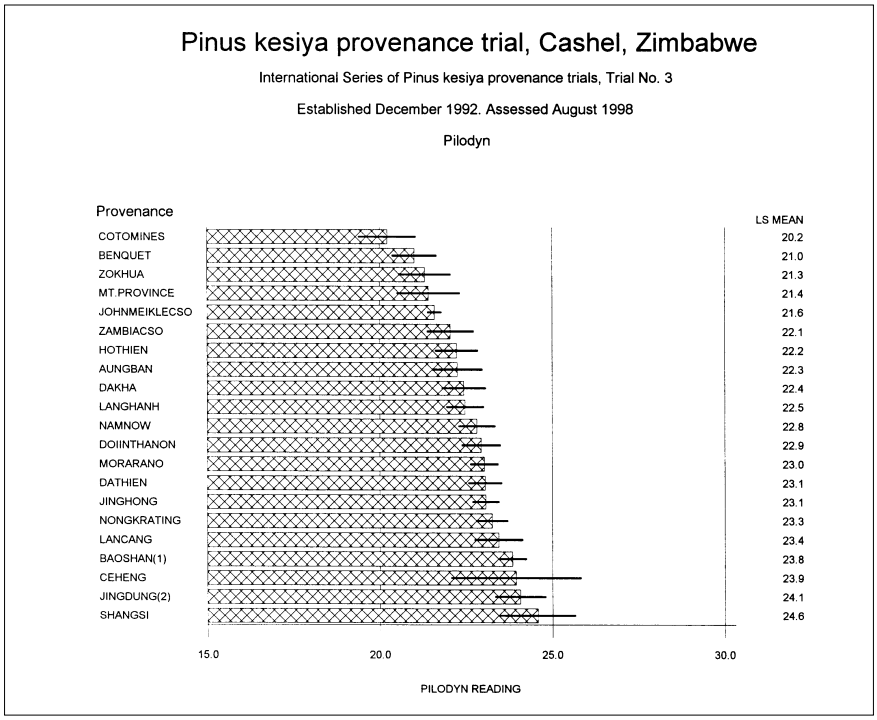


Figure 6. Lsmean values (pilodyn reading in mm) together with 95% confidence intervals.

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