Second Evaluation of an International Series of Teak Provenance Trials (1995)

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FOREST & LANDSCAPE

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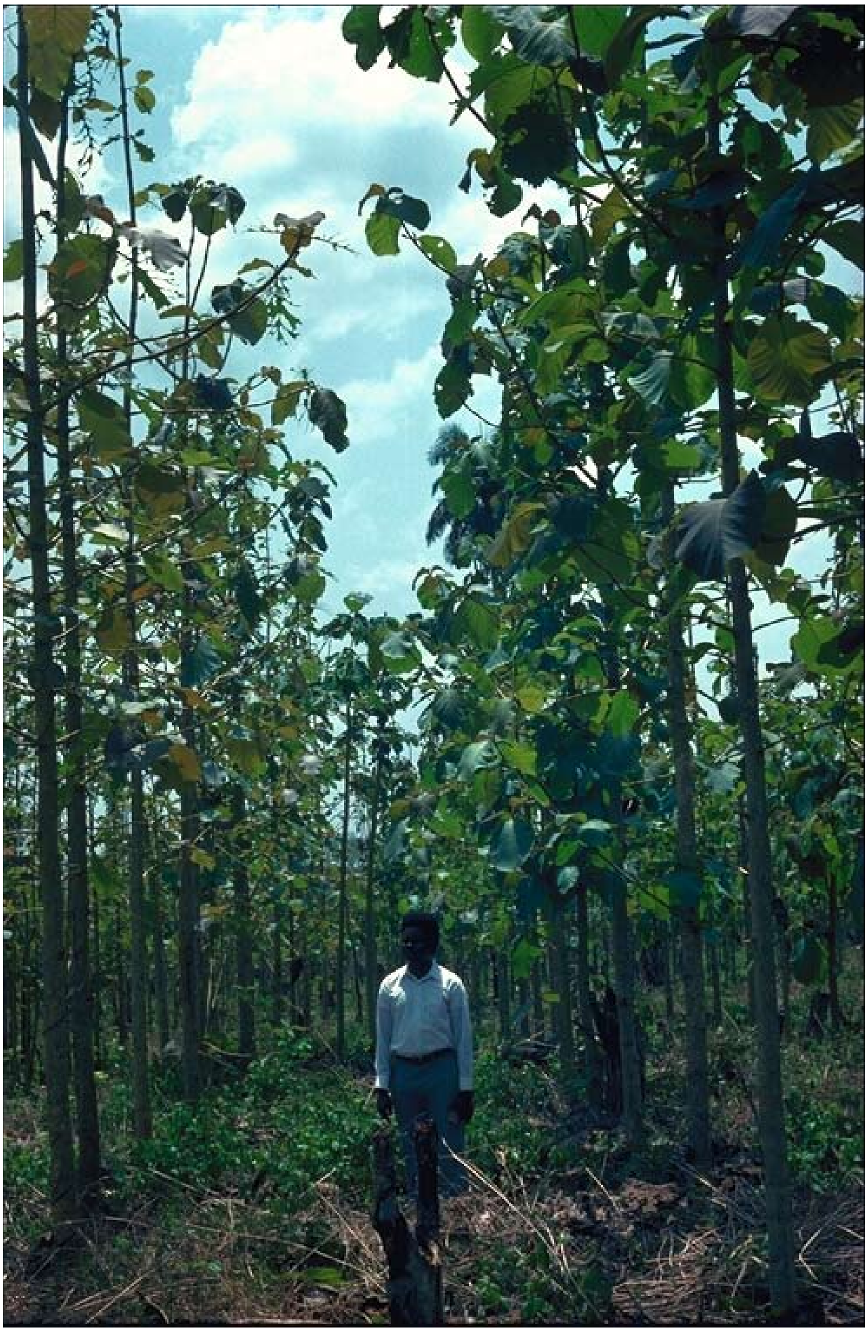

by Erik D. Kjaer, Elmer B. Lauridsen and Hubert Wellendorf

Title
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Authors
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Cover Photo
Cover photo shows two teak provenances in Gambari trial, Nigeria. Established 1973, photographed 1976. Left: Indian provenance (3021), Right: Indonesian provenance (3049) with more and larger leaves. H. Keiding phot.

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CONTENTS

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Humlebaek, January 1995.

Erik D. Kjaer, Elmer B. Lauridsen, and Hubert Wellendorf

Helpful Reading Instructions

How to find information relevant to your region

This report presents the findings from the second evaluation of an international series of teak provenance trials. It is a follow-up on the first evaluation, which was made when the trees were 7 -9 years old. At the time of the second assessment the trees were 17 years old. The present report focuses on the results at this age, but the findings are compared with results from age 7-9 in order to describe general trends.

The report consists of eight sections. Not all readers may find it necessary to read the full content of the report, as explained below.

Section 1 is an executive summary where results in terms of general provenance recommendations are presented. This section may be valuable for the reader who is only interested in bro ad provenance recommendations.

Section 2 (Introduction) and section 3 (The Experimental Material) state the background and objectives of this international series of provenance trials. The provenances and trials are also listed, and these two sections will be valuable for readers who will like to look into the findings in more details.

In section 4 (Selection of traits and their assessment) emphasis is on describing the assessment techniques. Section 5 and 6 give an introduction to the methods used in the statistical analysis. The three sections may be read more or less extensively, but it will be valuable for all readers to be at least somewhat familiar with the ideas behind the analysis. Especially section 5.3. (Estimation of predicted provenance performance) should be read, because the concept presented here is used to present results throughout the report.

Results from the individual trials are presented in section 7. Some general trends are presented in section 7.1. The results are organized in 4 sub-sections according to four so-called trial regions: "West Africa-moist and Brazil, West Africa-semi moist and dry, South East Asia, and Central America". Trial regions are regions for which general provenance recommendations can be given. In principle the reader can therefore restrict himself to reading the findings from the trial regions which are relevant to himself. The differences between provenances are presented graphically for each trial, whenever they are statistically significant.

In section 8 analyses of variation across the four trial regions are presented, mainly in term s of graphical illustrations. This section may be valuable to read as a supplement to the findings from section 7.

Not all trials were re-assessed. The re-assessed trials were selected so that they represent different growth regions of teak. However, the number of trials included in the second evaluation is less than half the number included at age 7-9. For trials that were not re-assessed, it may therefore be valuable to refer to the results from the first assessment presented in Keiding *et. al.* 1986.

1. EXECUTIVE SUMMARY

INTRODUCTION

A series of 48 international teak provenance trials were established during 1973-74. A total of 75 seed sources (= provenances) were sampled within eight ecological-geographical zones (= provenance regions): Moist India, Semi Moist India, Dry India, Laos, Thailand, and Indonesia plus landraces from Africa and Latin America.

21 of the trials were assessed during 1982-1985 for a number of important economic traits. Recommendations concerning choice of seed source was given based on the subsequent analysis (Keiding *et al.* 1986).

8 of the original 21 trials were reassessed during 1991-92 in order to examine the development of the provenances. The objective was to ascertain whether the conclusions and recommendations resulting from the first evaluation were still valid, and to examine if the inclusion of a number of additional characteristics, formerly not examined, would substantially modify conclusions.

A detailed account of the material and assessment is given in sections 2-4. The statistical analysis is discussed in sections 5-6. Results are presented in sections 7-8.

SUMMARY OF THE RESULTS

Results from the first assessment suggest that different seed sources will be superior in different regions. Based on the 21 trials assessed at the younger stage, the world was divided into four socalled »trial regions«. A trial region is a geographic area in which the trials are not significantly divergent. Analyses based on data from the second evaluation show that it is still important to give different recommendation for the different trial regions. An account of the analysis of the »interaction« between provenance regions and trial regions for the different traits is given in section 8.

An updated recommendation of provenance regions is given below in very general terms. More details can be found in section 7. Important variation between provenances within the larger regions are found for many traits, and this shall be recalled when discussing the recommendations at provenance regional level.

Trial region: West Africa-moist and Brazil

The Moist Indian provenances are found to be best in this trial region followed by the Indonesian provenances.

Both the Semi-Moist Indian, Moist Indian and the Indonesian provenances have high survival and show good health performance. The growth of the Indian moist provenances and the Indonesian provenances is good, the Moist Indian ones being on the average slightly better than the Indonesian ones.

The Indian provenances have a tendency to lose persistence of the main axis earlier than the Indonesian provenance(s), but stemform and branch characteristics are better for the Moist Indian provenances than for the Indonesian provenance.

Wood density characteristics of both Indonesian and Moist Indian provenances appear at satisfactory levels.

Both the Indonesian and the Moist Indian provenances have more epicormic branches than other provenances. The Indonesian ones have revealed a tendency to above average buttressing, which may be of concern.

Trial region: Dry and Semi-Moist West Africa

The local African landraces tested in this trial were found to have a high frequency of trees with poor stemform and low persistence. They should therefore be avoided if better seed sources are available. They also have a tendency to develop more epicormic branches and protuberant buds than average.

Provenances from Indonesia and Moist India grow relatively fast and are of good quality. The Indonesian provenances have a tendency to develop more epicormics and protuberant buds than the provenances from Moist India and Dry India.

Trial region: South East Asia

Provenances from Thailand and Laos are found to be of good quality, but especially provenances from Laos are less productive than average of the tested provenances.

Indonesian provenances are more productive, but are on the average of slightly lower quality. Indonesian provenances of very good quality can, however, be identified.

The Moist Indian provenances are in general found to be of lower productivity and quality than Indonesian provenances, especially due to low persistence of axis dominance. Branches are generally fine.

Trial region: Central America

The provenance representation is low at the second assessment, because of the loss of an important trial IP022 (Mexico).

The trials reveal a tendency to lower adaptation of Thai - and to some extent Moist Indian provenances compared to tested landraces from Africa and Central America. Generally the adaptation of all the provenances does, however, seem acceptable.

The results concerning stem quality from the two trials in this region are very different. In one of the trials the provenances from Moist India and Thailand are of better quality than the tested provenance from Indonesia and the African landrace, which corresponds to the findings in the first assessment. In the other trial - with conditions less suitable for teak - the ranking has changed completely. The Moist Indian provenances have experienced a severe reduction in quality, and the African landrace has therefore changed from being of inferior quality to being the provenance of relatively best quality.

Based on these results it is difficult to give general recommendations for Central America, as the provenance representation is so poor at the second assessment. Future recommendations must therefore, to a large extent, be based on local experience and the findings from the first assessment, which were based on a broader material (see Keiding *et al.* 1986 for details). Some inference can be made based on the second assessment.

Thai provenances in general seem less attractive in Central America due to below average growth and adaptation. The quality of the Moist Indian provenances may to some extent have been overestimated at the first assessment, and the very poor quality of the African landrace found in the first assessment may have been underestimated. The Indonesian provenance, together with the Moist Indian provenances, still seem to be a good choice.

2. INTRODUCTION

A series of internationally coordinated provenance trials of the broadleaved species teak, *Tectona grandis*, was subject to evaluation during 1981-84 when trials were 8-10 years old (Keiding *et al.* 1986). A second evaluation has been carried out during the years 1991-94 when trials were 17-19 years old. The purpose of the second evaluation is the following:

To ascertain whether the conclusions and recommendations resulting from the first evaluation are still valid, and to examine if the inclusion of a number of additional characteristics formerly not examined would substantially modify conclusions.

The scheme has its origin in the action programme formulated by the FAO Panel of Experts on Forest Gene Resources in 1969 (FAO 1969), in which teak, among other species, was given top priority for provenance investigations. Collection and distribution of provenance samples was carried out in 1971-73 and, in the years following the collections, trials were established through out the tropical zone in a variety of site conditions. Details of seed collections are given in chapter 2 of the report of the first evaluation, and only a summary is presented below:

No. of provenances collected	No. of trials established	No. of trials evaluated at age 7-9	No of trials evaluated at age 17
75	48	21	8

In the concept of provenance testing the present programme is a first stage provenance trial scheme (see Lines 1967), according to which the aim of seed collections is to: i) obtain as broad a representation from the whole range of distribution as possible, covering the more typical and distinctly different types of environments to determine the magnitude and pattern of variation between populations, and ii) to identify provenance regions. For practical seed collection it would be convenient if collections could be carried out in less specific localities, i.e. provenance regions, rather than in specific provenances usually recommended from provenance testing.

3. THE EXPERIMENTAL MATERIAL

3.1 Provenances and provenance regions

The term »provenance region« is used in the broad sense, which in accordance with the OECD's definition (O.E.C.D. 1974) is: The area or group of areas subject to sufficiently uniform ecological conditions on which are found stands showing similar phenotypic or genetic characters.

The natural distribution of teak covers a wide area geographically, ranging from the Indian subcontinent in the West, through Burma, Thailand and Laos, touching Cambodia to the East and being naturalized on Java as the southernmost occurrence. Teak grows naturally mainly in the mixed, deciduous forests of the monsoon belt with a distinct seasonal climate (wet and dry seasons). Apart from Java its latitudinal limits are roughly 9°-25° North and it is found in a wide range of rainfall regimes (600-3000 mm annually), soil types, topography and tree associations. A number of different habitat-associated populations can be distinguished both on morphological characteristics and adaptability.

Five types of natural teak forests are distinguished in India on the basis of 7 factors (rainfall, soil, biotic factors, percentage of teak, associated species, ground cover and regeneration) (Champion & Seth 1964), and they are:

i.	Very dry teak forest	600 - 900 mm annual rainfall
ii.	Dry teak forest	900 - 1300 mm annual rainfall
iii.	Semi-moist teak forest	1300 - 1600 mm annual rainfall
iv.	Moist teak forest	1600 - 2500 mm annual rainfall
v.	Very moist teak forest	> 2500 mm annual rainfall

Similar classifications were not available for the occurrences in the Burma, Thailand, Laos complex, although different types of forests are described for Burma (Troup, 1928) and may be distinguished in Thailand (Kaosa-ard 1981). The teak forests on Java constitute a separate group, being naturalised teak of probably South Indian origin with more than 400 years of domestication.

In addition to the natural distribution of teak, domesticated populations (so-called »Landraces«) are also available for investigation. The origins of the landraces are generally uncertain. Collections for this investigation were carried out from three sources:

a) Indigenous, natural teak,

b) Plantations deriving from natural teak in the same area,

c) »Landraces« outside the natural range of occurrence.

The provenance regions of the present programme were defined in two ways: One based solely on mean annual rainfall and one based on a combination of geographical and ecological factors.

Table 3.1 List of provenance collection sites and their allocation to provenance regions.

No. Designation	Provenance	Latitude	Longitude	Elevation m	Annual Rainfall mm	Provenance Region
		N	E			
SC 3002	Kolkaz, Maharashtra	21 °30′	77°15′	496	1638	INDIA
03	Nagpur, Maharashtra	21°18′	79°34′	400	1270	
05	Lohara, Maharashtra	19°55′	79°20′	200	1143	DRY
07	Allapally Plains, Maharashtra	19°23′	80°07′	160	1524	
08	Haliyal, Karnataka	15°21′	74°52′	610	1398	INTERIOR
15	Antersante, Karnataka	12°01′	76°17′	762	890	
22	Bairluty I, A.P.	15°51′	78°45′	305	1016	
23	Bairluty 2, A.P.	15°62′	78°45′	305	1016	
32	Jhirpa, M.P.	22°36′	78°28′	396	1016	
SC 3010	Dandeli, Bl.II, Karnataka	15°10′	74°35′	573	2032	
12	Kolikeri, Karnataka	15°01′	74°49′	579	1778-2032	INDIA
13	Arbail, Karnataka	14°50′	74°41′	69	2565	
16	Masale Valley, Karnataka	11°55′	76°10′	823	1270	MOIST
17	Mount Stuart I, T.N.	10°30′	76°47′	671	2032	
18	Mount Stuart 2, T.N.	10°30′	76°47′	640	2032	WEST
19	Ulandy, T.N.	10°23′	76°50′	732	2032	
20	Konni, Kerala	9°30′	76°41′	61	2540	COAST
21	Nilambur, Kerala	11 °21′	76°21′	49	2565	
71	Mt. Stuart, T.N.	10°30′	76°47 ′	640	2032	
SC 3026	Maripakala, A.P.	17°45′	82°15′	407	1524	INDIA
33	Berbera, Orissa	19°52′	85°05′	100	1200-1500	SEMI-MOIST
34	Purunakote, Orissa	20°	84°	133	1200-1500	
35	Monda Reserve For., Orissa	20°22′	82°45′	300	1200-1500	EAST
36	Bakbahal, Orissa	20°27′	82°47′	315	1200-1500	COAST
SN 001	Local source, A.P.	-	-	-	-	
SC 3038	Ban Cham Pui	18°29′	99°49′	520	1200	
39	Ban Maekut Luang	16°49′	98°36′	220	1644	
40	Ban Pha Lai	18°13 ′	99°59′	200	1100	
41	Ban Mae Pam	19°02′	99°02′	450	1200	THAILAND
42	Ban Huey Luang	18°14′	97°56′	220	1282	
43	Ban Doi Thon	19°03′	99°59′	562	1200	
SN 0133	Mae Huat, Selected Seed Stands	18°45′	99°59′	300	1200	
SC 3053	Pakse South I	15°04′	105°53′	170	1925	
54	Pakse South II	15°07′	105°51′	120	1925	
55	Savannakhet I	16°33 ′	104°45′	100	1309	
56	Savannakhet II	16°33 ′	104°45′	100	-	LAOS
57	Pak Lay East	18°13 ′	101°25′	150	1200	
58	Chumpi	15°16′	105°49′	50-100	1925	
59	Vientiane Town	17°56′	102°37′	50-100	1569	
60	Khong Island	14°10 ′	105°50′	50-100	1925	
61	Pak Lai Main Forest	18°10′	101°15′	20	1200	
SC 3047	Bangsri, Pati	6°30′	110°48′	75-100	3900	INDONESIAN
48	Nanas, Blora	6°57′	111 °30′	250-280	1700	+
49	Ngliron, Ngliron	7°12′	111 °22′	150	1200	PAPUA
50	Temandsang	7°12′	111°22,	104	1200	NEW GUINEA
51	Beran, Saradan	7°35′	112°45′	60	1830	
SLTG 14	Papua New Guinea, landrace					
SLTG 24	Papua New Guinea, landrace					

No. Designation	Provenance	Latitude	Longitude	Elevation m	Annual Rainfall mm	Provenance Region
		N	E			
SC 3037	Bouake, Ivory Coast	7°48′	5°07′	310	1200	
44	Jemar Ghana	7°50′	1°50′	267	-	
			E			AFRICAN
62	Yoh, Palime, Togo	6°50′	0°35′	350	1700	
63	Tove, Togo	6°40′	0°40′	200	1300	LANDRACES
64	Atakpame, Togo	7°30′	1°15′	200	1450	
		S	E			
65	Bigwa, Tanzania	6°50′	38°39′	580	-	
66	Kihuwi, Tanzania	5°12′	38°39′	260	-	
		N	W			
67	Bambuku, Cameroun	4°26′	9°16′	210	1900	
SG 01	Landrace, Ghana*	7°50′	1°50′	-	1100-1600	
03	Landrace, Ghana*	7°50′	1°50′	-		
04	Landrace, Ghana*	7°50′	1°50′	-		
		N	E			
SN 119	Landrace, Nigeria*	7°10′	3°52′	-	1300-1501	
		N	W			
SNTB 73	Landrace, Ivory Coast*	7°48′	5°07′	-	-	
SN 78	Landrace, Mexico*	18°26′	90°43′	-	900-1300	
79	Landrace, Mexico*			-		LATIN
80	Landrace, Mexico*			-		AMERICAN
81	Landrace, Mexico*			-		
82	Landrace, Mexico*			-		LANDRACES
83	Landrace, Mexico*	18°00′	65°50′	-		
SAB		.	-	-	2000	

* = approximate geographical locations

The provenance samples included in this series of provenance trials (table 3.1) represent the major parts of the natural distribution of teak, except Myanmar (former Burma). Provenances from this country were not available at the time of establishment.

Provenances from Myanmar have been tested together with provenances from India, China and Thailand in China (Bingchao *et al.* 1986). An impression of the performance of Myanmar provenances relative to Thai and Indian provenances can be found there. Please refer to this reference for more details.

3.2 Trials and trial regions

48 trials were originally established. In the first evaluation 21 trials were assessed, and the results from 18 trials only qualified for further analysis and evaluation. Details of trial locations are presented in table 3.2. The distribution of the trials is shown on the map in fig. 1.

In the second evaluation 8 trials were assessed and evaluated according to the procedure described in this paper.

In the first evaluation (Keiding *et al.* 1986) trials were initially grouped in to relatively small »trial-regions« based on geographical and obvious ecological regions. A number of trial regions were formed to be tested. Based upon the first assessment of the trials 4 trial regions were ultimately selected. The study of provenance x trial interaction was limited to growth, and only populations from the natural distribution were used for the establishment of trial regions. Details on methods and results are given in Keiding *et al.* (1986).

In the second evaluation, the grouping of trials into trial regions is based on findings from the first evaluation, but the validity of these regions has been re-examined. These results will be discussed in more detail in section 7 and 8.

The results from a particular provenance trial are strictly speaking only applicable for larger planting operations if conditions on trial and planting sites match well. The aim of a provenance trial scheme is to provide the tree planter with the means of choosing provenances for localities within larger areas. The purpose of an overall analysis across all trial sites is thus to find out whether it is possible to define plantation zones with different requirements for specific provenances, or provenance regions, Trial regions are therefore regions within which a number of provenances perform fairly uniformly.

Table 3.2 Location of Trials evaluated at age 7-9.

Trial No.	Country	Site Name	Latitude	Longitude	Annual Rainfall	Elevation
001	Thailand	Huey Som Poi	N 18°40′	E 99°55′	1400	350
003	Brazil	Aracruz	S 19°46′	W 40°16′	1400	50
005	..	..	..	..	..	..
008	Ghana	Pra Anum	N 06°15′	W 01°15′	1650	100
009	“	Tain	N 07°30′	W 02°30′	1140	100
016	India	Maredumilli, Tene	N 17°36′	E 81°43′	1470	500
018	Ivory Coast	El Tormento	N 06°05′	W 05°05′	1300	250
022	Mexico	Bende	N 18°26′	W 90°43′	900-1300	100
024	Nigeria	Sapoba	N 05°30′	E 07°38′	2150-2540	400
026	..	Gambari	N 06°01′	E 05°46′	2500	100
028	..	Nimbia	N 07°12′	E 03°53′	1260	400
029	..	Afaka	N 08°30′	E 09°30′	1750	600
030	..	Ederu	N 10°37′	E 08°17′	1290	600
032	Papua New Guinea		S 09°04′	E 147°06′	2000	50
038	Thailand	Pha Nok Khao	N 16°45′	E 102°00′	1300	300
045	Puerto Rico	Rio Abajo	N 18°22′	W 66°44′	2400	330
046	.. ..	Tract 105	N 18°15′	W 65°55′	2100	325
047	.. ..	Sl. Croix	N 17°45′	W 65″50′	1500	250

The representation of trials established within the four trial regions are:

- South East Asia with trials IPOOI & IP038 in Thailand, IPOl6 in India, and IP032 in Papua New Guinea,
- Central America with IP022 in Mexico, IP045 & IP046 in Puerto Rico, and IP047 in St. Croix,
- Moist West Africa and Brazil with IP003 & IP005 in Brazil, and IP024 & IP026 in Nigeria, and
- Dry-Semi-moist West Africa with IP008 & IP009 in Ghana, and IPOl8 in Ivory Coast, and IP028, IP029 & IP030 in Nigeria.

In the second evaluation only a limited number of trials were assessed and evaluated as follows:

- South East Asia with trial IP038 in Thailand,
- Central America with trials IP045 & IP046 in Puerto Rico, and IP047 in St. Croix,
- Moist West Africa and Brazil with IP003 & IP005 in Brazil, and
- Dry-Semi-moist West Africa with IP008 & IP009 in Ghana,

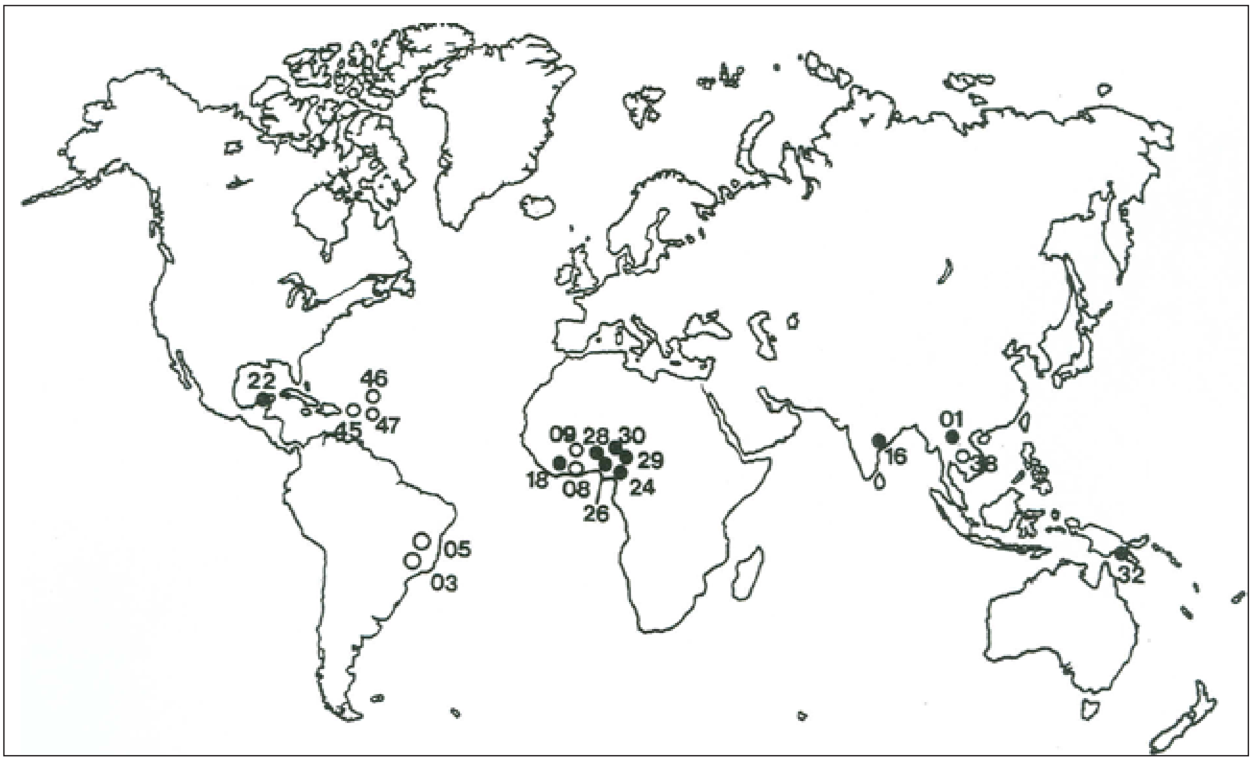

Figure 1 Location of evaluated trials. Only eight trials, 03, 05, 08, 09, 38, 45, 46, and 47 have been re-assessed.

4. SELECTION OF TRAITS AND THEIR ASSESSMENT

The characteristics selected for assessment were basically the same as assessed in the first evaluation, but some modifications and addition s have been made. This is described for the individual characteristics below.

4.1 Characters for assessment

Diameter
Pilodyn penetration (wood density) Bark -thickness
Axis persistence
Stem form (stem straightness) Branch size
Bole quality
- Epicormics
- Protuberant buds
- Buttressing (fluting)
Survival
Health

4.1.1 Diameter

Diameter (breast height) was used as the most important measure of growth (DBH). The diameters were converted into basal area (BA) for each tree. Basal area for all living trees were summarized and divided by plot size to obtain the basal area per ha (BA/ha).

4.1.2 Pilodyn

The pilodyn is an instrument which measures penetration of a small needle into the bole. It is an indirect measure of wood density (see Cown 1978).

The purpose of studying wood density for teak was merely to verify that otherwise »good« provenances do not have deviating wood densities. A low density would mean loss of strength characteristics, whereas a very high density would mean increased transport, handling and possibly processing costs.

4.1.3 Bark thickness

The thickness of the bark was measured at breast height (a small slip of bark was removed to reveal the thickness of the bark. The bark thickness was then measured by a bark-meter).

4.1.4 Axis persistence

Persistence, i.e. the height of unbroken axis, is an important characteristic related to commercial value of the bole.

A »branch« was considered a »stem« or »axis« if it exceeded the others by a quarter in thickness. Otherwise it was seen as a fork or multiple stem. The point of »branching-out« did occasionally come under dispute, where a single or two heavier branches had developed lower down on the stem. However, if a leading branch could be recognized by its size, the persistence scoring followed this branch.

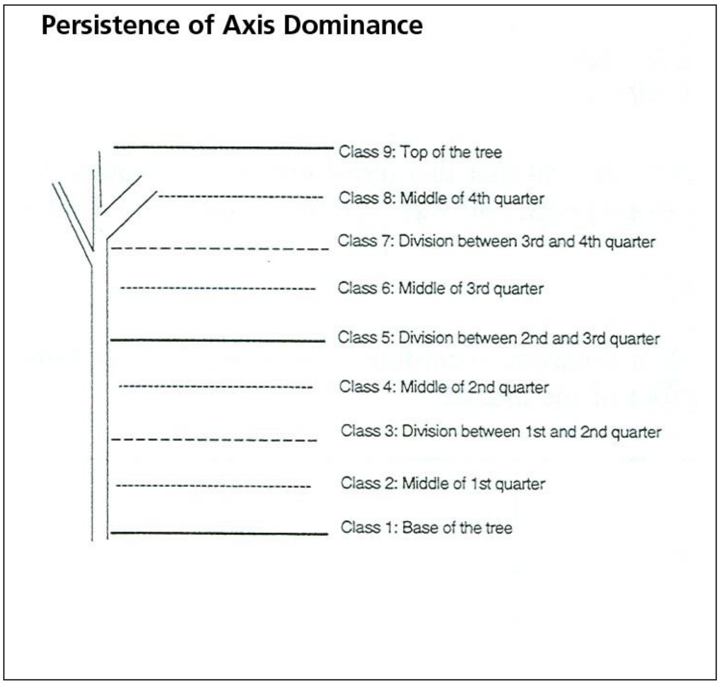

Figure 2. Classes for assessment of axis persistence.

The first assessment was based on five classes. Because of the present larger heights of trees, persistence was assessed using a 9-class scale instead of the 5-class scale used previously. The classes in figure 2 were used.

4.1.5 Stemform (Stem straightness)

Stemform was scored visually in five classes at both assessments.

At the second evaluation an additional label was registered to compensate for the fact that the trees had increased in size:

Score:

1	crooked tree with 3 or more severe bends
2	crooked tree with 1-2 severe bends
3	wavering tree, many small bends
4	slightly wavering, few small bends
5	straight tree

Label:

S: for straight tendency
W: for wavering tendency
C: for crooked tendency
B: for basal sweep
L: for leaning

The labels recorded at the second evaluation were used to modify the classes:

All trees below class 4 labelled with »S« were reclassified into class 4.
Trees recorded as class 2 labelled »W« were reclassified into class 3.

The subsequent analysis showed that this transformation increased the correlation between stemform at the two assessments, and was therefore used in the further analysis.

4.1.6 Branch size

Branches were scored in 5 classes according to size, viz. branch diameter in proportion to stem diameter at the foot of the branch.

Class	Proportion of branch diameter to stem diameter	Label
l	1/2 - 3/4	
2	≈ 1/2	R: Repeated forking/branching
3	1/4 - 1/2	M: Large branch competing with main stem
4	≈ 1/4	X: Many large branches arising from same level
5	< 1/4	

4.1.7 Bole quality

Bole quality refers here to the presence or absence of buttresses, epicormics and protuberant buds on the stem. Bole was defined as the stem or part of the stem stretching from ground level to the beginning of the crown.

Buttressing

Buttressing is a feature that typically develops with age and was therefore not recorded systematically at the first assessment. Buttresses reduce the utilization of the lower part of the stem and are considered an undesirable characteristic. Results from Bangladesh suggest some degree of genetic control (Banik 1993).

Three sub-characters were assessed in this evaluation:
- Measure of length of longest flute (F _LENGTH),
- Number of flutes (F _NUMBER)
- 4 classes of severity of buttressing (F _CLASS):

Scoring of F _CLASS includes the following groups (evaluated at l metre' s height):

CLASS	INTERPRETATION
4	Stem cross sectional area is near 100% of area of 'ideal stem'
3	Stem cross sectional area is ≈ 3/4 of area of 'ideal stem'
2	Stem cross sectional area is ≈ 1/2 of area of 'ideal stem'
1	Stem cross sectional area is ≈ 1/3 of area of 'ideal stem'

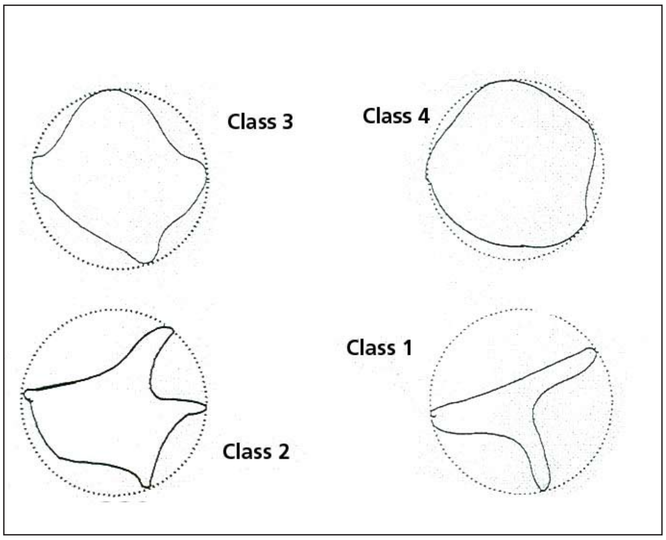

Figure 3. Example of classes in the assessment of buttressing.

The analysis of provenance differences in this investigation was performed on an aggregated index, combining the three different measures:

Degree of buttressing = F_LENGTH * F_NUMBER * (4 - F_CLASS)

Epicormics

Epicormics are shoots arising spontaneously from dormant buds on the stem and are (usually) easily distinguishable from branches by their density and smaller size. It is a common feature in teak and is a reaction of the tree to environmental stress or to sudden change in conditions, such as increased light after heavy thinning.

Epicormics are normally considered to be undesirable from an economic point of view. It may, however, be of adaptive value. Formation of epicormics is a natural reaction to defoliation, which is very frequent in teak plantations of South East Asia. It is therefore questionable if provenances without the tendency to produce epicormics are to be preferred.

In the previous assessment presence of epicormics was recorded in connection with branch size, but was not subject to analysis. In the present assessment scoring is as follows:

CLASS	INTERPRETATION
4	Stem free of epicormics
3	Around 25% of stem with epicormics
2	Around 50% of stem with epicormics
1	Around 75% or more of stem with epicormics

Protuberant buds

The phenomenon of protuberant buds is closely related to quality of the bole and branchiness of the stem. These may be described as bulging scars after natural pruning of branches (or epicormics). Assessment was made according to four classes:

CLASS	INTERPRETATION
4	Stem free of protuberant buds
3	Around 25% of stem with protuberant buds
2	Around 50% of stem with protuberant buds
1	Around 75% or more of stem with protuberant buds

4.1.8 State of health

A simple recording in 3 classes was applied at both first and second assessment as an information about adaptability.

CLASS	INTERPRETATION	LABEL
3	Tree healthy	G: for attack by insect
2	Tree affected by either pest or disease or physical damage	C: for attack by disease F: affected by fire
1	Tree affected by both pest and disease	U: Appear unhealthy, but cause not evident

The observations of distribution on health classes were combined with registration of survival to assess the relative adaptability of the provenances to the trial sites.

4.2 Characters excluded from the second assessment

The following characters were recorded at the first assessment, but were considered irrelevant for assessment at second assessment:

7. Mode of branching
8. Flowering

Mode of branching. The grouping of different branching types or formation of the crowns were recorded in the first assessment.

As branching habit becomes increasingly influenced by environmental factors with advancement of age, the genetic estimates become more uncertain, and it was therefore thought irrelevant to attempt an assessment at the later stage.

Initiation of flowering. The period of flower initiation had passed for all trees by the age of 17. Scoring of flowering was therefore omitted from the second assessment.

5. STATISTICAL ANALYSES OF INDIVIDUAL TRIALS

The statistical models used for analysis of the data in the investigation are described in this section. The major emphasis is laid on discussing the interpretation of results of the different statistical modes. A detailed account of the statistical properties of the analyses is not given here, in order to keep the description short and clear. References to more detailed descriptions are provided. All statistical analyses were made with the SAS-programme package (SASinstitute 1990).

5.1 Comparison of the results from the first and second assessment

A major objective of this investigation is to compare the variation between provenances at the later age with the differences that were found at the earlier age:

- What has happened in the period between the two assessments - and how important are these changes?

or put in another way:

- How much new information has been accumulated - and do the recommendations from the first assessment still hold?

Another objective is to look at new traits which were not assessed at the first assessment, e.g. epicormic branches, protuberant buds, fluting, wood density and bark thickness.

The correspondence between results in the first and second assessment has been examined and quantified through three steps for each reassessed trial:

1. Analysis of provenance differences based on data measured at the young age (7-9 years) and the later age (17 years).

2. Analysis of the development from the first to the second assessment. Have some provenances had, for example, significantly lower increment in a given trait than others, during the intermediate period?

3. Calculation of the correlation between the average performance of the provenances at the young and later age.

5.1.1 Separate analysis of provenance performance at the young age and later age

All trials were originally designed as a random block layout. The number of blocks (replications) varied from 4 - 8. The number of trees per plot varied from 4 - 25.

Separate analyses were performed on plot averages for each trait and trial at each of the two assessments. They were used to test whether significant differences between provenances could be found. Mean average provenance performances were also estimated as least square means corrected for any unbalance in the trial.

The provenances are organized in provenance regions, as described in section 3.1. There are therefore two interesting questions which can be put forward concerning genetic variation between seed sources. First, are there any significant differences between the provenances for a given trait - and if so: are there any significant differences between provenance regions? In the latter case we can say that there are significant differences on a regional level. This means that we can identify provenance regions from which the seed sources perform differently from other regions, ie. the variation in seed source performance is associated with provenance regions rather than individual provenances within regions.

More specifically four situations may occur:

1. N*o significant differences between provenances:*
   We must conclude that measured differences between provenances might be random.

2. *Significant differences between provenances, but the differences are not significant on a provenance regional level - only between provenances within regions:*
   We must conclude that there are significant differences between the tested seed sources, but the variation between provenances within regions is large compared to the differences between provenance regions. This indicates a complex pattern of variation. Generally we can only recommend specific seed sources in this situation, not geographic/ecological zones, as different stands from the same regions may give different results.

3. *Significant differences between provenances and significant differences between both provenance regions and provenances within provenance regions*: In this case we must conclude that we can identify some provenance regions from which the seed sources in general perform differently from others. There are, however, still significant differences between provenances within the separate regions. Additional gain can therefore be achieved if it is possible to select the best of the tested provenances within best regions.

4. *Significant differences between provenances and significant differences between provenance regions - but not significant difference between provenances within provenance regions:*
   In this case we must conclude that we can identify some provenance regions from which the seed sources in general perform differently from others. The use of seed sources from the best provenance region(s) may therefore be important, but within the regions the seed sources must be assumed to be fairly homogeneous. This result corresponds to the most simple genetic pattern.

The test of significant *differences between provenances* is based on model (I):

(l) $X_{ij} = \mu + Prov_i + Block_j + f_j(position\ within\ block) + \varepsilon_{ij}$

where X_{ij} is the average value of given trait of all living trees in plot (ij).

The term μ is the grand mean.

$Prov_i$ is the effect of provenance number *i.* It is assumed to be a random effect, which means that the effect of the provenances can be seen as samples from a normal distribution with an expected value of zero and a variance of σ_{pr}^2 (X_{ij} N(0, σ_{pr}^2)).

$Block_j$ is the effect of block (j) (replications) in the trial. lt is assumed to be a random effect.

ε_{ij} is the residual in plot (ij), assumed to be normally distributed (N(0, σ_e^2)).

The term$_j$ (position within block) is an optional co-variate in the model used to reduce the within block variation in trials with large, or heterogeneous, blocks. It may contain linear or quadratic terms of the two-dimensional position in each block. The actual composition is selected individually for each trait and trial. The composition is based on comparison of a number of models. The co-variate is constructed as a trade off between four objectives: i) a good fit, i.e. no systematic errors in the expectation structure of the model, ii) low standard deviation on estimates of average provenance performance, iii) low residual variance compared to variance between provenances, and iv) preference for simple models. The two first objectives are considered to be the most important ones.

The significance of differences between provenances in a given trait was tested by an F-test comparing the variance between provenances with residual variance. If the F-test was significant and the reported differences between provenances therefore unlikely to be random, then the effect of provenances for a given trait (or put even shorter: the given trait) was said to be significant. This terminology is used throughout this publication.

The test of significant *differences between provenance regions - and provenances within regions* - is based on model (II), where the effects of provenances are split into an effect of provenance regions and an effect of provenances within regions :

$$\text{(II) } X_{ij} = \mu + Provreg_k + Prov(Provreg_k) + Block_j + f_j\ (position\ within\ block) + \varepsilon_{ij}$$

Model (II) is identical with model (I) except for the effect $Provreg_k$, which is assumed to be a fixed effect originating from the provenance region to which provenance (i) belongs. $Prov_i(Provreg_k)$ is then the effect of provenance (i) within provenance region (k) (still random effect).

The significance of differences between provenance regions was tested by an approximate F-test based on the so-called Satterthwaite procedure (Satterthwaite 1946).

Both model (I) and (II) are subject to a number of standard assumptions (see e.g. Box *et al.* 1978 for reference), which must be checked for each trait and trial. In this investigation it has been done by graphical standard procedure s (see e.g. Graudal 1993). For some combinations of traits and trials the analysis of variance (ANOVA) had to be discarded, because the assumptions could not be met.

Correction for tree size.

Pilodyn penetration and bark thickness were adjusted for individual variation in tree size prior to the analysis. These two traits normally correlate highly with the tree size. Large trees normally have thicker bark then small trees. The wood density may also be influenced by growth rate of individual trees.

The regressions between tree size and bark thickness/pilodyn penetration were estimated. These linear relations were used to correct the measurements so as to correspond with »the average tree size« in the trial. Variance in the traits due to difference in individual tree size was thus removed as much as possible from the data. The provenances were compared assuming that they had the same average tree size. It can be said that we have compared the level of the traits rather than their actual value. It was also investigated whether the provenances had the same bark thickness for the same tree size. Obviously fast growing provenances with large trees on the average have thicker bark than slow growing provenances with small trees.

5.1.2 Analysis of development from the first to the second assessment

The development from the first to the second assessment, that is:

$$Dx_{ij} = X_{ij}(late) - X_{ij}(early),$$

was also analyzed for each trait and trial. DX_{ij} (the increase in the average plot value of $plot_{ij}$) was analyzed with the models (III) and (IV):

$$\text{(III) } DX_{ij} = \mu + Prov_i + X_{ij}(early) + Block_j + f_j(position\ within\ block) + \varepsilon_{ij}\ .$$

$$(IV)\ DX_{ij} = \mu + Provreg_k + Prov/Provreg_k) + X_{ij}\ (early) + Block_j + f_j\ (position\ within\ block\} + \varepsilon_j.$$

where X_{ij}(early) is the average value of the plot at the early stage. This value is used as a covariate in this analysis. Other effects are as described for model (I) and model (II) above.

The models (III & IV) were used for tests of significant differences between provenances regarding increment/decrease of the given trait. With these models we have analyzed whether the increment/decrease in the specified trait has been significantly different for the different provenances (model III), or between provenance regions and provenances within regions (model IV). The plot value at the early age (X_{ij}(early) was included as a co-variate. This means that these models focused on differences *other than those which simply reflected differences already found at the young age*. Three situations can be considered of which only situation 3) can be said to correspond to a case where significantly new information has been found in the most recent assessment :

NO SIGNIFICANTLY NEW INFORMATION FROM THE SECOND ASSESSMENT:

1) *Effects provenances*[1] *and the effect of* X_{ij} *(early), are all non significant.*
It must be concluded that it has not been possible to identify any significant differences between the average increment of the provenances.

2) *Effects of provenances*[1] *are not significant. Effect of* X_{ij}*/ early) are significant.*
It must be concluded that the increment/decrease of the individual plots is correlated significantly with the plot value at the younger age. The change thus reflects differences already observable at the young age. No new information concerning provenance differences has, however, been revealed in the period between the first and second assessment, because the effects of provenances are not significant. The provenances may actually have had a different average increment, but only one that may be considered as a prolongation of results found during the first assessment.

NEW INFORMATION FROM THE SECOND ASSESSMENT:

3) *Effects of provenances*[1] *are significant. Effect of* X_{ij}*/ early) may - or may not - be significant.*
It must be concluded that the increment/decrease has been significantly different for different provenances. The differences reflect a new genetic pattern, because the changes cannot be explained simply by differences already seen at the younger age.

The analysis according to model (III) and (IV) can be seen as a »test of additional information«. In situation 3) significant changes in terms of different development of the provenances have been revealed. Additional information has thus been gained from the second assessment. The differences in average development in the period between the two assessments will be useful in ranking the provenances.

5.1.3 Calculation of correlation between the performance at the two assessments

A quantitative measure of the agreement between the first and second assessment is the **correlation** between the assessed values. These can be estimated as phenotypic correlations (r_p) at different levels: Between the measures of the single trees (correlation on single tree level) or between the provenance means (provenance level). The phenotypic correlations, r_p were calculated in this investigation at the provenance level, because the provenance mean is the most relevant figure to compare. High correlation (close to 1.00) means that the performance of the provenances relative to each other is approximately the same at the two assessments. Low, or even negative, correlation means that the relative performance has changed.

The correlations between the provenance averages are subject to effects of so-called environmental correlation. Another estimate of the correlation is the »genetic correlation« (r_g), which is based on an analysis of covariance (ANOCOV) between the data of the two assessments. The genetic correlation can only be estimated with an acceptable accuracy if the number of provenances is adequate, and significant variation is found at both ages. r_g was calculated as an alternative to r_p in this investigation whenever these prerequisites were met by the data. Please refer to Becker (1986) for a detailed account of estimation of r_g, and to Wellendorf *et al.* (1986) for more detailed interpretation of r_g in provenance research.

5.2 Levels of significance

All the tests used in this investigation were assumed to be significant if the tested hypothesis could be rejected at a significance level of 5% ($\alpha=0.05$). This level was chosen as a suitable compromise between risks of judging as »significant« differences in performance actually caused by chance, and failing to detect as »significant« differences caused by true differences between provenances.

Still $\alpha=0.05$ means, that »one out of twenty« apparently significant effects will be due to chance and so »falsely significant«. This is problematic considering the large number of traits and effects tested in this investigation.

The problem of false significance was to some extent addressed by using the so-called Sequential Bonferonni technique. The idea behind this technique is to adjust the levels of significance for each test separately. The correction is based on (i) the number of analogous tests performed, and (ii) the level of significance of the individual test compared to the rest of the analogous tests. The technique is described in detail by Holm (1979). An additional test using this technique was performed in model I for provenance effects found significant according to the traditional 5%-level criteria. Each

[1] or in model IV: Provenance regions and /or provenances within regions.

trait was considered to be a separate analysis, and the number of analogous tests used for correction is therefore typically eight, because eight trials have been analyzed. Tests for provenance variation which were found to be significant according to Bonferonni criteria as well as to the simple 5%-criteria, are marked with an asterisk in the ANOVA tables in section 7 and 8. Some approximations were made. Details on the interpretation of significance according to simple 5%-level test compared to significance according to the sequential Bonferroni tests are given by Rice (1988).

5.3 Estimation of predicted provenance performance

The average provenance performance ($X_i.$) was estimated as a least square mean from the ANOV A described above. The performance of the individual provenances was obtained by transforming the LS-means to the deviations from the overall average (X..) in percentage.

$$PD_i = 100\%*((X_i - X..)/X..),$$

where $X_i.$ is the estimated LS-mean of the provenance, X.. is the overall average in the trial, i.e. the average of all provenance means.

The estimates are only determined with a certain degree of accuracy. The standard errors of the estimates can be calculated on the basis of the ANOV A. Unfortunately the size of the standard error varies highly between trials and traits. This makes it difficult to compare the results of different traits, and of different trials. Here we have therefore chosen to reduce the PD_i's by the so-called provenance heritability (h_p^2), rather than present the differences with their corresponding standard deviations. This technique was also used in the first evaluation (Keiding *et al.* 1986).

The provenance heritability can be seen as a generalization of the family heritability concept (see e.g. Falconer 1989). It is here used to describe the ratio between genetic and phenotypic variance of provenance means. The provenance heritability can be calculated from the estimated variance components in model (I).

$$h_p^2 = V_{prov}/(V_{prov} + V_E) \approx \sigma^2_{pr}/(\sigma^2_{pr} + \sigma^2_e/r_i)$$

(Burley and Wood 1976)

where V_{prov} is the variance due to provenances. σ^2_{pr} is the variance component due to provenances obtained from the ANOVA (model (I)).

V_E is the variance (due to environmental deviations) of the estimate of the provenance mean. V_E can - in balanced experiments with r randomized blocks - be estimated as σ^2_e/r_i. This corresponds to the error variance of the average of r replications. In unbalanced experiments and/or experiments where the position of the plots within the blocks are used as co-variates in the ANOVA this is no more correct. The number of replications (r_i) may be different for the different provenances, if some provenances are missing in some of the replications. A poorly represented provenance will therefore have a lower provenance heritability than a completely replicated provenance, because the average performance are determined with a larger standard error. Application of co-variates in order to reduce the within block variance f (position within block) in model (I) complicates the calculation further, because the position of the provenances in the blocks also influences the standard error of the predicted average performance.

In this investigation the provenance heritabilities were therefore calculated by applying the modified formula:

$$h_p^2(i) \approx \sigma^2_a/(\sigma^2_a + \sigma^2_{e'(i)})$$

where $\sigma^2_{e'(i)}$ is the specific estimate for variance of the LS-mean corresponding to provenance (i). This variance was estimated - as well as provenance means - as least square estimates by the GLM-procedure in the SAS-programme package (SAS-Institute 1990). By applying this general procedure we have handled the combined effects of unequal representation and effects of co-variates on the LS-means.

The predicted provenance value (PPV) of a given trait in a given trial was then calculated as:

$$PPV_i \;=\; h_p^2(i) \cdot PD_i$$

The provenance heritability will always lie between zero and one. The differences between the provenance means (PD_i) , as observed in the trials were thus reduced by the factor $h_p^2(i)$ in order to achieve the predicted provenance value (PPV_i}

The predicted provenance value (PPV_i) can be interpreted as **the breeding value** of the provenance, this is *the expected perfomance of the provenance (i), if the same plants were grown again in the same trial, and under the same conditions*.

The use of provenance heritability is discussed in more details by Burley and Wood (1976) and Graudal (1993). The idea of »shrinking« phenotypic differences into provenance breeding value is discussed and justified in Kung (1979).

Example of calculation of Predicted Provenance Value for tree size.

The average tree size of the Moist Indian provenance SC3016 is e.g. 19% larger than the average of the provenances tested in the Thai trial IP038.

This estimate is influenced by a certain degree of random error due to stochastic environment. The provenance heritability can be calculated from the analysis of variance to be only $h_p^2 = 0.38$. This is low, although the differences actually are significant. Our prediction of the genuine value of this provenance is therefore only:

$$PPV(3016) = 0.38*19\% = 7\%.$$

This PPV for average tree size is our best estimate for superiority. The correction and scaling makes it easier to compare this value with values for other traits - and also results from other trials.

6. STATISTICAL ANALYSES ACROSS TRIALS

The trials were arranged in four trial regions based on the first evaluation, as described in section 3.2. These regions were maintained as basic units in this analysis, but their validity was tested in three of the trial regions: Brazil & moist parts of West Africa, West Africa semi-moist & dry, and Central America. Only one trial was re-assessed in the South East Asian trial region, and it is therefore not possible to test the validity in this region. The test can only be seen as a partial examination, as only 8 of the original 21 trials were re-evaluated.

6.1 Interaction within trial regions

The validity of the trial regions was examined in two ways:

l) The performance in the replicated trials within the trial region was analyzed for any interaction between provenances and trials.
2) The size of the interaction was quantified by calculation of phenotypic and genetic correlations between provenance performance at different locations.

The results are presented for each trait and trial region in section 7.1-7.4. The methods are described in more detail below.

6.1.1 Test of interaction

The interactions were tested by separating the accountable variance into components corresponding to trials, provenances, blocks within the trials and finally interaction between trials and provenance (Model (V)):

$$(V)\ X_{ij} = \mu + Trial_k + Prov_i + Block_i(Trial_k) + Trial_k * Prov_j + \varepsilon_{ij}.$$

All effects were assumed to be random in this model.

Standard assumptions concerning independence and normal distribution were made and checked analogous to the analysis described in chapter 5. The residual variances are generally not the same in different trials. This problem is met by weighting the SS-values in the model V ANOVA with the inverse of the residual variance of each trial. More details on this procedure are e.g. given by Cotterill *et al.* (1982).

A significant »Trial-by-Provenance« effect means than provenances perform significantly different on the different locations. It does not automatically mean that the ranking is different. Significant interaction may for example occur if the differences are small in one location, but large in another - even if the ranking is the same. This type of interaction is not very problematic from a practical point of view, as the same set of provenances are the best in both trials.

Significant interaction combined with *change in ranking* is more problematic, as this indicates that different provenances are recommendable on different sites, and the trials therefore can be said to belong to different trial region s (with reference to that specific trait). Still, the size of the interaction is important.

A detailed discussion of interpretation of interaction between provenances and trials (environments) is given by Matheson & Cotterill (1990).

6.1.2 Correlation between trials

The agreement between performance of two trials can be quantified by calculating the correlation between the provenance performance in a given trait at one pair of trials. Phenotypic correlation between trials (r_{pij}) was calculated as the correlation between the average performance of a set of provenances in a given trait in one pair of trials.

»Genetic« correlation (r_{gij}), i.e. correlations corrected for the size of random environmental influence, was calculated as,

$$r_{gij} = r_{pij}/(\sqrt{h^2_i}\sqrt{h^2_j})$$

where $\sqrt{h^2_i}$ and $\sqrt{h^2_j}$ are the square roots of the average provenance heritabilities of the given trait at the two locations. The heritabilities were calculated as described in section 5.2. The genetic correlations were only estimated if the provenances are significantly different at the two locations for the specific trait.

A high correlation indicates that performance was comparable at the two sites, and that there is no interaction of practical importance.

Correlation in performance between pairs of trials was typically determined with large standard errors in this investigation, because relatively few provenances were tested at two locations.

The application of correlations to estimate provenance-by-trial interaction is a generalization of analogous examination of genotype-by-environment interaction suggested by Falconer (1989) and Burdon (1977). Wellendorf *et al.* (1986) have applied it to provenance research. For more details, see mentioned references.

6.2 Interaction between trial regions

It is also interesting to examine to what extent interaction between the trial regions occur. At the younger age such interaction was found for growth (this was the reason for analysis within trial regions).

The data is highly unbalanced. The analysis was therefore performed at the level of provenance regions according to model (VI):

$$(VI) \quad X_{ij} = \mu + Trial\_reg_l + Trial_k(Trial\_reg) + Prov\_reg_m + Trial\_reg_l{*}Prov\_reg_m + \varepsilon_{ij'}$$

where $Trial\_reg_1$ is the effect of the trial region, $Trial_k$ is the effect of the trial within the trial region, $Prov\ \_reg_m$ is the effects of the provenance region. Trials within trial regions were assumed to be a random effect. Other effects were assumed to be fixed. The analysis was performed weighted with the inverse of the residual variance of the separate trials.

F-tests were according to Satterthwaite (1946).

Attention is drawn to the circumstance that the analysis of interaction at a provenance region level will have a tendency to overestimate the »trial-region by provenance-region« interaction, because the provenance regions typically are represented by different provenances in the different trial regions. What appears to be interaction between provenance regions and trial regions may actually be partly due to variation between provenances within provenance regions.

The results are presented in section 8.

7. RESULTS FROM THE FIRST AND SECOND ASSESSMENT OF THE INDIVIDUAL TRIALS

A summary of the general trends from the 8 re-assessed trials is given in section 7.1.

In the second evaluation, the grouping of trials into trial regions was based on findings from the first evaluation, but the validity of these regions has been re-examined. An account of the validity of each trial region is given for traits assessed at the second evaluation in section 7.27.5. Results from an analysis across regions are given in section 8.

A detailed account of the differences found in each trial is given separately for each trial region in sections 7.2.-7.5. In these sections we focus on a discussion of the validity of the recommendations of the first evaluation for the specific trial regions. Changes between the first and second evaluation are discussed under the subheadings: Adaptation, stem quality, and growth. The representation of trials within the four trial regions is: South East Asia with trial (IP038 in Thailand), Central America with (IP045, IP046 in Puerto Rico and IP047 in St. Croix), Moist West Africa and Brazil (with IP003 and IP005 in Brazil), and Dry-Semi-moist West Africa with (IP008 and IP009 in Ghana), see figure 1, page 9.

7.1 General trends

7.1.1 Agreement between the results in the first and second assessment

Six traits were assessed at both ages: Survival, health, persistence of axis, stemform (straightness), branch size and growth rate. One of four situations occurred for each trait in each trial:

A) The trait was not significant in either assessment.

B) The trait was found to be significant at the first assessment, but the differences are no longer significant at the second assessment. The long term differences may be overestimated if based on the results from the first assessment.

C) The trait was found not to be significant during the first assessment, but the provenances have developed differently since then, so that the differences now are significant.

D) The traits were found to be significant at both ages. The differences found at the two assessments may, or may not, be in the same direction.

The results in terms of situations (A-D) in the 8 re-assessed trials are summarized in Table 7.1 (some approximation is made):

Table 7.1 Distribution of different ‘situations’ of significance for the tested traits

TRAIT	**Situation A**	**Situation B**	**Situation C**	**Situation D**	**SUM**
	Age 7-9:NS Age 17: NS	**Age 7-9: SIGN Age 17: NS**	**Age 7-9: NS Age 17: SIGN**	**Age 7-9: SIGN Age 17: SIGN**	
Survival	4	I	2	1	8
Health	2	2	O	1	5
Persistence of axis dominance	2	2	1	3	8
Stemfonn	1	O	3	3	7
Branch size	2	2	O	3	7
Tree size (Ba/tree)	2	O	4	2	8
Growth rate (Ba/ha)	3	1	2	2	8
SUM	16	8	12	15	51

NS = Not significant provenance variation (simple 5%-level). SIGN = Significant provenance variation (simple 5% level). See text for further explanation.

The picture is not simple. There is a tendency that situation B occurs more often than C for health and branch size, i.e. significant differences have »disappeared« more often than they have »appeared«. The opposite seems to be the case for stemform and tree size. Stemform differences were found to be significant in six of eight trials at the later age opposed to the younger age, where they were significant in only three trials.

It is important to realize that the two measures of growth are influenced differently by differences in early survival/mortality. If early mortality is evenly spread, then the heavier the mortality the less the subsequent competition between the trees. This can result in higher increment in tree size (Ba/tree) of the affected provenance, but lower increment in growth rate (Ba/ha). If, on the other hand, a provenance is poorly adapted to the site, then poor survival will be followed by poor growth of the survivors, as they are unhealthy themselves.

Another way of looking at the differences is by testing »if new information has evolved«. This technique is described in section 5.1. The idea is to examine if the development from the first to the second assessment has given us new information on provenance differences (if so = YES) - or if the development is without any pattern or merely an increase of differences already observable at the younger evaluation (if so = NO).

The results of this investigation are seen in Table 7.2.

Table 7.2 Number of significant tests for new information

TRAIT \ NEW INFORMATION?	YES	NO	SUM
Survival	3	5	8
Health	1	4	5
Persistence of axis dominance	4	4	8
Stemform	6	1	7
Branch size	3	4	7
Tree size (Ba/tree)	1	7	8
Growth rate (Ba/ha)	3	5	8
SUM	**21**	**30**	**51**

See text for further explanation.

New information has been revealed in two-thirds of the situations according to this test. Six out of seven trials have revealed new information for stemform. Significant new information is also found for persistence of terminal axis in half the trials.

Significant new information for tree size was found only in one trial, although »new« significant information appeared in half the trials (situation C in table 7.1).

7.1.2 New traits

A number of traits was assessed for the first time at the second assessment:

Epicormic branches
Protuberant buds
Buttressing
Bark thickness
Wood density (measured by pilodyn penetration)

Significant differences were found between provenances in all of these traits, although not in all trials. We have not tried to quantify the economic importance of these new quality traits, but the differences can be included in an overall recommendation based on local conditions and experience. The provenance differences are presented in section 7.2-7.5.

7.1.3 Provenance regions versus provenances (seed sources) within regions

In this investigation we have tried to separate significant differences between provenances into two components, (i) The variation due to differences between provenance regions, and (ii) the variation due to differences between seed sources within the same provenance region. The trials were not designed for this examination originally , and the provenance representation is highly unbalanced. It was therefore not possible to separate the variation in all trials. A summary of the findings is given in Table 7.3. Only data from four trials are included in this presentation. Some approximations are made.

Table 7.3 Distribution of variation between-regions and within-regions

Trait\Source of variation	**Mainly between regions**	**Mainly within regions**	**Both**
Survival	I	O	I
Health	O	O	I
Persistence of axis dominance	2	O	I
Stemform	3	I	O
Branch size	O	O	I
Epicormics	3	O	I
Protuberant buds	3	O	I
Relative pilodyn	I	I	2
Relative bark	2	O	O
Tree size (Ba/tree)	2	I	I
Growth rate (Ba/ha)	I	O	I

Only trials with suitable design and significant provenance differences (model I) are considered. See text for further explanation.

Provenance regions have been able to explain the largest amount of variation between seed sources in many cases, especially for epicormics, protuberant buds and bark thickness. Important within-region variation is, however, found for several traits, and recommendations can therefore not always be based on the broad provenance regions. The detailed account of the differences is given in section 7.2.-7.5.

7.2 Trial region: West Africa-moist and Brazil

This trial region covered four trials IP003 & IP005 (Brazil) and IP024 & IP026 (Nigeria) in the first evaluation. The two Brazilian trials were re-evaluated at age 17. The Moist Indian, Semi-moist Indian, Laos and Thai provenance regions were represented by more than one provenance. The data were therefore analyzed by both model (l) & (II) in order to examine if any observed differences would imply the presence of general differences between regions, or if the differences between provenances within region were more important than average regional differences.

Six provenances were tested in both trials. These six provenances were used to test for interaction between the two trials. The trials are located close to each other, and any significant interaction is therefore unlikely. The results of the analyses across trials are presented in table 7.4. The results are discussed in section 7.2.1-7.2.3.

Table 7.4 Analysis of interaction across the two trials in the trial region

Effect of	**TRIAL**		**PROVENANCE**		**TRIAL *PROVENANCE**	
Trait (age)	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	2.39	0.153	1.66	0.1 04	0.51	0.766
Survival (17)	0.75	0.404	**3.73**	**0.001**	0.48	0.788
Health (9)	0.35	0.565	**3.53**	**0.001**	0.93	0.471
Health (17)	**6.51**	**0.032**	**3.07**	**0.003**	1.19	0.329
Persist. (9)	0.99	0.337	**3.11**	**0.002**	0.48	0.788
Persist. (17)	0.04	0.842	**3.28**	**0.002**	0.51	0.768
Stemform (9)	**4.49**	**0.045**	**4.97**	**0.001**	1.14	0.301
Stemform (17)	0.74	0.411	**5.25**	**0.001**	1.60	0.176
Br. size (9)	0.24	0.632	**3.98**	**0.001**	0.44	0.821
Br. size (17)	2.11	0.176	**2.14**	**0.030**	0.54	0.748
Epicormics	0.52	0.485	**4.66**	**0.001**	0.56	0.727
Protub. Buds	0.13	0.728	**2.37**	**0.016**	0.42	0.835
Buttressing	0.13	0.726	**3.48**	**0.001**	**2.70**	**0.031**
Ba /tree (9)	**9.07**	**0.008**	**4.99**	**0.001**	2.24	0.064
Ba /tree (17)	**6.61**	**0.023**	**5.61**	**0.001**	**2.63**	**0.035**
Ba /ha (9)	1.24	0.278	**4.46**	**0.001**	0.86	0.517
Ba /ha (17)	2.26	0.150	**7.86**	**0.001**	1.08	0.381

Note: Effects significant at a simple 5%-level are typed in bold.

Table 7.5 Correlation between provenance performance in the two trials

Effect of	**Age 9**		**Age 17**	
Trait	r_p	r_g	r_p	r_g
Survival	0.22	-	0.78	-
Health	0.45	0.63	0.99	-
Persistence	0.71	-	0.70	-
Stem form	0.42	0.61	0.61	0.86
Branch size	0.93	-	0.71	-
Ba /tree	0.32	-	0.51	-
Ba /ha	0.55	-	0.85	-

The »genetic correlation« is only estimated for traits where significant differences are found in both trials (see section 6.1.2 for details).

Table 7.6 Correlation (within trial) between provenance performance at age 9 and 17

Effect of	**IP003**		**IP005**	
Trait	r_p	r_g	r_p	r_g
Survival	0.43	-	0.81	-
Health	0.64	-	0.02	-0.51
Persistence	0.72	-	0.76	0.92
Stem form	0.35	0.77	0.76	0.97
Branch size	0.28	-	0.74	-
Ba /tree	0.91	-	0.96	1.08
Ba /ha	0.57	-	0.93	0.82

The »genetic correlation« is only estimated for traits where significant differences are found at both ages (see section 5.1.3 for details).

7.2.1 Adaptation

Survival and health were assessed in both trials at age 9 and 17. The results of the ANOVA's and ANOCOV's are presented below in table 7.7 and 7.8. Correlations between provenance averages at age 9 and 17 are presented in table 7.6. (above).

Table 7.7 ANOVA for adaptive traits

IP003	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	1.48	0.663	-	-	-	-
Survival (17)	0.54	0.772	-	-	-	-
Health (9)	**3.38**	**0.028**	0.87	0.591	3.91	0.045
Health (17)	1.97	0.139	-	-	-	-
IP005	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	1.99	0.068	-	-	-	-
Survival (17)	**4.15**	**0.001 ***	2.33	0.168	2.34	0.058
Health (9)	**3.69**	**0.002***	1.10	0.448	**3.40**	**0.012**
Health (17)	**2.55**	**0.021**	2.38	0.165	1.53	0.203

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Table 7.8 ANOCOV for development from first to second assessment

IP003	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development in:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Survival	**0.027**	0.158	0.589	0.053	0.158
Health	0.319	0.365	-	-	-

IP005	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Survival	**0.001 ***	**0.002**	**0.017**	0.417	**0.002**
Health	**0.027**	**0.002**	0.139	0.246	**0.002**

Notes: Effects significant on a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk is also significant according to the sequential Bonferonni procedure (see section 5.2).

No significant differences in **survival** were found in **trial IP003** in either the first or the second evaluation. There were however, significant differences between provenances in the **increase in mortality**. The Semi-moist Indian (SC3034), Moist Indian (SC3020) and African (SC3044) have had relatively low mortality at age 9, and significantly lower mortality than average from age 9 to 17 indicating that these provenances seem generally healthy. Besides this information **IP003** has not contributed much to expose differences between the provenances concerning adaptation.

The other trial, **IP005**, gives more information about adaptation differences. Significant differences in survival were found at both ages. The differences assessed at age 17 are not strictly statistically significant at a regional level, but a clear pattern of regional differences is revealed (figure 4). Provenances from Laos and Thailand have poor survival in general in contrast to provenances from Moist India. The provenance from Indonesia has turned out to have the highest relative survival.

The average survival of all provenances at age 9 is relatively well correlated with the average survival at age 17, rp=0.81, but the mortality in the period has been significantly different for the provenances. The significance is especially caused by a very low mortality of the Indonesian (SC3049) and the Moist Indian (SC3020) provenances in the period, and by high mortality from age 9 to 17 of the Laotian provenance (SC3056). The differences have thus increased in a way that is not simply an extrapolation of the findings from age 9. The general ranking of the provenance regions has, however, not changed much.

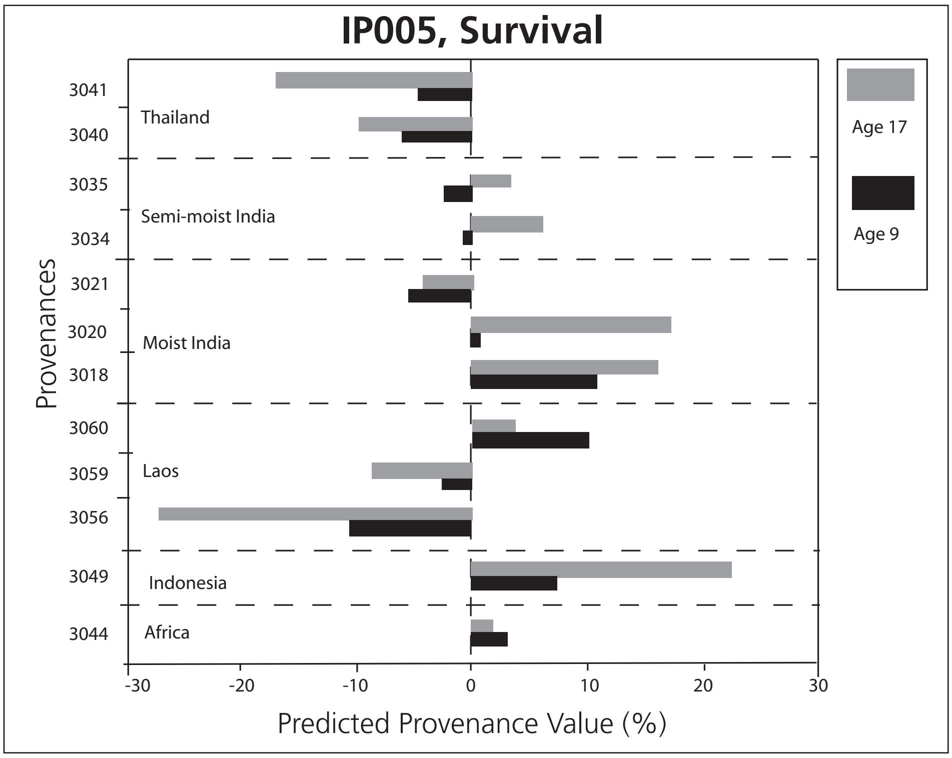

Figure 4. Survival in IPOO5. Aracruz, Brazil.

No significant interaction between the two trials was found in **survival** at any of the two ages. The results from the two trials do not suggest that the trials should belong to different trial regions. The correlation between the performance of provenances in the two trials is much better at age 17 (r_p^{17} = 0.78) than at age 9 (r_p^{9} = 0.22).

In **trial IP003** the differences between provenances within provenance regions in average health were small though significant in the first assessment. More trees were found to be unhealthy at the later stage, but the differences were not significant at this age. There were no significant difference between provenances in the relative change in health.

The differences between provenances in health were significant at both ages in **IP005**. In addition, the changes in health from age 9 to 17 has been significantly different for the provenances, i.e. new information has been accumulated. The correlation is very low between the average performance at age 9 and 17, rp=0.02. The genetic correlation is even negative, rg = -0.51, which corresponds to changes in rank (figure 5). The provenance regions contribute more to the health differences at the later age than at the early age.

The differences in health are small, and more emphasis should be put on the much larger differences in survival when discussing adaptation differences.

No significant interaction in **health** was found between the two trials at either age. The correlation between the trials is high at age 17, rp=0.99. Thus the results from the two trials do not suggest that the trials should belong to different trial regions.

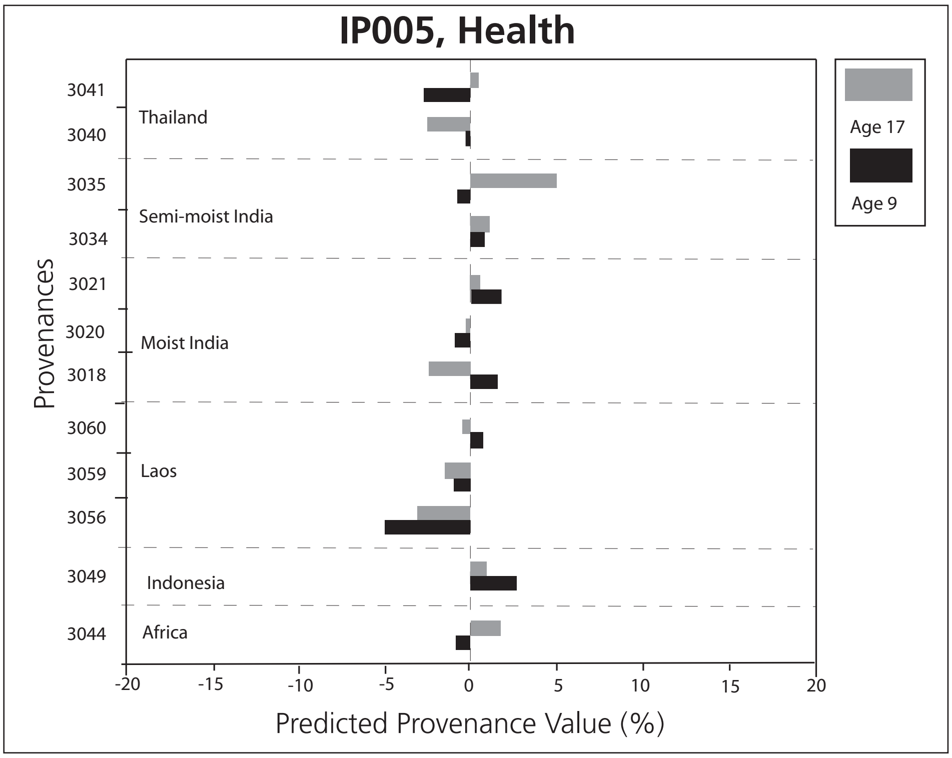

Figure 5. Health in IP005, Aracruz, Brazil.

GENERAL CONCLUSIONS CONCERNING ADAPTATION

The general picture in this trial region at age 17 may be summarized as follows: The Moist Indian and Indonesian provenances have generally shown a better long term adaptation than provenances from Laos and Thailand. The differences range from approximately 80% survival among Indonesian and Moist Indian provenances to approximately 60% survival among the Thai and Laos provenances.

Significant variation within provenance regions was found in the first assessment. At age 17 this variation within provenance regions has decreased, while differences between provenance regions have increased.

7.2.2 Stem quality

Three characters were assessed at both ages: Persistence of the axis, stemform and branch size. Pilodyn (wood density), epicormic branches, protuberant buds and bark thickness were assessed for the first time at age 17.

TRAITS ASSESSED AT BOTH AGES

Results of the ANOVA's and ANOCOV's are presented in table 7.9. and 7.10. Correlations between juvenile and mature assessments are presented in table 7.6. (above).

Table 7.9 ANOVA for persistence, stemform and branch size

Trial: IP003	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Persistence (9)	0.89	0.530	-	-	-	-
Persistence (17)	0.54	0.772	-	-	-	-
Stemform (9)	**2.95**	**0.045**	7.28	0.060	0.48	0.631
Stemform (17)	**2.90**	**0.047**	3.17	0.216	1.21	0.326
Branch size (9)	**3.56**	**0.024**	1.55	0.416	3.09	0.077
Branch size (17)	1.42	0.275	-	-	-	-
Trial: IP005	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Persistence (9)	**4.92**	**0.001 ***	0.92	0.529	**4.06**	**0.005**
Persistence (17)	**2.55**	**0.001 ***	2.05	0.207	**2.90**	**0.024**
Stemform (9)	**3.84**	**0.002***	0.65	0.673	**4.74**	**0.002**
Stemform (17)	**4.62**	**0.001 ***	1.02	0.481	**4.45**	**0.002**
Branch size (9)	**3.45**	**0.004***	**5.00**	**0.004**	1.22	0.324
Branch size (17)	1.90	0.082	-	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Table 7.10 ANOCOV for development from first to second assessment

IPOO3	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Persistence	0.692	0.572	-	-	-
Stemform	**0.015**	**0.001**	0.363	0.1127	0.001
Branch size	0.344	0.151	-	-	-
IPOO5	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Persistence	**0.013**	**0.019**	0.179	0.098	**0.019**
Stemform	**0.026**	**O.001**	0.479	**0.036**	**0.001**
Branch size	0.357	0.270	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

In trial IP003 no significant differences were found in the **persistence of the terminal axis** at either age. Similarly, there were no significant differences in the relative axis development from 9 to 17 years of age.

Contrary to this, the results from trial **IP005**, revealed significant differences in axis persistence at both ages. At both ages there were significant differences between provenances within provenance regions, but not at the provenance regional level. The changes in the maintenance of axis persistence from the first to the second assessment were significantly different. Especially the Laotian, SC3056, and the Moist Indian provenances, SC3018 and SC3020, have changed in a negative direction compared with the first assessment (figure 6). The persistence at age 9 is, however, still well correlated to persistence at age 17, rp=0.76 & rg=0.92. The provenances have in general kept their relative rank. The persistence remains good for the Thai provenances, SC3041 being the best in the trial, and for the Indonesian provenance, SC3049.

No significant interaction was found in persistence of axis between the two trials at either of the two ages. The correlation between the performance in the two trials is fairly high at both ages. The results from the two trials do not suggest that they should belong to different trial regions.

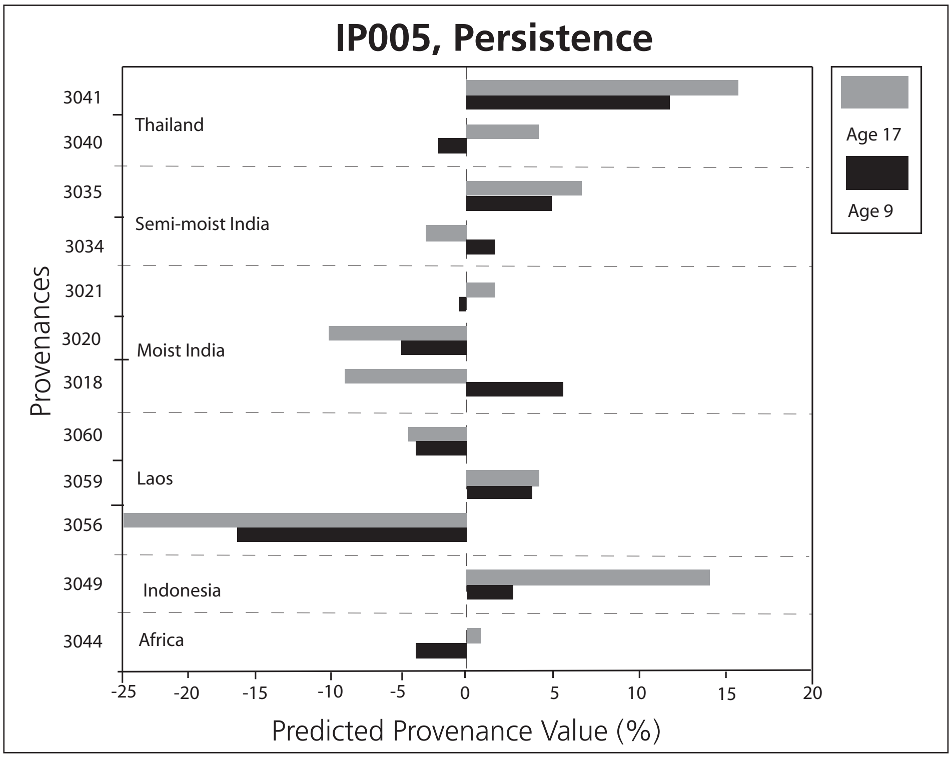

Figure 6. Persistence in IP005. Aracruz, Brazil.

In trial IP003 the stemform differed significantly at both ages. The different provenances have, however, developed differently in the intermediate time interval in such a way that the amplitude of the differences has decreased. The correlation between the first and second assessment is intermediate, rp=0.35 & rg=O.77. The ranking has to some extent changed (figure 7). The stemform of the African landrace (SC3044) has remained poor. The Thai provenances (SC3039 and SC3040) are of average stemform at age 17, while they were relatively superior at age 9. The Moist Indian provenances (SC3020 and SC3021) have generally improved in relative performance at the expense of the Indonesian and Thai provenances.

The **stemform** also differed significantly at both ages in **IP005**. The different provenances have, as in IP003, developed differently in the time between the two assessments causing the amplitude of the differences to decrease. The correlation between the first and second assessment is high, rp=0.76 & rg=0.97. The ranking has consequently changed less than in **IP003**. The stemform of the African landrace (SC3044) has remained poor. The Thai provenances (SC3040 and SC3041) are, along with the Indonesian provenances, still relatively good. The Moist Indian provenances (SC3018, SC3020, and SC3021) have all improved their performance (figure 8).

No significant interaction was found in **stemform** between the two trials at either of the two ages. The correlation between the trials is higher at age 17 than at age 9. The results from the two trials do not suggest that the trials should belong to different trial regions.

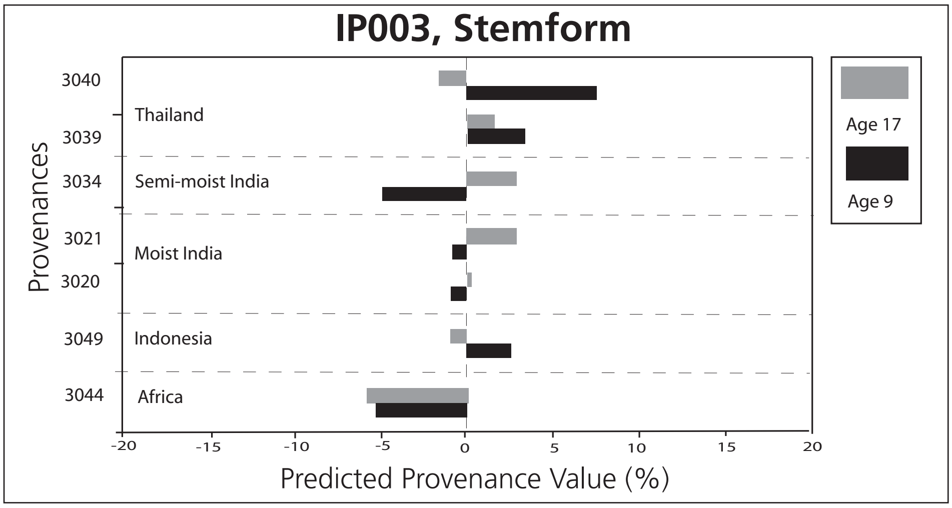

Figure 7. Stemform in IP003. Aracruz, Brazil.

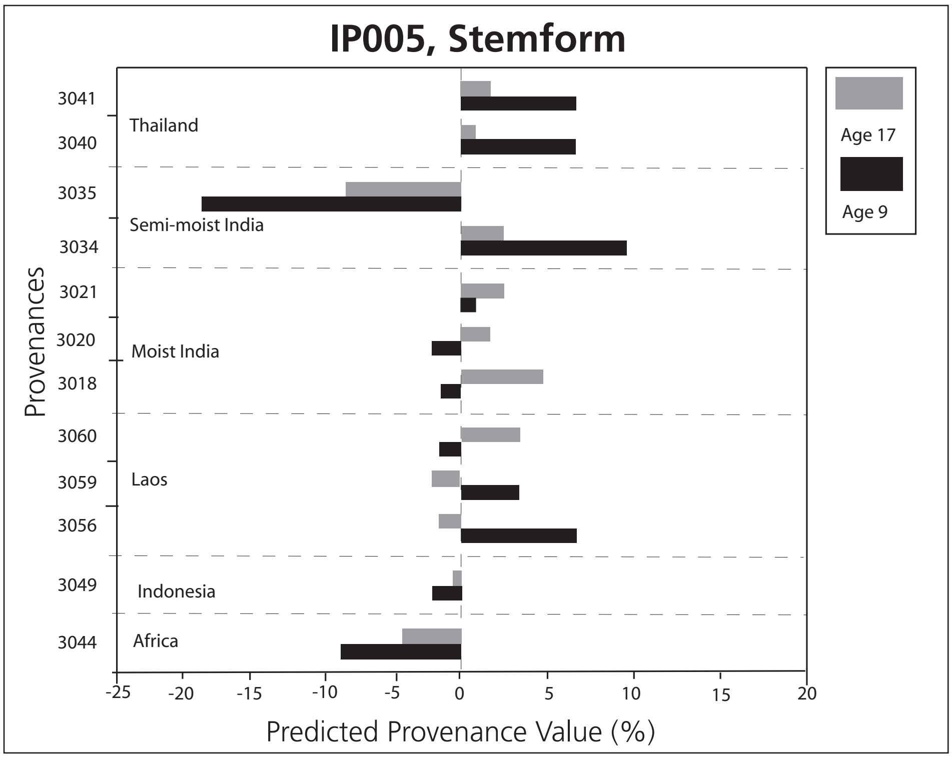

Figure 8. Stemform in IP005. Aracruz, Brazil.

Branch size differed significantly between provenances at age 9 in **IP003**, but the differences were small (less than +/- 5%), figure 9. The differences have changed in such a way at age 17, that they are no longer significant. The development in branch size from age 9 to age 17 did not differ significantly between provenances. Looking at the differences at age 17, they seem largely of the same pattern as at age 9 (figure 9), although the correlation is low. Possibly the change to non-significance of provenance differences may be caused by difficulties in properly assessing branch size when trees become taller. Inferring this, we consider that provenances differ more or less according to the results at age 9. The Indian provenances are thus likely to be the better provenances, but the differences are very small.

Branch size differed significantly at age 9 in **IP005**. At age 17 the differences were no longer significant, although closer to significance than in IP003. The significant differences at age 17 could be ascribed mainly to differences between provenance regions. The Moist Indian provenances still prove to have finer branches than the rest of the provenances tested at the two sites. The correlation between the average performance at 9 and 17 years in IP005 is rp=0.74, so the general ranking of provenance regions does not appear to have changed. In this trial the Moist Indian provenances are dearly the best provenances.

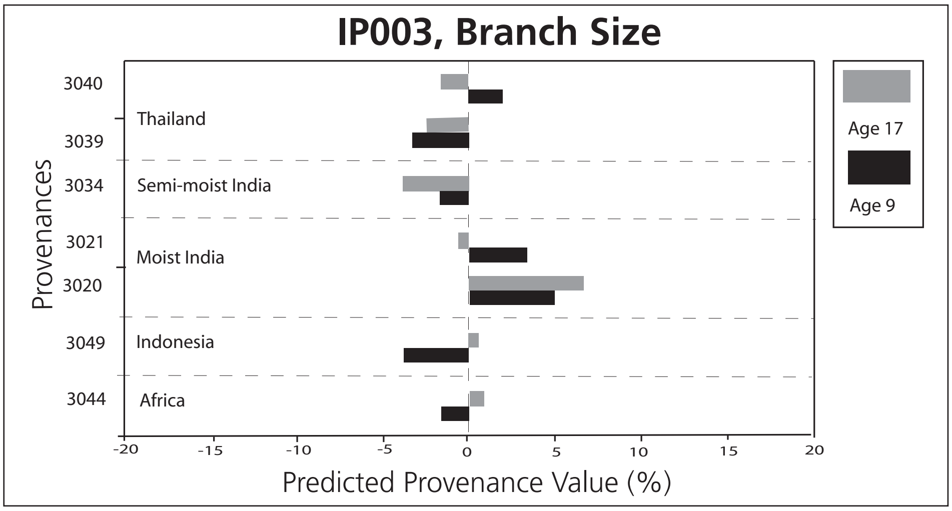

Figure 9. Branch size in IP003. Aracruz, Brazil. (Note: Positive values signify fine branches).

No significant interaction was found in **branch size** between the two trials at either of the two ages. The correlation is high at both ages, and the results from the two trials do not suggest that they should belong to different trial regions.

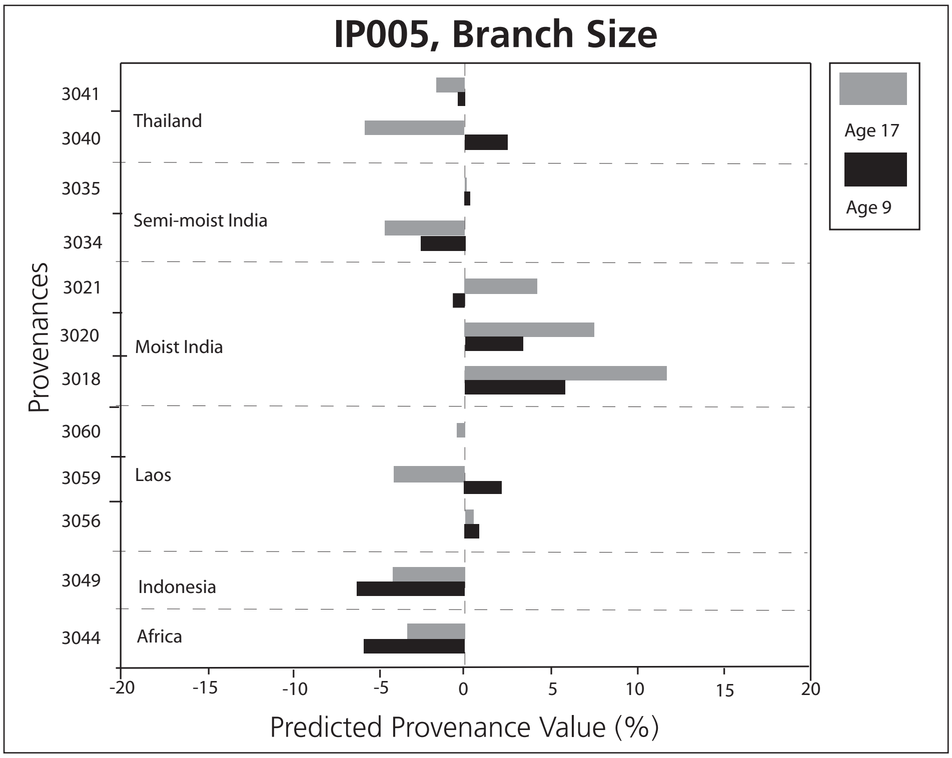

Figure 10. Branch size in IP005. Aracruz, Brazil. (Note: Positive values signify fine branches).

CONCLUSION CONCERNING TRE QUALITY TRAITS ASSESSED AT BOTR AGES

Based on the 17th year assessment the general picture is that the provenances from the Thai provenance region must still be considered of overall superior quality due to good stemform and persistence of terminal axis. The Moist Indian provenances have revealed a tendency to perform below average persistence, but their stemform has improved to above average. They have revealed fine branches, and the overall result is, therefore, that they should still be looked upon as being of high quality in this trial region. The one Indonesian provenance (SC3049) has improved in axis persistence, kept its reasonable stemform, and has generally maintained its intermediate or inferior branch size. It has therefore improved its relative performance in terms of stem quality. This is probably the most important change from the first evaluation, where the general quality of this provenance was found to be below average. Still, it is also important to recognize that the differences between provenances in the various characteristics have in general decreased.

QUALITY TRAITS ASSESSED ONLY AT THE SECOND EVALUATION

Results of the ANOVA' s are presented in table 7.11.

Table 7.11 ANOVA for epicormic branches, protuberant buds, relative pilodyn penetration (wood density) and buttressing

Trial: IP003	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait:	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Epicormics	**4.91**	**0.007***	2.23	0.318	3.08	0.078
Protuberant buds	0.56	0.752	-	-	-	-
Relative pilodyn	**5.14**	**0.006***	1.25	0.484	**4.45**	**0.032**
Buttressing	**3.92**	**0.013***	2.06	0.398	0.07	0.920

Trial: IP005	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait:	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Epicormics	**2.97**	**0.009***	2.40	0.162	1.69	0.159
Protuberant buds	**2.70**	**0.014**	1.29	0.378	2.38	0.051
Relative pilodyn	**2.90**	**0.011 ***	1.98	0.218	1.83	0.128
Buttressing	**3.00**	**0.007***	**10.42**	**0.006**	0.57	0.752

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

The differences in **relative wood density** (as measured by the **pilodyn**) are rather small, but significant, in the two trials in the region, i.e. less than +/- 4% of the average (figure 13 and 14). After conversion of the difference into absolute wood density the differences would normally be around half of this. In the present case differences would therefore be less than +/- 2% which corresponds to a variation around 700 kilos/cbm of +/- 14 kilos/cbm. The Indian provenances would generally have a better wood density than other provenances. The Indonesian, Thai and Laos provenances have a tendency to wood density on the lower side. However, in either case the differences cause no concern.

No significant interaction was found in **pilodyn** between the two trials. The results from the two trials do not suggest that the trials should belong to different trial regions.

Differences in **epicormic branches** are significant in both trials. The Moist Indian, Indonesian, and African provenances have more epicormic branches in this region than other provenances. The Indian provenances have e.g. from 2% to 12% more epicormic branches than the average of all provenances.

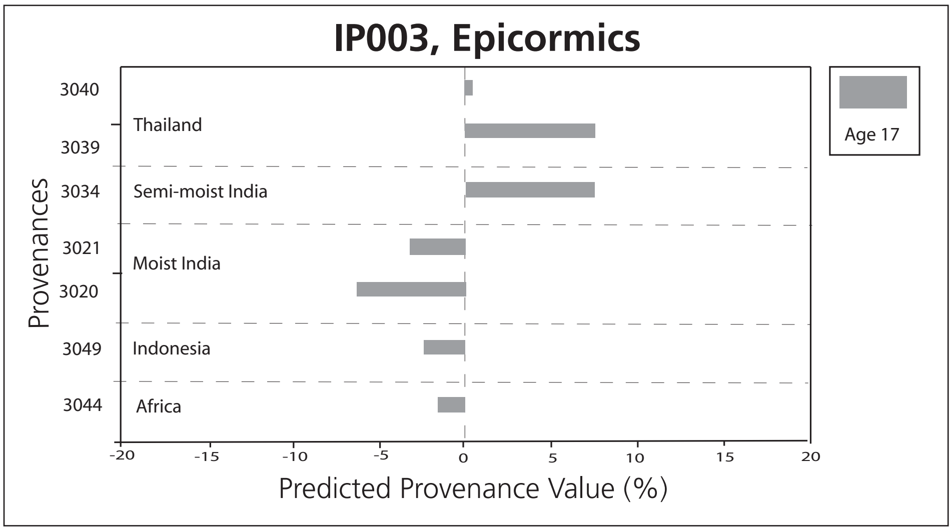

Figure 11. Epicormic branches (score) in IP003. Aracruz, Brazil.
(Note: Positive values signify small number of epicormics).

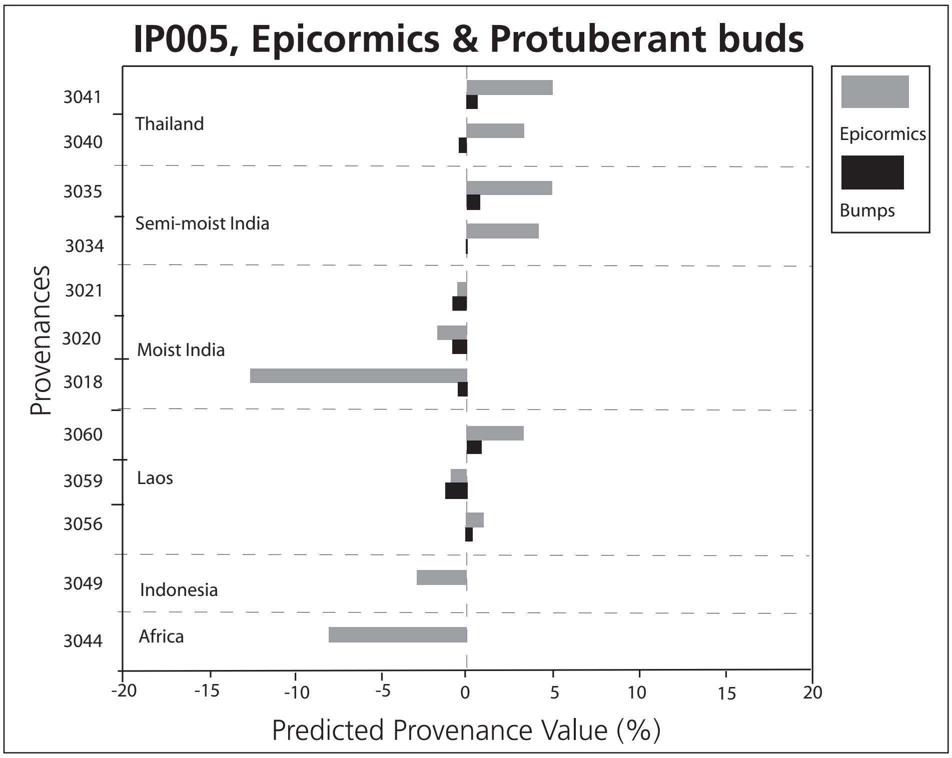

Figure 12. Epicormic branches and protuberant buds in IP005. Aracruz, Brazil.
(Note: Positive values signify small number of epicormics and bumps).

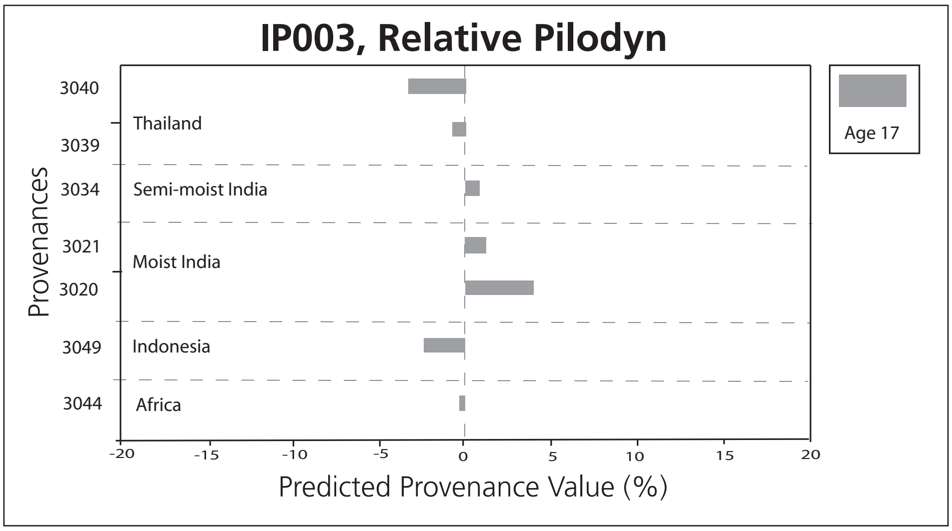

Figure 13. Relative pilodyn (wood density) in IP003. Aracruz, Brazil. (Note: Positive values signify small penetration or high wood density.

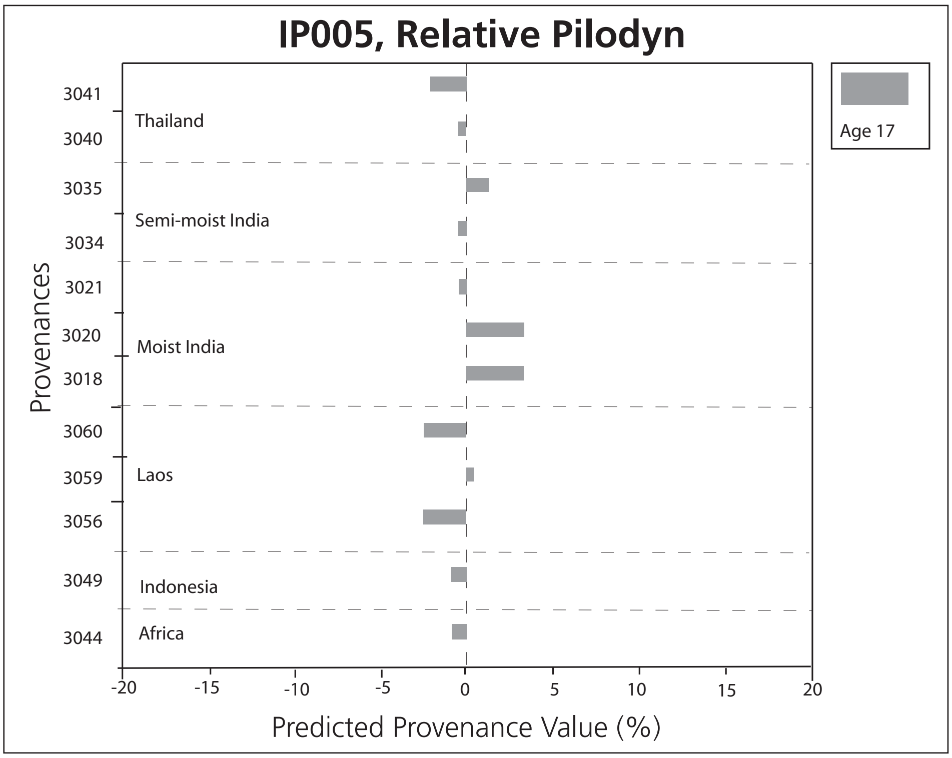

Figure 14. Relative pilodyn (wood density) in IP005. Aracruz, Brazil. (Note: Positive values signify small penetration or high wood density).

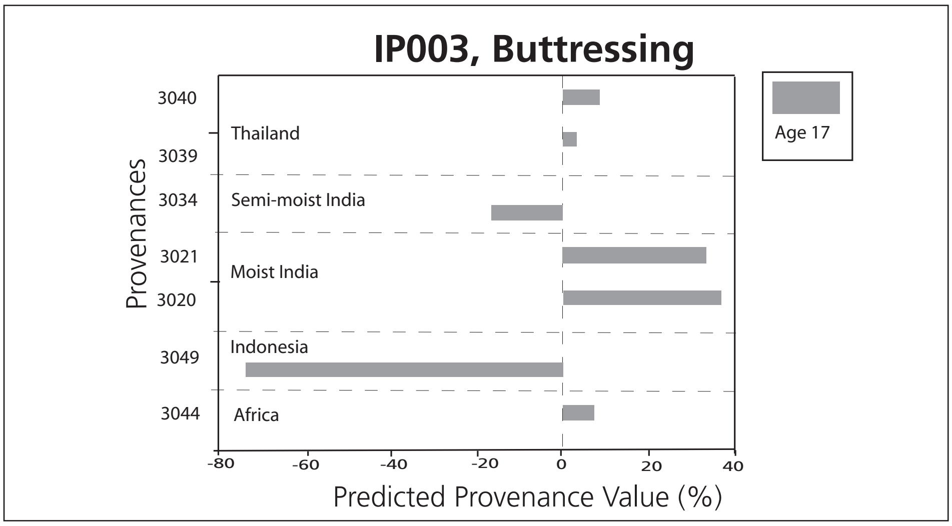

Figure 15. Buttressing (fluting of the stem) in IP003. Aracruz, Brazil. (Note: Positive values signify less buttressing, i.e. more circular cross-sections).

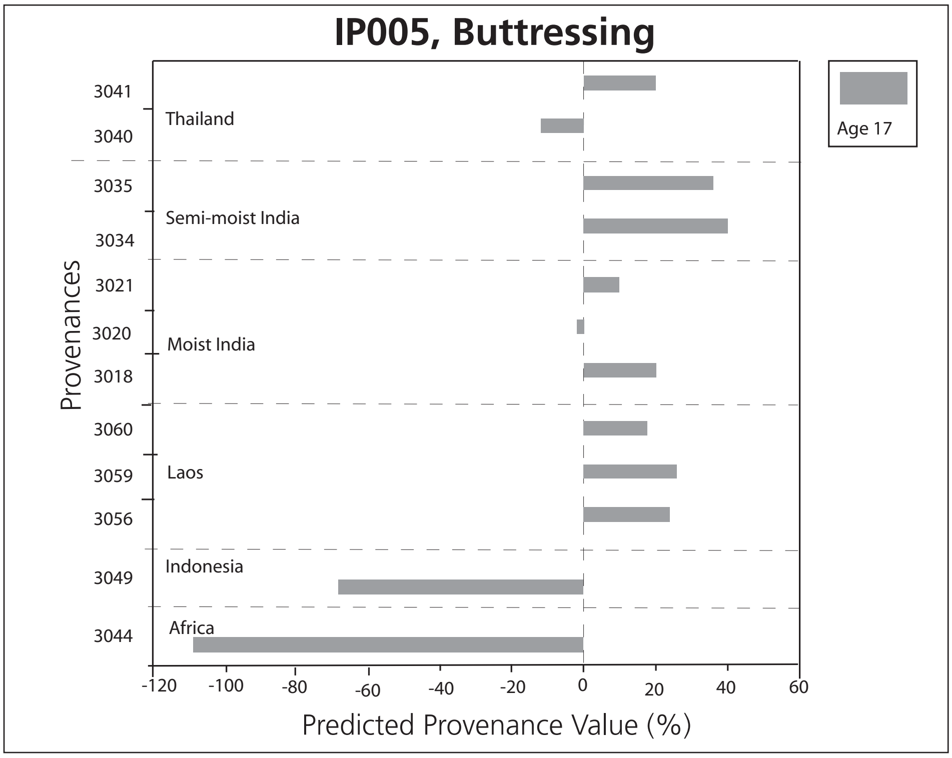

Figure 16. Buttressing (fluting of the stem) in IP005. Aracruz, Brazil. (Note: Positive values signify less buttressing, i.e. more circular cross-sections).

No significant interaction was found in **epicormics** between the two trials. The results from the two trials do not suggest that the trials should belong to different trial regions.

Buttressing (fluting of the stems) was significantly different in both **IP003** and **IP005**. The differences are large in **IP005**, but somewhat smaller in **IP003** (figure 15 and 16). The African landrace (SC3044) had much more buttressing than provenances from Moist India, Semi-moist India, Thailand and Laos in **IP005**. The Indonesian (SC3049) is also heavily affected by buttressing compared to the other provenances in this trial. The differences are also large in **IP003**, but the African SC3044 has performed relatively much better in this trial. The Indonesian (SC3049) still is much more affected than average in the trial. The measure used for fluting is an aggregate index based on (i) number of flutes, (ii) length of flutes, and (iii) their importance described by 4 classes (see section 4.1.7). The very poor performance of the Indonesian SC3049 compared to the other provenances is a result of (mainly) inferior performance in terms of number of buttresses combined with more severe deformation due to these buttresses. To illustrate this the distribution of trees from the two best provenances were compared with the distribution of trees from the two worst provenances in **IP003** (figure 17 and 18) and IP005 (figure 19 and 20). The Indonesian provenance has relatively few trees without buttresses in both trials (23% in IP003 and 40% in IP005). Of the trees with buttresses, the fluting is generally more severe in the Indonesian provenances compared to other provenances. These figures are based on approximately 80 trees per provenance. The difference are c1early significant, but may not seem so large as would have been expected from the dramatic differences in the combined index (figure 15 and 16). It is difficult to give a clear assessment of the practical importance of the observed differences, but clearly the differences between the provenances are large.

The interaction between the two trials was found to be significant for **buttressing**. The interaction mainly originates from the African SC3044, which has performed so differently in the two trials.

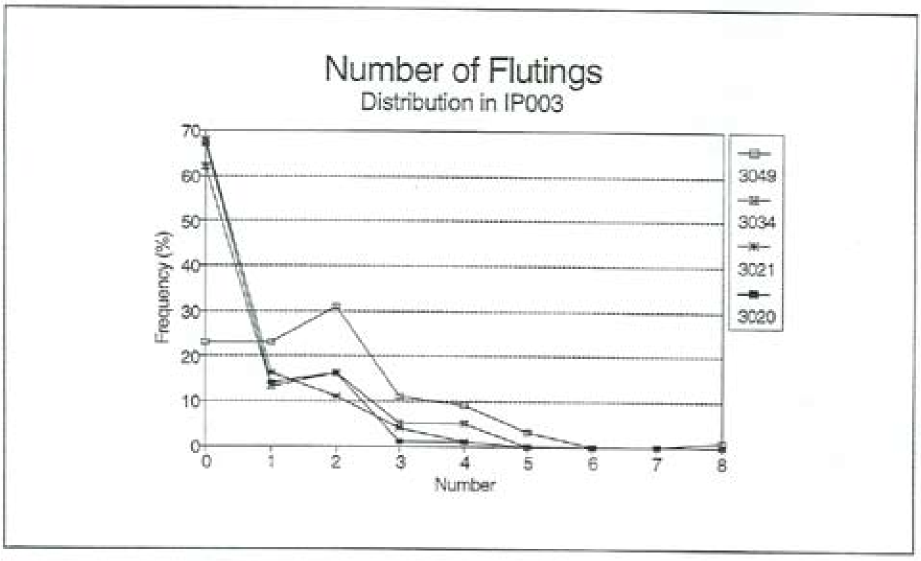

Figure 17. Distribution of number of flutes in IP003. Aracruz, Brazil.

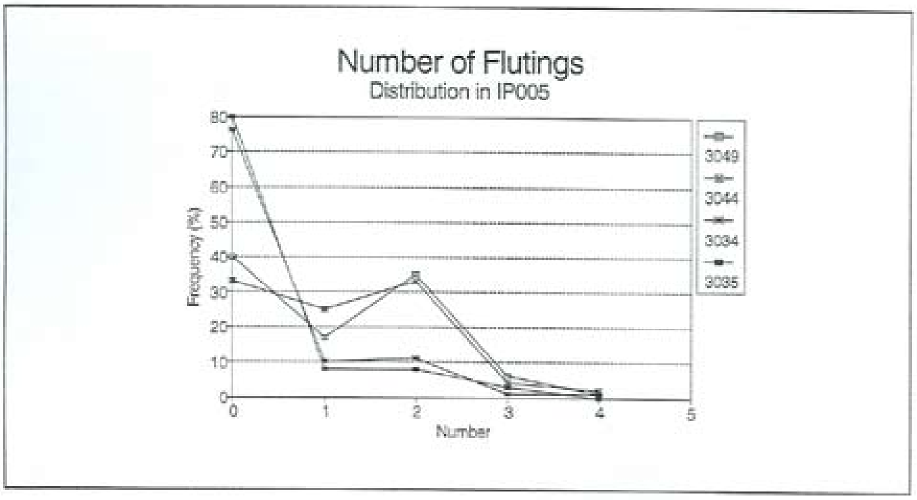

Figure 18. Distribution of number of flutes in IP005. Aracruz, Brazil

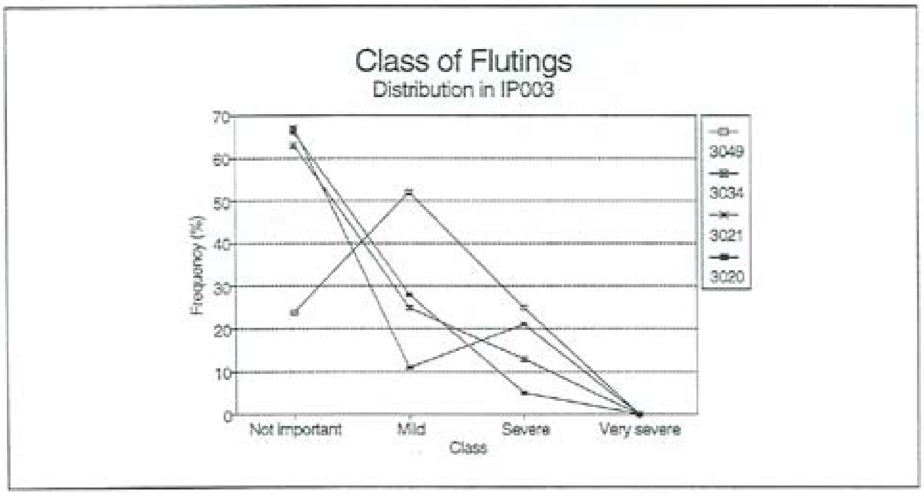

Figure 19. Distribution of classes of flutes in IP003. Aracruz, Brazil.

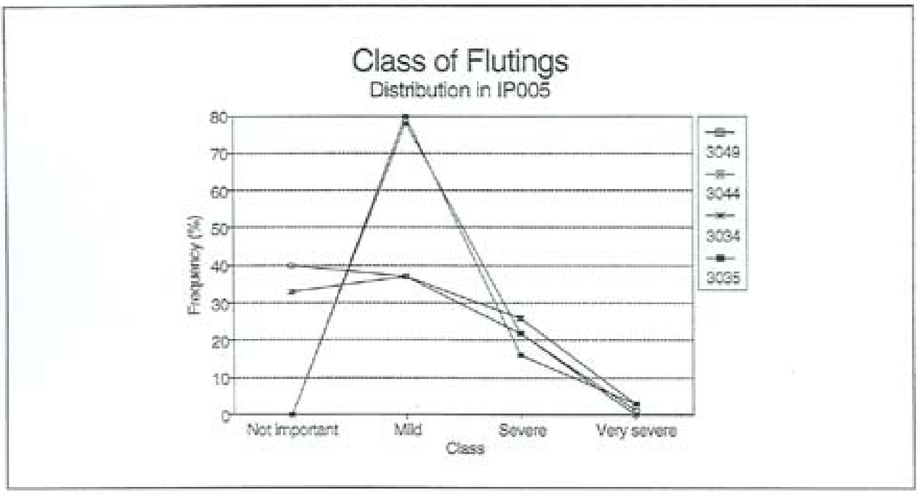

Figure 20. Distribution of classes of flutes in IP005. Aracruz, Brazil.

7.2.3 Production and growth rate

The diameter of all living trees was recorded at age 9 and 17. The average basal area per tree was calculated, and basal area per ha. estimated. The results of the ANOVA's and ANOCOV's are presented below in table 7.12 and 7.13. Correlation between provenance averages at age 9 and 17 are presented in table 7.6 (above).

Table 7.12 ANOVA for basal area per tree (Ba/tree) and basal area per ha (Ba/ha)

TRIAL: IP003	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Ba / tree (9)	0.83	0.566	-	-	-	-
Ba / tree (17)	0.80	0.583	-	-	-	-
Ba / ha. (9)	1.90	0.152	-	-	-	-
Ba / ha. (17)	1.18	0.372	-	-	-	-
TRIAL: IP005	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Ba / tree (9)	**5.06**	**0.001 ***	4.15	0.059	1.89	0.116
Ba / tree (17)	**4.52**	**0.001 ***	**7.20**	**0.018**	1.09	0.349
Ba / ha. (9)	**5.50**	**0.001 ***	**5.81**	**0.029**	1.60	0.182
Ba / ha. (17)	**7.78**	**0.001 ***	**8.95**	**0.010**	1.55	0.198

Table 7.13 ANOCOV for development from first to second assessment

IP003	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
BA / tree	0.186	0.653	-	-	-
BA / ha	**0.001 ***	**0.001**	0.714	**0.009**	**0.001**
IP005	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
BA / tree	0.076	**0.001**	0.060	0.580	**0.001**
BA / ha	**0.001***	**0.001**	**0.043**	**0.048**	**0.001**

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Production - expressed as basal area per hectare - did not differ significantly in the two evaluations of **IP003**. The correlation is relatively high, rp=0.57.

The **increment** in **IP003** in basal area per hectare from age 9 to age 17 differed, however, significantly between provenances within provenance regions. This result is mainly due to differences in increment between the two Thai provenances in the trial, and it is directly associated with their change of survival from age 9 to age 17. The results at year 9 are therefore not presented.

The differences in the **average size of trees** in **IP003** - expressed as basal area per tree - are non-significant in both evaluations. The correlation is high, rp=0.91, though.

However, the differences in increment in size are significant at the provenance regional level in **IP003**. The relative increment of the Moist Indian provenances has been significantly higher than for the rest of the provenances (figure 21). The non-significant differences of treesize at age 17 may be expected to increase to significance in the future if the differences in increment are maintained.

The **production** in **IP005** - expressed as basal area per hectare - differed highly significantly at both ages at the provenance regional level. Clearly, provenances from the Indonesian and Moist Indian regions produce significantly more than all other provenances. The correlation is high, rp=0.93 & rg=0.82. The **increment** in basal area per hectare from age 9 to age 17 differed significantly between provenance regions.

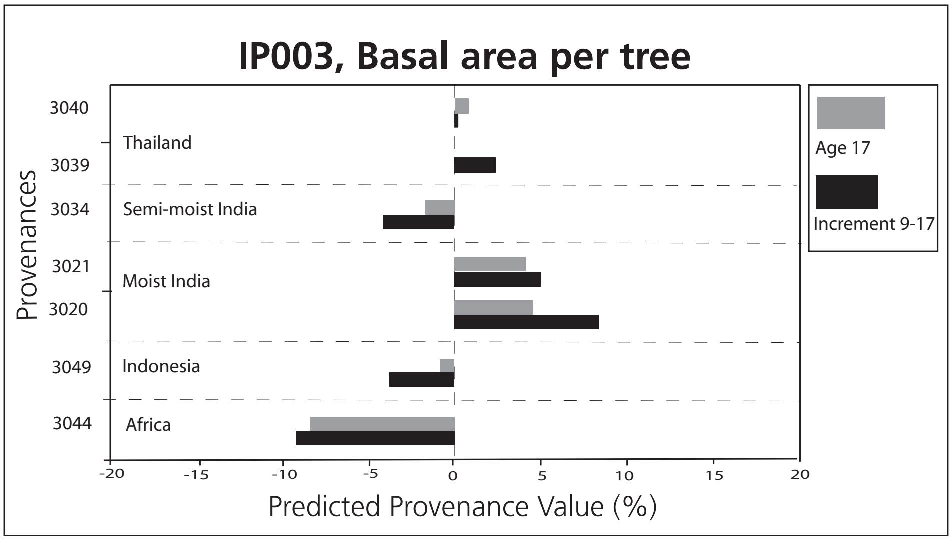

Figure 21. Basal area per tree in IP003. Aracruz, Brazil.

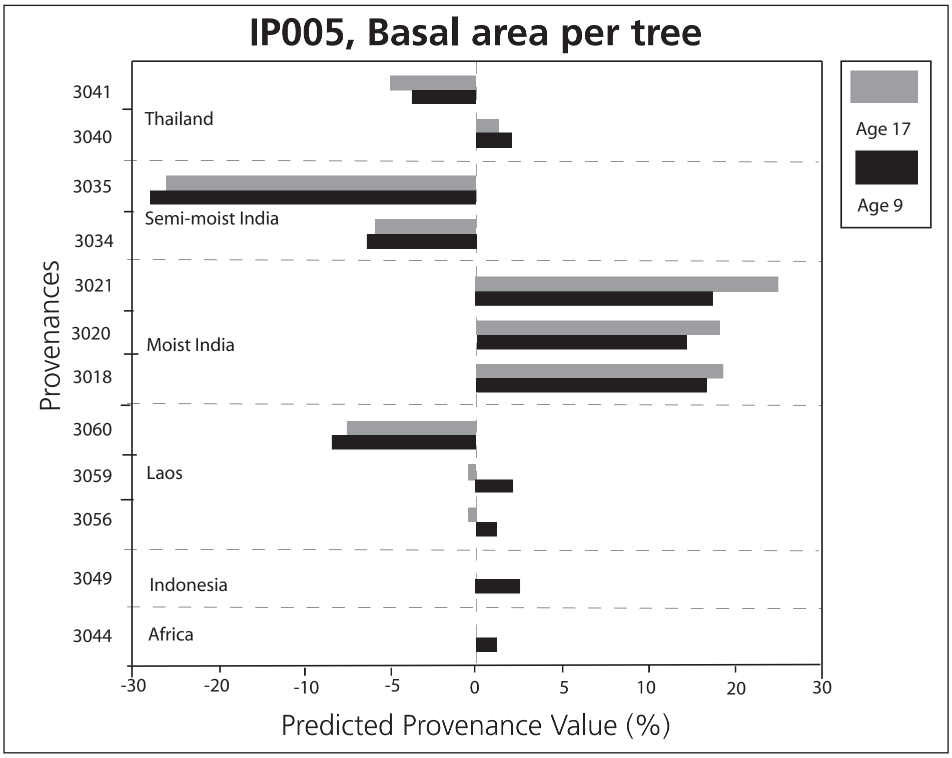

Figure 22. Basal area per tree in IP005. Aracruz, Brazil.

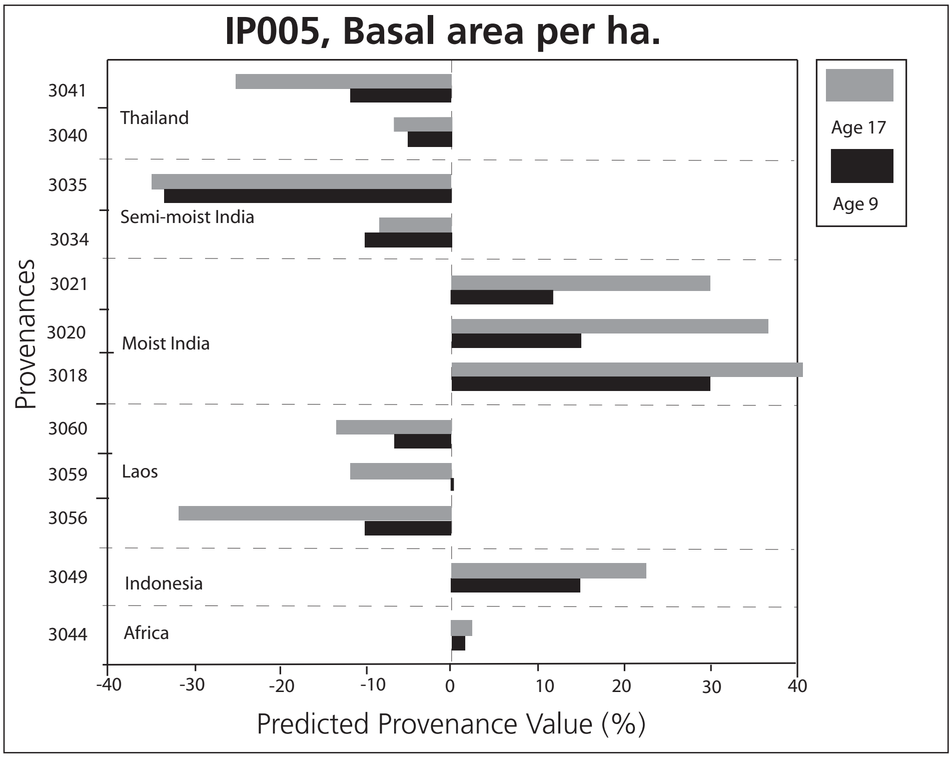

Figure 23. Basal area per ha in IP005. Aracruz, Brazil.

The provenances from Moist India are growing much faster than average. The Indonesian provenance is also superior, leaving the Laos, Semi-moist Indian, and Thai provenances behind. The African Landrace has maintained its relative position. This is approximately the same ranking as found at age 9, but the differences have increased and the conclusions are therefore more evident at this stage (figure 23). There are also significant differences between provenances within provenance regions.

The differences in the **average size of trees in IP005** - expressed as basal area per tree - are just about significant at age 9 and become highly significant at age 17 at the provenance regional level. There are no significant changes of rank between regions or provenances from age 9 to age 17.

The differences in **increment** in size are just about significant at the provenance regional level.

For basal **area per tree** (both at age 9 and 17), significant interaction was found between the two trials, but not in **production per ha.** The correlation between the two trials' basal area per tree is »intermediate«, rp=0.51, at age 17. The significance of the interaction is partly a result of the different size of the provenance variation in the two trials. The relative ranking is not very different, and there is therefore no reason to question that the trials belong to the same trial region.

CONCLUSIONS CONCERNING PRODUCTION

The superiority of the Moist Indian provenances found at age 9 is not only maintained at age 17, but has also increased relatively to all other provenances. The Indonesian provenance is still above average in production, but is falling behind compared to the Moist Indian provenances.

7.2.4 General recommendations for trial region West Africa-moist and Brazil

The choice of provenances must be based on the relative priority that is given to different traits. This may be different for different planting situations. The persons or organizations planting teak must weigh the importance of the quality characteristics before finally deciding on provenance(s).

Normally adaptation and growth rate will be of high importance. On this assumption, the Moist Indian provenances would have first priority in this trial region followed by the Indonesian provenance(s).

Both the Indian and the Indonesian provenances have high survival and good health.

The main concern is that the Indian provenances have a tendency to lose persistence of the main axis earlier than the Indonesian provenance(s). The Moist Indian provenances have, however, better stemform and branch characteristics than the Indonesian provenance.

The wood density of the Moist Indian provenances was found to be above average, although the wood density probably remains at an acceptable level for all provenances.

The Indonesian provenance has revealed a tendency towards above average fluting in these two trials. The differences seem large, and may call for concern. The Moist Indian provenances were found to be much less affected by fluting.

Both the Indonesian and the Moist Indian provenances have more epicormic branches than other provenances.

It goes for all traits that the correlation between the performance of the provenances at the two trials are higher (or for persistence, as high) at age 17, than at age 9. The two trials have thus developed in such a way that they give more similar results at age 17 than they did at age 9. We see this as an indication in the direction that findings based on the second evaluation are more reliable than findings based on the first only, as they are now more repeatable at two closely located sites.

7.3 Trial region: West Africa, semi-moist and dry

This trial region covered six trials, IP008 & IP009 (Ghana), IP018 (Ivory Coast) and IP028, IP029 & IP030 (Nigeria) in the first evaluation. The two trials in Ghana were re-evaluated at age 17. A total of 13 provenances were tested. The two trials contain exactly the same provenances, and it is therefore possible to test for interaction between the two trials. Results are presented in table 7.14. The correlation between the average performance in the two trials is also estimated (table 7.15), as the number of provenances is sufficient to give a meaningful estimate of the co-variances.

Table 7.14 Analysis of interaction across the two trials in the trial region

Effect of:	**TRIAL**		**PROVENANCE**		**TRIAL*PROVENANCE**	
Trait (age)	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	0.25	0.627	0.97	0.526	**3.27**	**0.001**
Survival (17)	**10.64**	**0.009**	1.10	0.438	**2.24**	**0.017**
Health (9)	2.54	0.136	1.14	0.417	**7.44**	**0.001**
Health (17)	0.01	0.909	**3.25**	**0.026**	0.54	0.873
Persist. (9)	**15.35**	**0.007**	**3.23**	**0.031**	**1.88**	**0.049**
Persist. (17)	2.77	0.143	**3.81**	**0.017**	1.24	0.270
Stemform (9)	**5.91**	**0.035**	1.00	0.502	**2.75**	**0.004**
Stemform (17)	0.03	0.865	**5.35**	**0.003**	1.03	0.423
Br. size (9)	**8.86**	**0.015**	1.08	0.453	**2.10**	**0.026**
Br. size (17)	0.10	0.765	I.I8	0.390	0.95	0.494
Epicormics	0.50	0.505	**4.77**	**0.006**	1.06	0.397
Protub.Buds	0.81	0.400	**3.30**	**0.027**	**2.43**	**0.009**
Buttressing	-	-	-	-	-	-
Ba /tree (9)	**101.17**	**0.001**	**4.29**	**0.009**	0.84	0.600
Ba /tree (17)	**28.06**	**0.001**	**5.66**	**0.003**	0.87	0.568
Ba /ha (9)	**163.86**	**0.001**	1.67	0.207	1.85	0.056
Ba /ha (17)	**12.59**	**0.004**	2.67	0.0516	0.69	0.754

Notes: Effects significant at a simple 5%-level are typed in bold.

Table 7.15 Correlation between provenance performance in the two trials

	Age 9		**Age 17**	
Trait	**r_p**	**r_g**	**r_p**	**r_g**
Survival	0.00	0.00	-0.34	-
Health	0.36	-	0.10	-
Persistence	0.65	1.18	0.69	-
Stemform	0.01	-	0.69	1.49
Branch size	0.Q7	-	-0.19	-
Ba /tree	0.57	-	0.48	-
Ba /ha	0.58	-	0.19	-

The »genetic correlation« is only estimated for traits where significant differences are found at both trials (see section 6. L2 for details).

Table 7.16 Correlation (within trial) between provenance performance at age 9 and 17

	IP008		**IP009**	
Trait	**r_p**	**r_g**	**r_p**	**r_g**
Survival	0.83	0.88	0.28	-
Health	0.77	-	0.56	-
Persistence	0.58	0.59	0.82	0.95
Stemfonn	0.25	-	0.24	0.57
Branch size	0.22	-	0.15	-
Ba /tree	0.87	-	0.83	-
Ba /ha	0.72	-	0.70	-

The »genetic correlation« is only estimated for traits where significant differences are found at both ages (see section 5.1. for details).

7.3.1 Adaptation

Survival and health were assessed in both trials at age 9 and 17. The results of the ANOVA's and ANOCOV's are presented below in table 7.17 and 7.18. Correlations between provenance averages at age 9 and 17 are presented in table 7.16. Analysis of interaction between the two trials and correlation between them are presented in table 7.14 and 7.15.

Table 7.17 ANOVA for adaptive traits

IP008	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	**2.73**	**0.014**	1.33	0.340	**2.48**	**0.040**
Survival (17)	**2.71**	**0.015**	3.58	0.060	1.50	0.202
Health (9)	**14.41**	**0.001 ***	**8.15**	**0.006**	**4.13**	**0.002**
Health (17)	1.21	0.322	-	-	-	-
IP009	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	**2.67**	**0.018**	0.26	0.895	**3.49**	**0.007**
Survival (17)	0.74	0.704	-	-	-	-
Health (9)	1.19	0.342	-	-	-	-
Health (17)	0.28	0.628	-	-	-	-

Table 7.18 ANOCOV for development from first to second assessment

IP008	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development in:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Survival	0.154	**0.001**	-	-	-
Health	0.645	0.184	-	-	-
IP009	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development in:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Survival	0.784	**0.001**	-	-	-
Health	0.941	**0.006**	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Significant differences in **survival** were revealed at both evaluations in **IP008**. The increase in mortality from year 9 to 17 has not been significantly different for the different provenances. The correlation between the average survival at age 9 and 17 is accordingly high, rp=0.83. The differences at age 17 reveal distinct differences between regions, where the provenances from Laos have had (almost) significantly higher mortality than provenances from the other regions (figure 24). Provenance SG 1 (African Landrace), se 3021 (Moist India) and 3049 (Indonesia) have been the best surviving provenances in this trial.

Mortality was lower in **IP009** compared to **IP008**. The differences in mortality was significant at the time of the first evaluation, mainly due to higher survival of SG 1 (African landrace) than the rest of the provenances. The differences between the other provenances were small (figure 25). At age 17 the differences were not significant, because SG 1 was no longer found to be significantly better than the remaining provenances. The correlation between the survival at age 9 and 17 is low, rp=0.33.

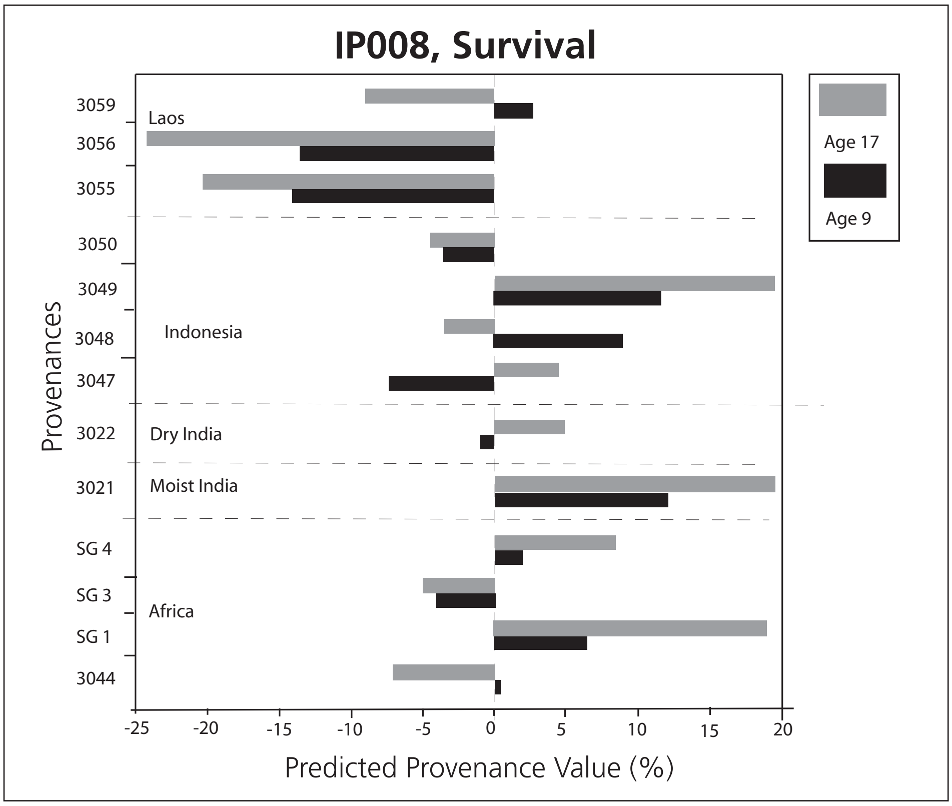

Figure 24. Survival in IP008, Pra Anum, Ghana.

The average survival of the provenances at the two locations can be said to be quite different, as the phenotypic correlation is low, rp=0.00 at age 9 and rp= -0.34 at age 17. This is mainly a result of the non-significance in IP009 at age 17.

The average **health** was significantly different in **IP008** at age 9. The differences were significant at the regional level, the Laotian provenances being of inferior health. The differences were no longer significant at age 17, although the correlations were fairly high rp=0.77. No significant differences were found in **IP009** in health.

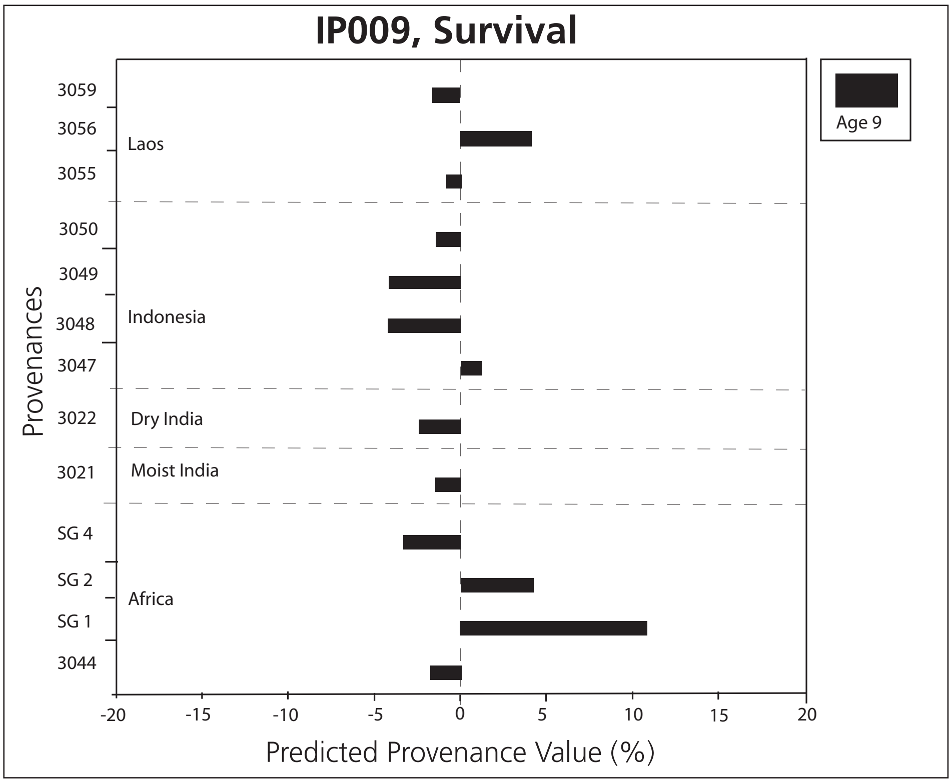

Figure 25. Survival at IP009, Tain, Ghana.

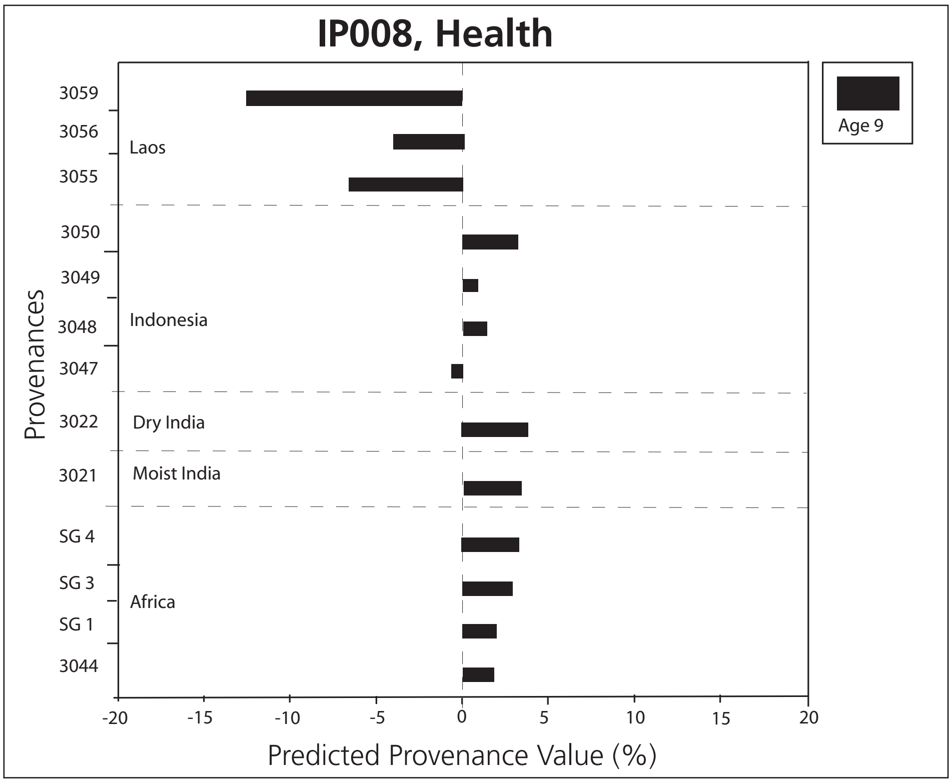

Figure 26. Health in IP008, Pra Anum, Ghana.

CONCLUSIONS CONCERNING ADAPTATION

The general picture in this trial region at age 17 is in summary the following: The provenances from Laos have shown inferior long term adaptation compared to the Indonesian, Indian and African provenances. On the average only approximately 30% of the trees of Laos origin have survived till age 17 in **IP008**. Approximately 50% of the trees have survived on average for provenances of Moist Indian, Dry Indian and Indonesian origin. Moist India seem especially promising with an average survival of almost 60%. Unfortunately only one provenance of this origin was tested in the trial. The provenance differences in long term survival are thus important, although not large enough to be significant in **IP009**, where the general survival was much better. The existence of significant interaction also weakens the conclusion.

The conclusions from the first evaluation remain, however, in general valid after the second evaluation.

7.3.2 Stem quality

Three characters were assessed at both ages: Persistence of the axis, stemform and branch size. Pilodyn (wood density), epicormic branches, and bark thickness were assessed for the first time at age 17. Buttressing was assessed in IP009 at age 17.

TRAITS ASSESSED AT BOTH AGES

The results of the ANOVA' s and ANOCOV's are presented below in table 7.19 and 7.20. Correlations between provenance averages at age 9 and 17 are presented in table 7.16. Analysis of interaction between the two trials and correlation between them are presented in table 7.14 and 7.15.

Table 7.19 ANOV for persistence, stemform and branch size

Trial: IPOO8	Model I		Model II			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Persistence (9)	**3.07**	**0.007***	2.54	0.)23	1.87	0.105
Persistence (17)	1.90	0.079	-	-	-	-
Stemform (9)	1.55	0.166	-	-	-	-
Stemform (17)	**2.12**	**0.05**	**4.48**	**0.035**	1.03	0.439
Branch size (9)	0.99	0.485	-	-	-	-
Branch size (17)	1.04	0.442	-	-	-	-

Trial: IP009	Model I		Model II			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Persistence (9)	**2.28**	**0.038**	**8.73**	**0.002**	0.61	0.760
Persistence (17)	1.98	0.070	**5.93**	**0.010**	0.73	0.667
Stemform (9)	**2.51**	**0.017**	1.45	0.303	1.90	0.094
Stemform (17)	**2.19**	**0.046**	**8.45**	**0.002**	0.56	0.800
Branch size (9)	1.10	0.399	-	-	-	-
Branch size (17)	1.44	0.211	-	-	-	-

Table 7.20 ANOCOV for development from first to second assessment

IP008	Model I		Model II		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Persistence	**0.020**	0.648	0.640	**0.018**	0.648
Stemform	**0.022**	**0.004**	**0.050**	0.305	**0.004**
Branch size	0.248	-	-	-	-

IP009	Model I		Model II		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Persistence	0.555	0.441	-	-	-
Stemform	0.051	**0.002**	**0.003**	0.820	**0.002**
Branch size	0.500	**0.006**	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

In trial **IP008** the **persistence of the terminal axis** was significantly different at age 9, but not significant at age 17. The change in average performance has not been significantly different for the different provenances, but the correlation between the average performance at age 9 and 17 is only intermediate, rp=0.58. The differences are not large in this trial at any of the ages (figure 27), but there was a clear tendency that the African landraces were less likely to maintain their terminal axis than the rest of the provenances tested in this trial at the young age. This tendency is much weaker in **IP008** at age 17. The trait is not significant any more, and the African provenances are no longer found to be inferior at age 17.

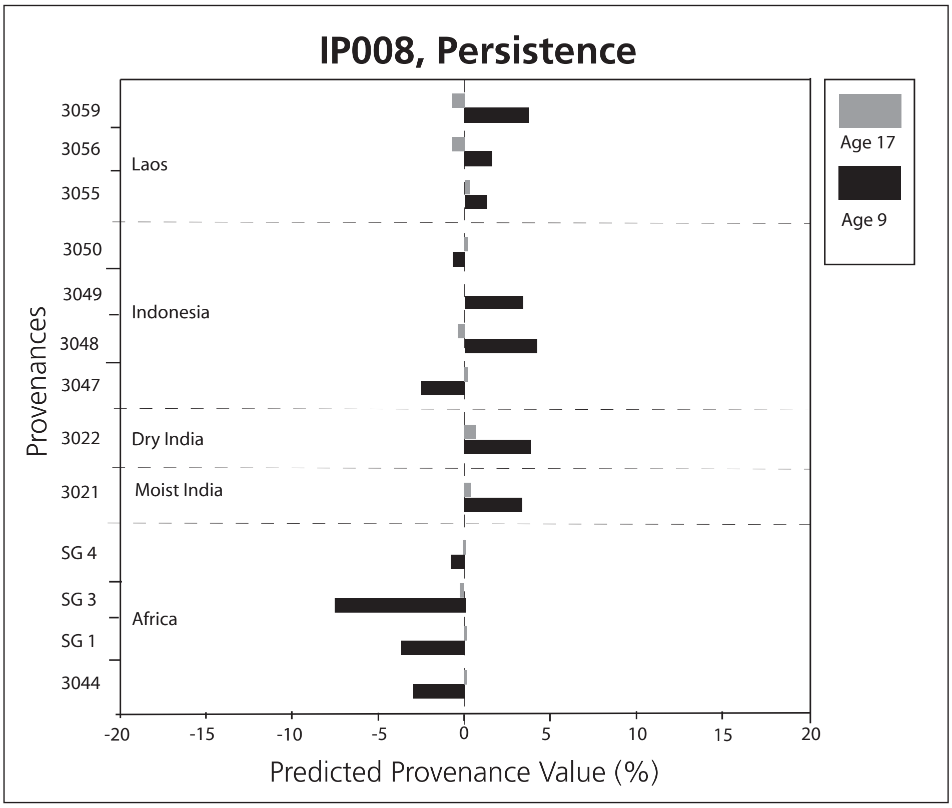

Figure 27. Persistence in IP008, Pra Anum, Ghana.

The differences in persistence are larger in **IP009** (figure 28), and significantly different at both ages. The differences are distinct between provenance regions. The African provenances in general have a low tendency to maintain their terminal axis, provenances from Laos and India being better. One of the Indonesian provenances, SC3049, performs below average, the rest are above average. The correlation between performance at age 9 and 17 is high, rp=0.83, and the changes from the first to the second evaluation are not significantly different for the different provenances. Approximately 30% of the trees in SC3021 (Moist India), SC3059 (Laos), and SC3049 (Indonesia) have maintained the persistence of their terminal axis in the highest quarter (class 7-9). The African landraces (SC3044, SG1, SG3 and SG4) have only 15-20% trees in these classes at age 17 (average of both trials).

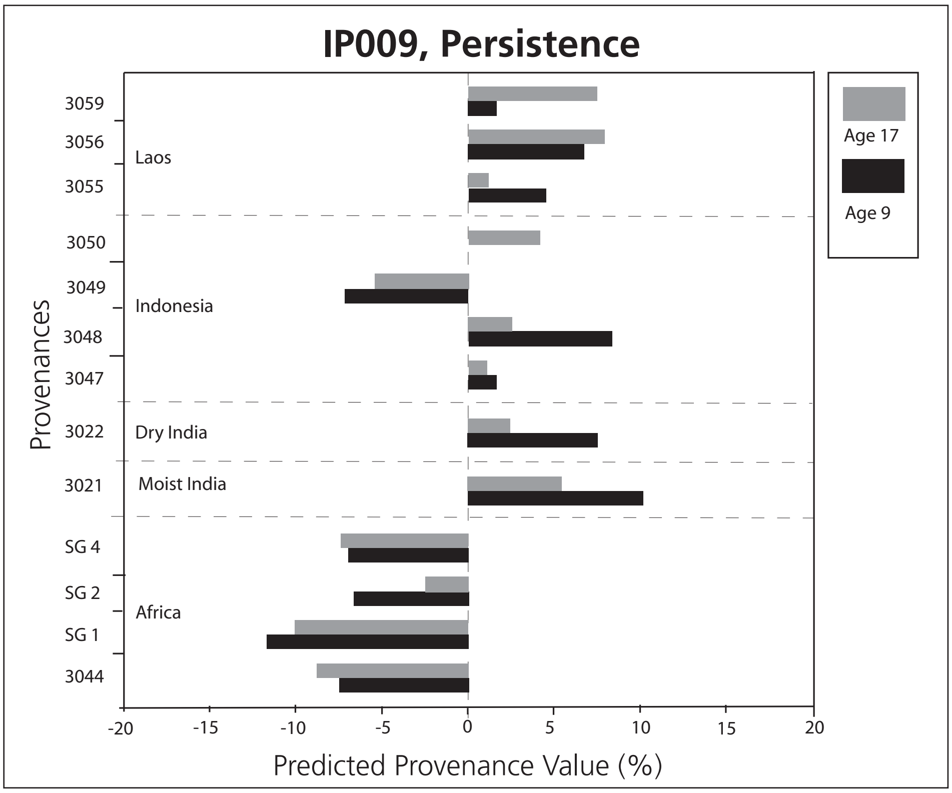

Figure 28. Persistence in IP009, Tain, Ghana.

The results from the two trials point in the same direction, and no significant interaction between the trials has been found. The correlation between performance in persistence of axis was almost the same at both ages, rp=0.66 (age 9) and rp=0.69 (age 17). At age 9 the »genetic correlation« is estimated to above unity, rg= 1.18. The »true« correlation can, of course, never exceed 1, because this refers to full co-variation of the values from age 9 and 17. The genetic correlation is, however, estimated from the ANOCOV with fairly high standard error as discussed in section 5.1.3. The **estimate** can therefore occasionally exceed one.

In trial **IP008 stemform** did not differ significantly at age 9, but significant differences at provenance regional level were found in the second evaluation. The different provenances have developed differently in the intermediate time span, and the correlation between the performance at age 9 and 17 is low, rp=0.26. The differences in stemform at age 17 are not large. They are presented in figure 29. Stemform is best in the Moist Indian provenance SC3021. The local African landrace (SC3044) has the poorest average stemform.

In trial **IP009 stemform** differed significantly at both ages. At age 17 the differences were significant at the regional level. The different provenances have developed differently in this trial, too. The correlation between stemform at age 9 and age 17 is therefore also fairly low, rp=0.24. The differences were relatively small at both assessments (figure 30). The provenance with the best stemform at age 17 is the Moist Indian provenance (SC3021) in this trial as was the case in IP008. The African landrace SC3044 is the poorest performing in terms of stemform in both trials. There has been an interesting development from age 9 to 17. At age 9 there was low correlation between the average performance in stemform between

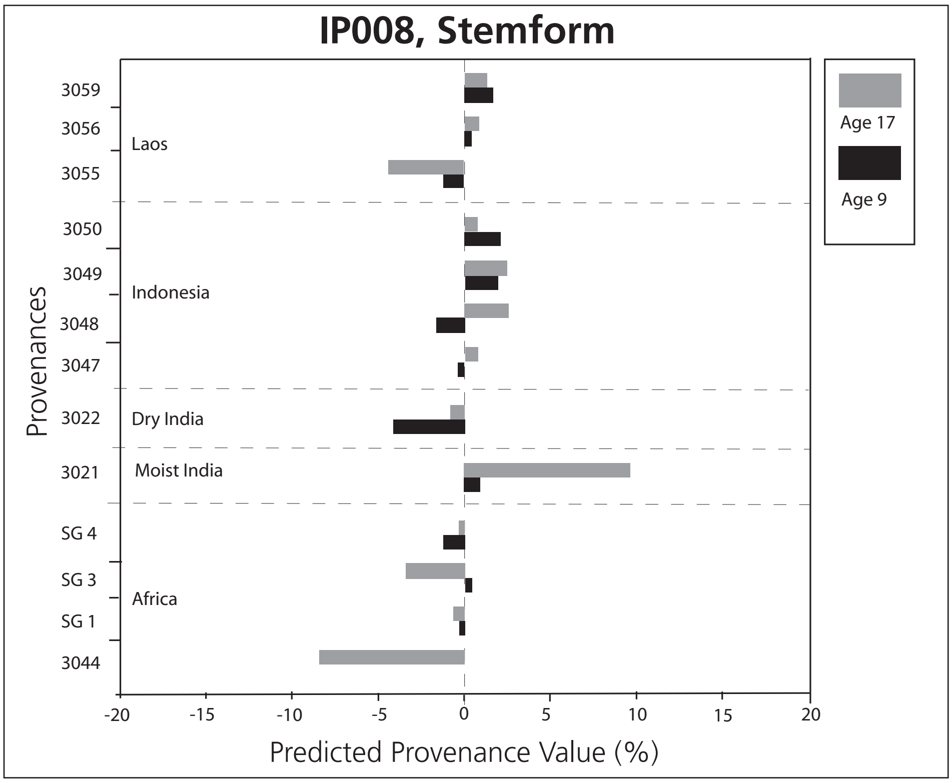

Figure 29. Stemform in IP008, Pra Anum, Ghana.

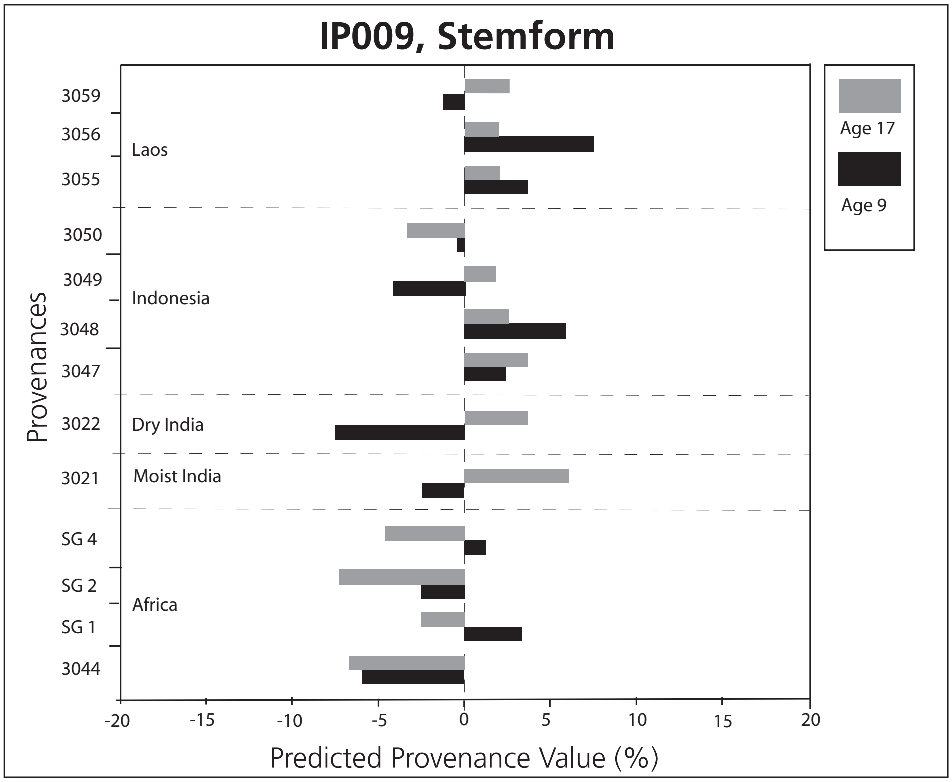

Figure 30. Stemform in IP009, Tain, Ghana.

the two trials, rp= 0.01. The provenances thus performed quite differently in the two trials at age 9. This situation has changed favourably in the period between the two assessments. At age 17 the correlation is much higher, rp=0.69, and a combined analysis reveals no interaction between the trials and provenances at this age. Both trials thus reveal superior stemform of Moist Indian, Laotian and Dry Indian provenances compared to the African landraces. The differences correspond to differences in **per cent of trees in the best classes** (c1ass 4 or 5) as follows (average of both trials): The Moist Indian SC302l cmd Indonesian SC3047 being the best with almost 30% straight trees (class 4 or 5), and SC3044, SG3, SG4 (African landraces) being worst with only 15% straight trees. SC3050 (Indonesia) and SC3055 (Laos) also had relatively few straight trees (20%).

Branch size was not significantly different in any of the trials at either of the two assessments.

CONCLUSIONS CONCERNING THE QUALITY TRAITS ASSESSED AT BOTH AGES

The general picture based on the 17 year assessment is that the African landraces are of inferior quality due to poor stemform and tendency to lose persistence of axis at an early stage. The differences between the other provenances in terms of quality are not large. The Moist Indian provenance (SC302l) has revealed good persistence and stemform in both trials. But provenances from Laos, Indonesia and Dry India have also performed acceptably. The performance in terms of persistence at age 17 reveals no new information compared to age 9. The assessment of stemform has, however, changed considerably. At age 17 the differences in stemform follow the differences in persistence more closely than at age 9, thus allowing a clearer recommendation in terms of stem quality.

QUALITY TRAITS ASSESSED ONLY AT THE SECOND EVALUATION

The results of the ANOV A's are presented below in table 7.21. Analysis of interaction between the two trials is presented in table 7.14.

Table 7.21 ANOVA for epicormic branches, protuberant buds, relative pilodyn penetration (wood density), relative bark thickness and buttressing

Trial: IP008	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait:	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Epicormics	**2.39**	**0.028**	3.25	0.074	1.43	0.228
Protuberant buds	**4.35**	**0.001 ***	**5.29**	**0.022**	1.43	0.215
Relative pilodyn	2.09	0.053	**4.69**	**0.031**	1.02	0.447
Relative bark thickness	4.59	**0.001 ***	**9.02**	**0.005**	1.22	0.325
Buttressing	-	-	-	-	-	-

Trial: IP009	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait:	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Epicormics	**2.27**	**0.039**	**3.61**	**0.050**	1.24	0.315
Protuberant buds	**2.66**	**0.018**	**13.21**	**0.001**	0.46	0.874
Relative pilodyn	**3.54**	**0.003***	1.96	0.188	**2.67**	**0.028**
Relative bark thickness	**4.99**	**0.001 ***	**6.74**	**0.010**	2.09	0.068
Buttressing	**3.68**	**0.001 ***	3.46	0.063	2.03	0.071

Notes: Effects significant at a simple 5%level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

The **pilodyn penetration** (wood density) was (nearly) significantly different in both trials, but the differences are small (figure 31 and 32) and probably unimportant in terms of reduced strength. Significant interaction was found between trials and provenances, and the ranking is different in **IP008** and **IP009**.

The **bark thickness** was significantly different in both trials. Results are presented in figure 31 and 32. The relative bark thickness was generally found to be low for African and Indonesian provenances. No significant interaction was found.

Significant differences were found in number of **epicormic branches** in both **IP008** and **IP009**. The differences were found to be mainly regional differences, and there was found no interaction between the trials. The correlation between the average provenance performance in the two trials was found to be intermediate however, rp=0.49.

African landraces and Indonesian provenances tested in this trial generally have many epicormic branches in contrast to provenances from Laos, the provenance from Moist India (SC3021) - and especially the dry Indian provenance (SC3022), which have fewer epicormic branches (figure 33 and 34). The differences are fairly large in IP008, but smaller in IP009.

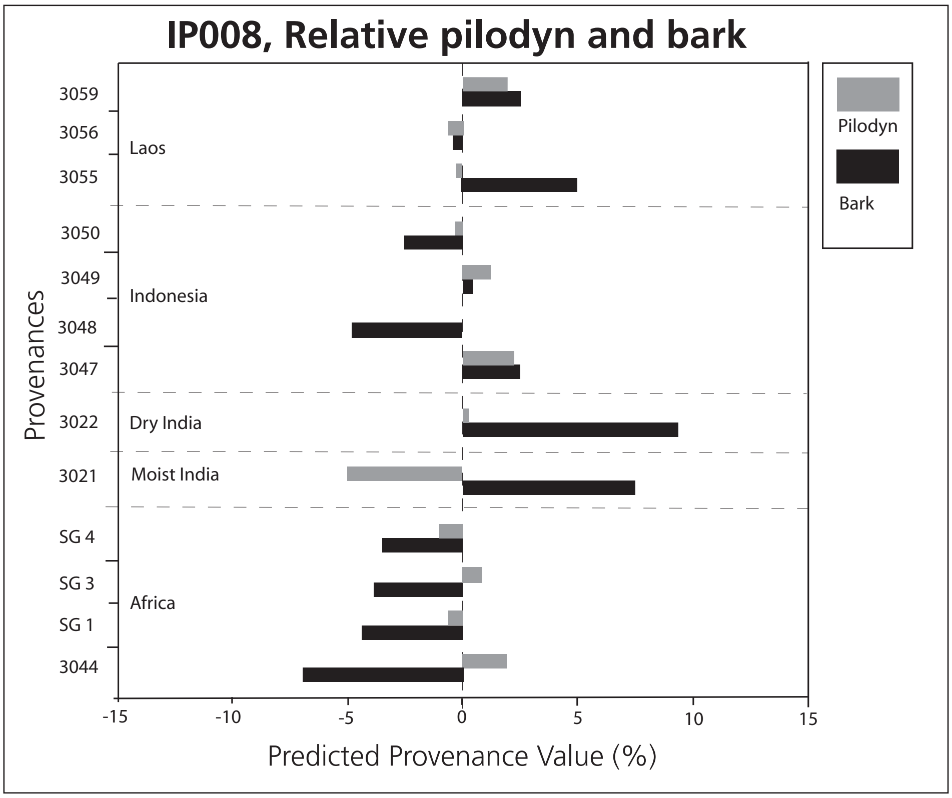

Figure 31. Relative pilodyn and Bark in IP008, Pra Anum, Ghana. (Note: Positive values signify small penetration, i.e. high er wood density, and thick bark).

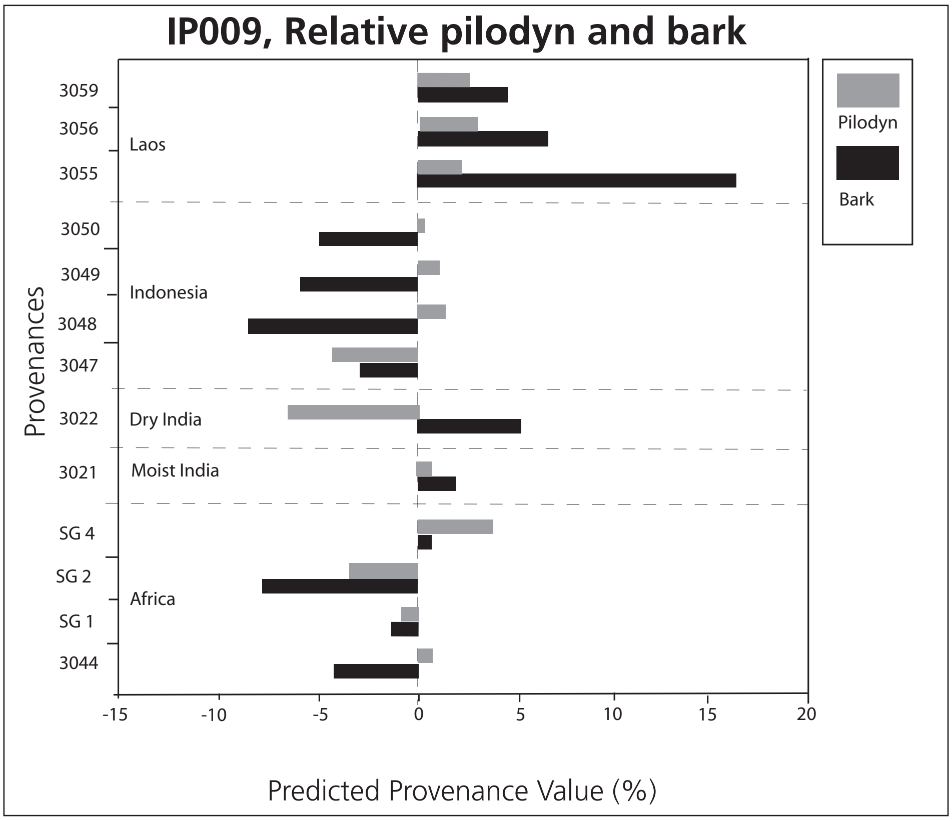

Figure 32. Relative Pilodyn and Bark in IP009, Tain. (Note: Positive values signify small penetration, i.e. higher wood density, and thick bark).

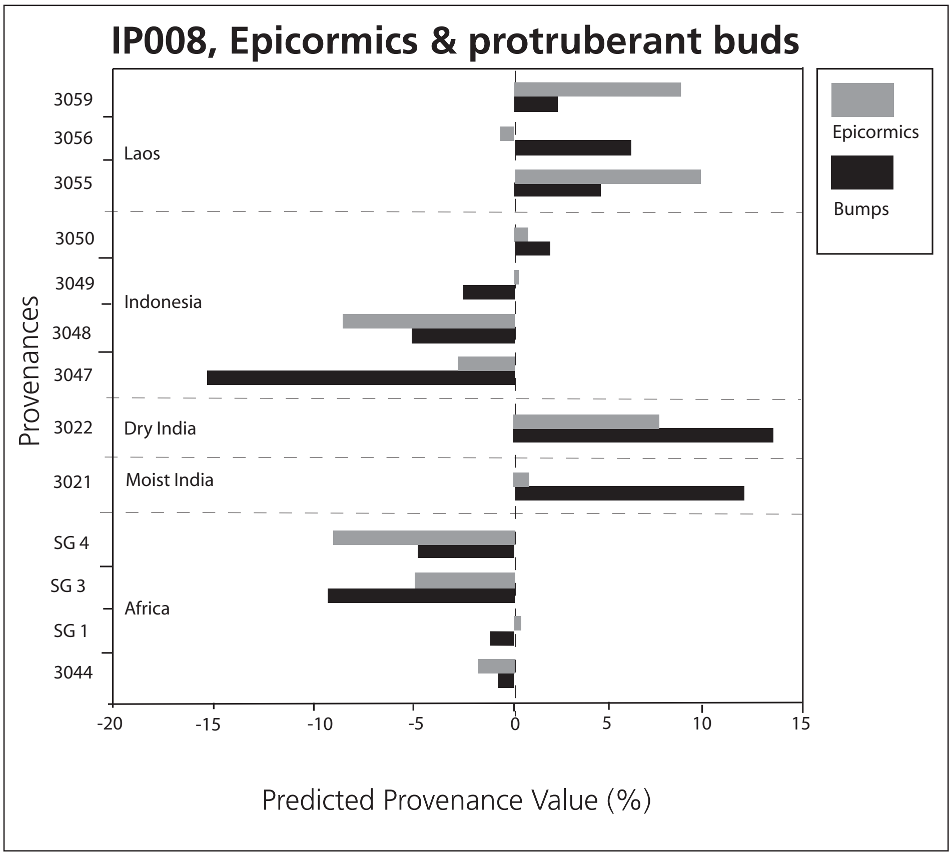

Figure 33. Epicormics and Protuberant Buds in IP008, Pra Anum. (Note: Positive values signify small number of epicormics and bumps).

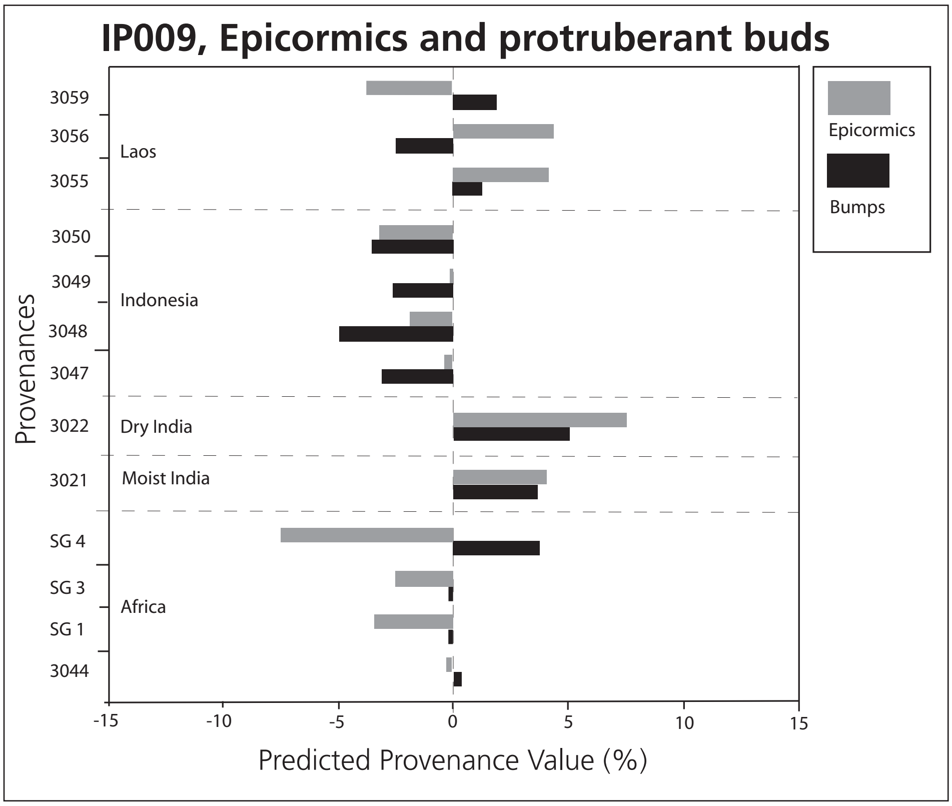

Figure 34. Epicormics and Protuberant Buds in IP009, Tain. (Note: Positive values signify small number of epicormics and bumps).

Differences in the number of **protuberant buds** (bumps) were found to be significant in both trials. The differences were found to be mainly differences between provenance regions. Provenances from Indonesia and African landraces had significantly more bumps than provenances from Laos, Moist and Dry India (figure 33 and 34). There was no significant interaction between trials and provenances.

Buttressing was only assessed in IP009. Significant differences were found in this trial, and the relative differences are large (figure 35). Especially the Indonesian SC3050 were much more influenced by buttressing than, e.g. the Dry Indian (SC3022) and Moist Indian (SC3021) provenances.

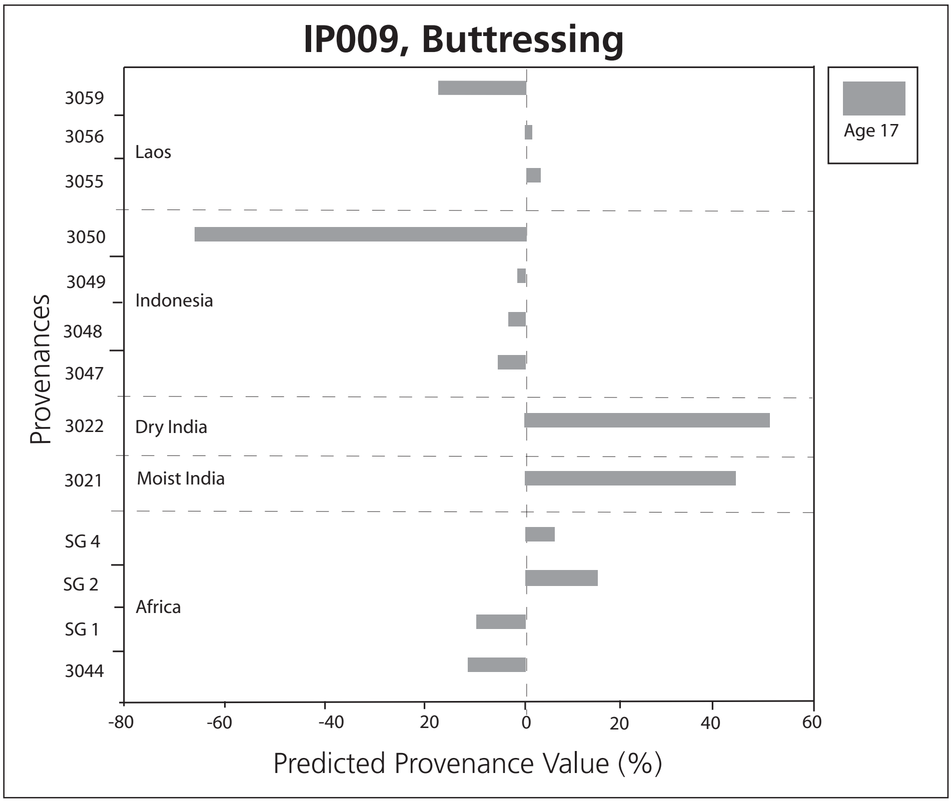

Figure 35. Buttressing in IP009, Tain. (Note: Positive values signify less buttressing, i.e. more circular cross-sections).

CONCLUSIONS CONCERNING WOOD DENSITY, EPICORMIC BRANCHES, PROTUBERANT BUDS AND BUTTRESSING.

Significant differences in wood density were found in both trials, but the trials point in different directions. The size of the differences seems to indicate that they do not reduce the wood density below any critical level, although this has not been examined explicitly.

Provenances from Indonesia and African landraces have generally more epicormic branches and protuberant buds than provenances from Laos, Moist India and Dry India. Indian provenances have less buttressing than provenances from Indonesia, but there is considerable difference between Indonesian provenances.

7.3.3 Production and growth rate

The diameter of all living trees was recorded at age 9 and 17. The average basal area per tree was calculated, and basal area per ha. estimated. The results of the ANOVA's and ANOCOV's are presented below in table 7.22 and 7.23. Correlations between provenance averages at age 9 and 17 are presented in table 7.15. Analysis of interaction between the two trials and correlation between them are presented in table 7.14 and 7.15.

Table 7.22 ANOVA for basal area per tree (Ba/tree) and basal area per ha (Ba/ha)

TRIAL: IP008	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Ba I tree (9)	1.35	0.246	-	-	-	-
Ba I tree (17)	**2.77**	**0.013**	0.36	0.830	**3.40**	**0.008**
Ba I ha. (9)	**3.54**	**0.003***	**7.43**	**0.009**	1.12	0.380
Ba I ha. (17)	1.73	0.113	-	-	-	-
TRIAL: IP009	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Ba I tree (9)	0.83	0.625	-	-	-	-
Ba I tree (17)	1.89	0.055	**5.03**	**0.022**	0.87	0.550
Ba I ha. (9)	1.20	0.335	-	-	-	-
Ba I ha. (17)	**2.11**	**0.050**	1.71	0.233	1.92	0.100

Table 7.23 ANOCOV for development from first to second assessment

IP008	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
BA I tree	0.097	0.391	-	-	-
BA I ha	0.403	-	-	-	-
IP009	Model I		Model II		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
BA I tree	0.208	0.233	-	-	-
BA I ha	0.219	**0.022**	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Production - expressed as basal area per hectare - differs significantly in **IP008** at age 9. At age 17 the differences are no longer significant. The correlation between the basal area per ha at age 9 and 17 is only intermediate, rp=0.59. The differences found at age 9 and age 17 are presented in figure 36. It should be recalled that the differences at age 17 are no more significant at a 5% level. The figure does, however, give indications that SC3021 (Moist India) is still fast growing, whereas SC3056 (Laos) and SC3022 (Dry India) have improved compared to the first evaluation.

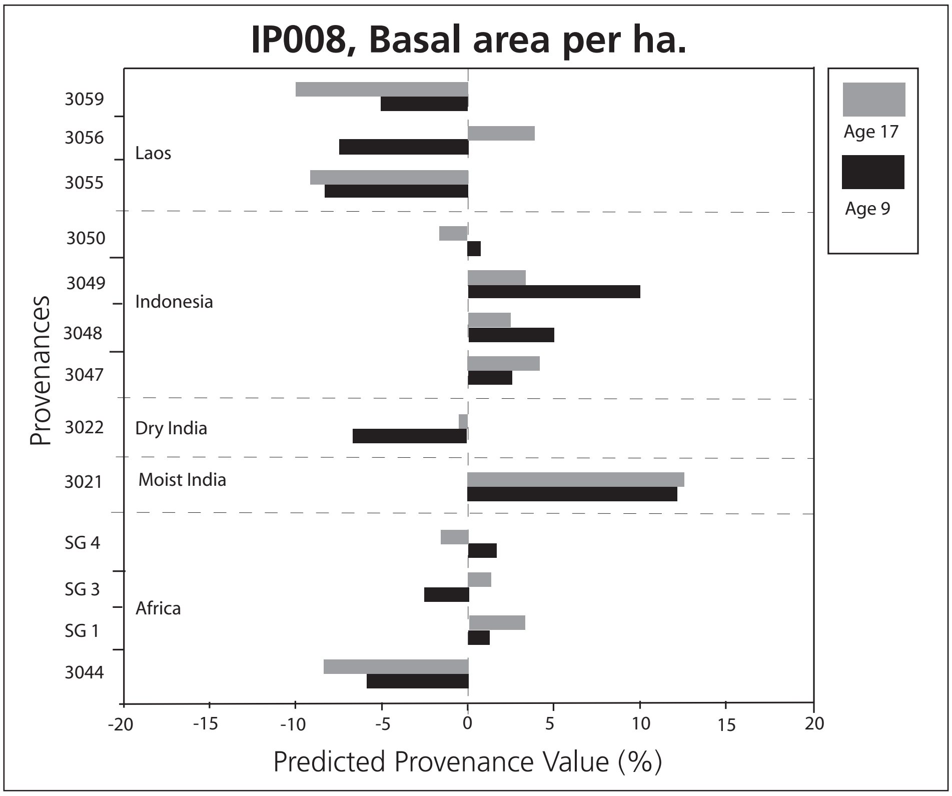

Figure 36. Basal area per ha. in IP008, Pra Anum, Ghana

The differences in the **average size of trees** - expressed as basal area per tree - were significant only at the second evaluation in **IP008** (figure 38).

Production - expressed as basal area per hectare - differs significantly in **IP009** at age 17, but the differences can only be partly described as differences between regions. At age 9 no significant differences were found. The correlation between the basal area per ha at age 9 and 17 is higher than in IP008 (rp=0.79). The differences found at age 9 and age 17 are presented in figure 37. The differences are small. The **increment** in basal area per hectare from age 9 to age 17 was not significantly different among provenances in IP009, other than what could be described by differences found at age 9 (the increment from age 9 to age 17 corresponds to the differences already seen at age 9). The results at age 17 can thus be seen as a result of an increase of the differences found at age 9.

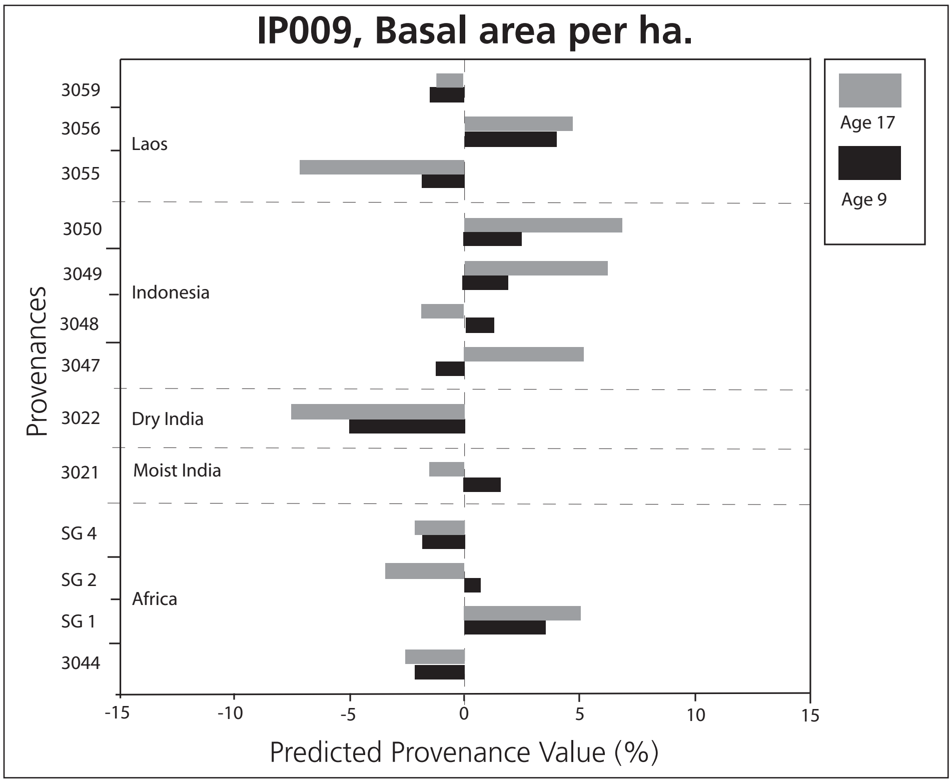

Figure 37. Basal area per ha. in IP009, Tain.

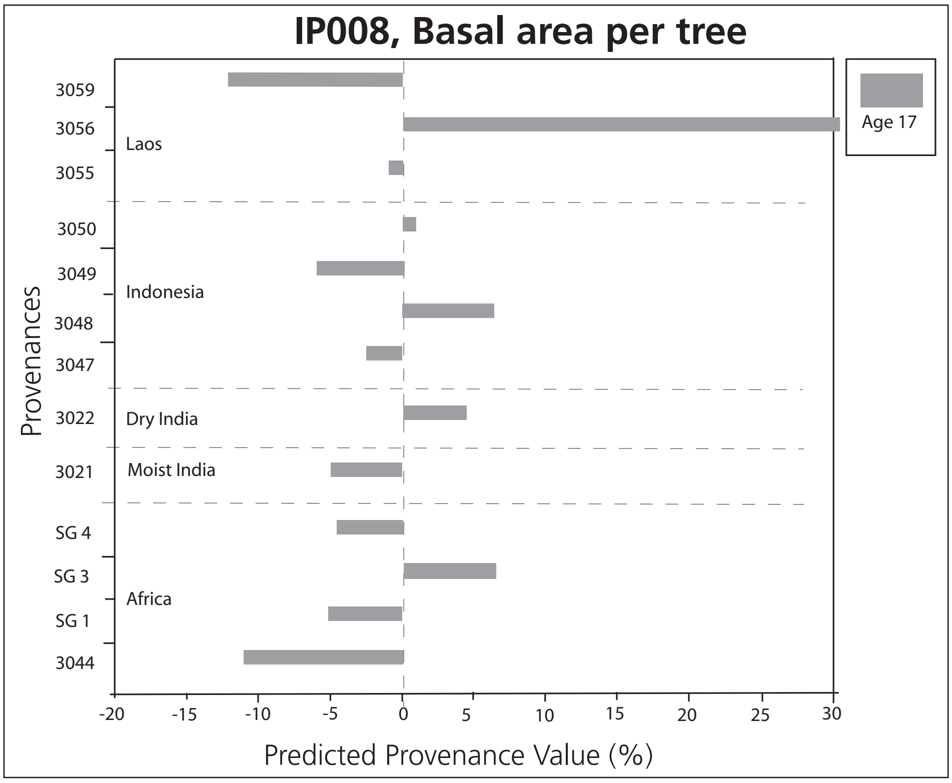

Figure 38. Basal area per tree in IP008, Pra Anum, Ghana

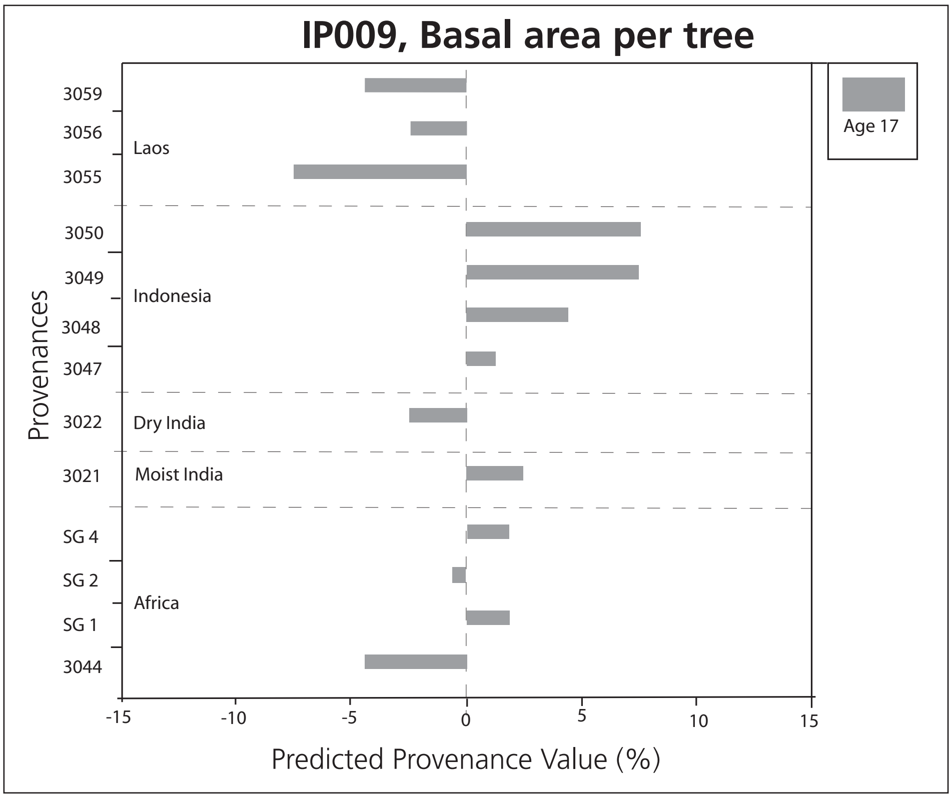

Figure 39. Basal area per tree in IP009, Tain, Ghana.

The differences in the **average size of trees** - expressed as basal area per tree - were significant at the second evaluation. The differences are significant at a regional level (figure 39). They follow to some extent the differences found in basal area per ha. The differences can mainly be described as a result of different mortality. For example, SC3056 (Laos) has had better survival than the two other Laotian provenances and therefore has significantly higher basal area per ha, although the average size of the trees is not different.

There were no significant interactions between provenances and trials in **basal area per ha.** The correlation between average provenance performance in the two trials is intermediate, rp=0.58. This is partly due to the non-significance in IP008. There are, however, significant interaction between the trials in terms of **basal area per tree**. The correlation is low, rp=0.19.

CONCLUSIONS CONCERNING PRODUCTION

Three provenances were found to be relatively fast growing in this trial: SC3047 (Indonesia), SC3049 (Indonesia) and SC3021 (Moist India). Provenances from Dry India and Laos were in general slower growing, with the exception of IP3056 (Laos), which has produced above average. African landraces also produce below average, especially SC3044. In general the differences must, however, be considered to be relatively small in this trial region.

7.3.4 General recommendations for trial region West Africa, semi-moist and dry

The African landraces tested in this trial (SC3044, SG l, SG 3, SG 4) were found to have a high frequency of trees with poor stemform and low axis persistence. They can therefore not be recommended. They have also a tendency to develop more epicormic branches and protuberant buds than average in the two trials.

Provenances from Laos (SC3055-56, SC3059), in general, have shown poor adaptation in terms of health and survival. The growth is also below average.

In general provenances from Indonesia (SC3047-50) and the provenance from Moist India (SC3021) grow fast and are of good quality. The Indonesian provenances have a tendency to develop more epicormics and protuberant buds than the provenances from Moist India and Dry India. This may or may not be considered a disadvantage.

7.4 Trial region: South East Asia

This trial region covered 4 trials at the time of the first assessment, IP001 & IP038 (Thailand), IP016 (India) and IP032 (Papua New Guinea). Only one trial, IP038 (Thailand) was re-evaluated at age 17. This trial contains 25 provenances. Most provenance region s are represented by more than one provenance, and the trial therefore gives a good opportunity to test whether differences are mainly between regions, or between provenances within regions.

Table 7.24 Correlation (within trial) between provenance performance at age 9 and age 17.

	IP038	
Trait	r_p	r_g
Survival	0.84	-
Health	0.28	-
Persistence	0.65	0.77
Stem form	0.56	-
Branch size	0.62	0.88
Ba /tree	0.59	-
Ba /ha	0.42	-

The »genetic correlation« is only estimated for traits where significant differences are found at both ages (see section 5.1. for details).

7.4.1 Adaptation

Survival and health were assessed at age 9 and 17. The results of the ANOVA's and ANOCOV's are presented in table 7.25-7.26. Correlations between provenance averages at age 9 and 17 are presented in table 7.24.

Table 7.25 ANOV A for adaptive traits

IP038	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (9)	1.50	0.102	-	-	-	-
Survival (17)	1.08	0.391	-	-	-	-
Health (9)	1.28	0.218	-	-	-	-
Health (17)	1.38	0.153	-	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Table 7.26 ANOCOV for development from first to second assessment

IP038	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development in:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Survival	0.867	0.008	-	-	-
Health	0.070	0.001	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

No significant differences in **survival** or **health** were found in this trial at either of the two ages. The differences were, however, large at age 9 and the predicted provenance values are presented in figure 40. It should be recalled that the differences are not significant. The increased mortality and health from age 9 to 17 did not differ significantly between the provenances from the trends revealed by differences at age 9. The correlation between average performance at age 9 and 17 is high for survival, rp=0.84, but lower for health, rp=0.28.

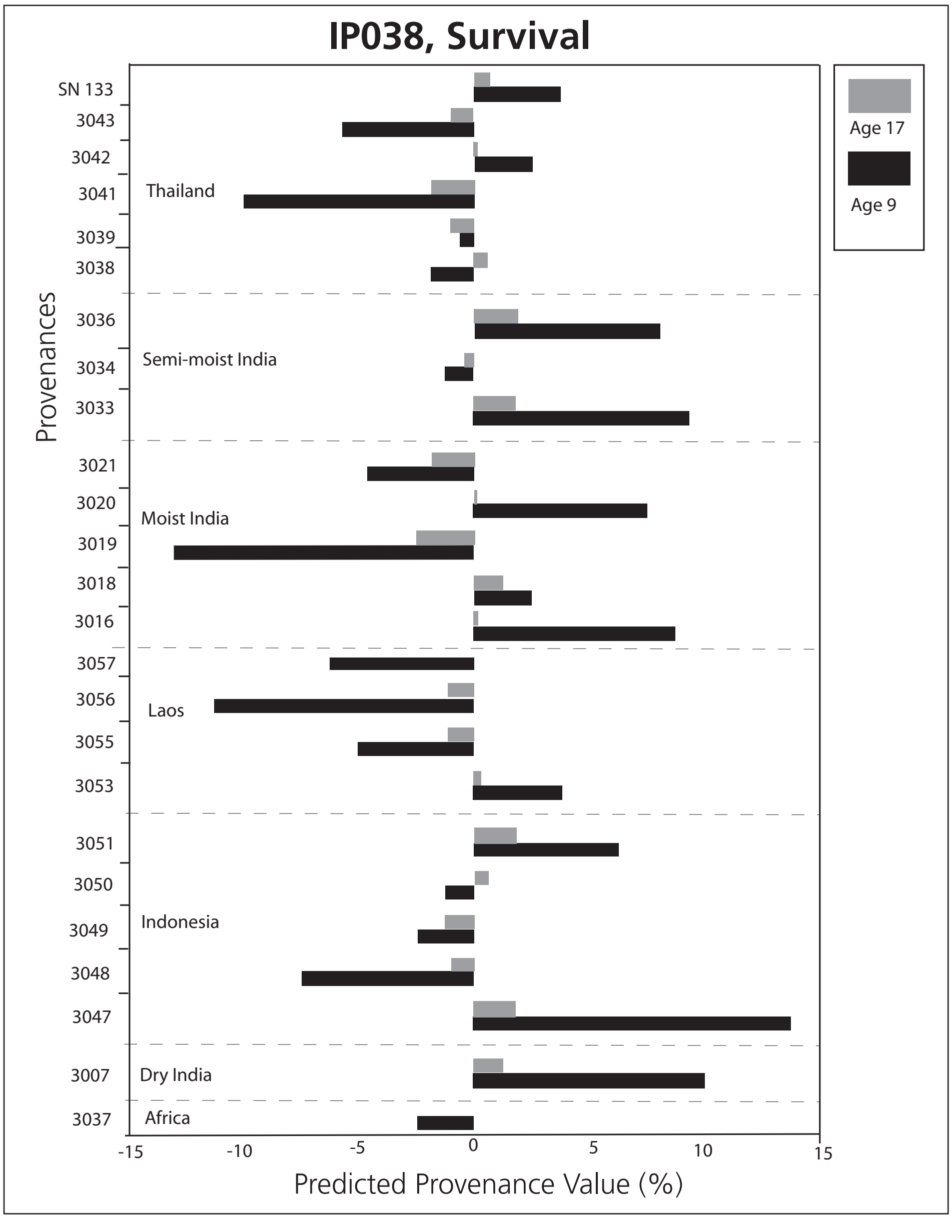

Figure 40. Survival in IP038, Pah Nok Kan, Thailand.

7.4.2 Stem quality

Three characters were assessed at both ages: Persistence of the axis, stemform and branch size. Pilodyn (wood density), epicormic branches, bark thickness and buttressing were assessed for the first time at age 17.

TRAITS ASSESSED AT BOTH AGES

The results of the ANOVA's and ANOCOV's are presented in table 7.27.-7.28. Correlations between provenance averages at age 9 and 17 are presented in table 7.24.

Table 7.27 ANOVA for persistence, stemform and branch size

Trial: IP038	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Persistence (9)	**1.81**	**0.031**	0.99	0.458	1.49	0.125
Persistence (17)	**1.93**	**0.019**	2.14	0.096	1.44	0.144
Stemform (9)	0.97	0.516	-	-	-	-
Stemform (17)	**1.79**	**0.033**	**3.52**	**0.016**	1.06	0.415
Branch size (9)	**3.26**	**0.001 ***	**4.26**	**0.007**	**1.80**	**0.045**
Branch size (17)	**2.43**	**0.003***	2.33	0.075	**1.79**	**0.046**

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferroni procedure (see section 5.2).

Table 7.28 ANOCOV for development from first to second assessment

IP038	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
Persistence	0.177	0.417	-	-	-
Stemform	0.120	**0.001**	-	-	-
Branch size	0.056	**0.001**	0.054	0.193	**0.001**

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferroni procedure (see section 5.2).

Significant differences were found in **persistence of axis** at both ages. At age 9 the differences were mainly at a provenance region level, but more within-provenance region variance was found at age 17. The correlation between the performance at age 9 and 17 is fairly high, rp=0.65 & rg=0.77. The changes from age 9 to age 17 are not significantly different for the different provenances. The predicted provenance differences are presented in figure 41. Provenances from Thailand, and Laos in general have the best persistence (figure 41). Provenances from Moist India have the lowest persistence.

There were no significant differences between provenances in stemform at the first assessment. At age 17 significant differences were found - and now

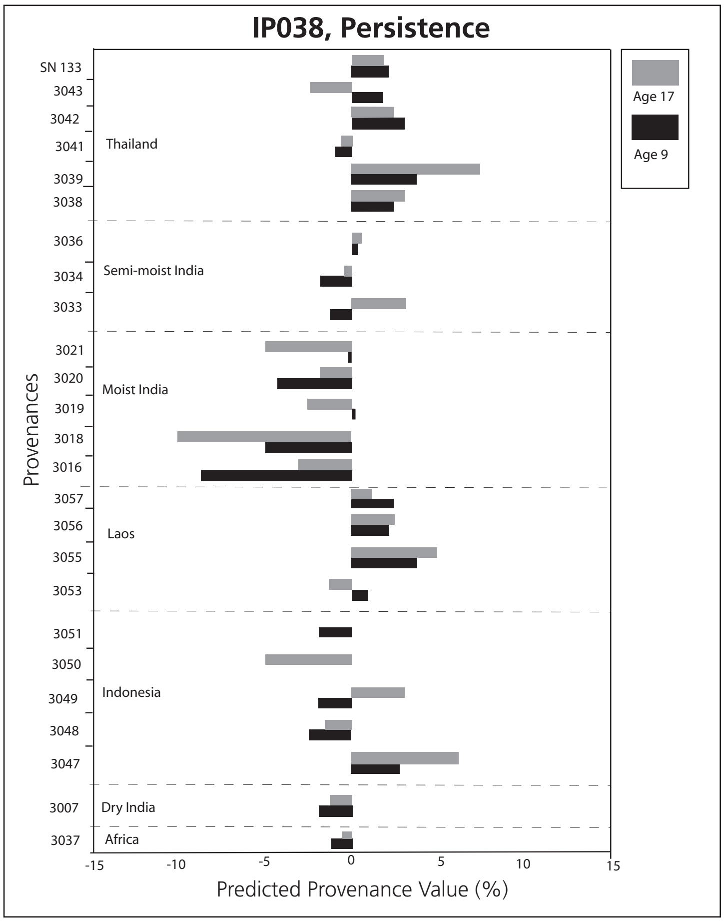

Figure 41. Persistence in IP038, Pah Nok Kau, Thailand.

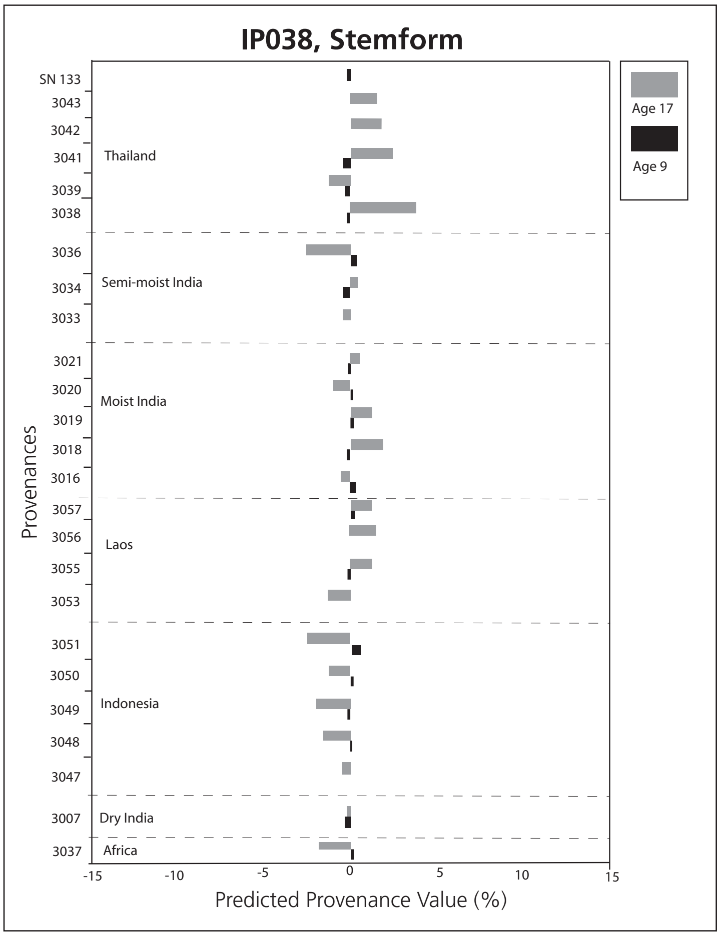

Figure 42. Stemform in IP038, Pah Nok Kau, Thailand.

at a regional level. The predicted provenance values are presented in figure 42. Provenances from Thailand and Laos are of significantly better stemform than provenances from Indonesia, but the differences are small. The correlation between the first and second assessment is intermediate, rp=0.56.

Significant differences between relative branch size were found at both ages. Significant differences were found between regions, but there were also significant differences within provenance regions (figure 43). Provenances from Moist India have finer branches than provenances from Laos and Africa (only one provenance tested). There is variation between the provenances within Thai and Indonesian provenance regions.

The changes from age 9 to 17 was significantly different for the provenances. Especially provenances from Laos and Africa have developed larger branches compared to the first assessment, but the general ranking from the first assessment still seems valid for these provenances. Provenances from Indonesia have also revealed a tendency to have above average branch size and this information is new. The correlation is fairly high, rp=0.62 & rg=0088.

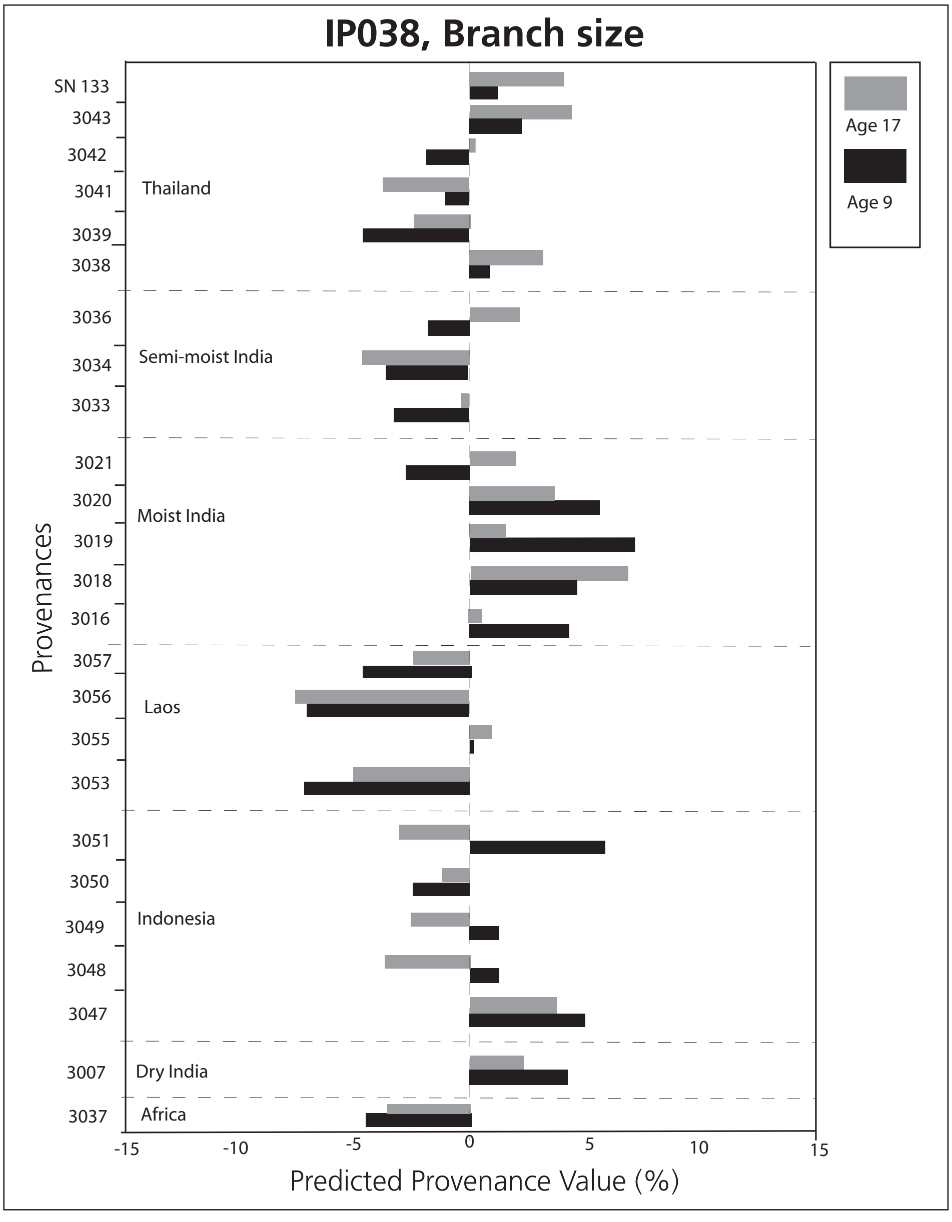

Figure 43. Branch size in IP038, Pah Nok Kau, Thailand. (Note: Positive values signify fine branches).

CONCLUSION CONCERNING THE QUALITY TRAITS ASSESSED AT BOTH AGES

The performance in terms of persistence of axis, stemform and branch size has not changed much from age 9 to age 17, although the differences have in general increased. New information has especially been revealed in stemform. Thai provenances in general are of good quality due to good ability to maintain their terminal axis and their above average stemform. Provenances from Laos in general have good persistence and stemform, but branches are larger than average in this trial. Moist Indian provenances have fine branches, but the persistence is below average for all the tested provenances. This tendency has increased in the period between the first and second assessment. The Moist Indian provenances were found to be of above average quality after the first assessment, but with a tendency towards lower quality at the later stage. Indonesian provenances are variable, some are of below average quality, while others, e.g. SC3047, are of good quality. Still, the differences are small.

QUALITY TRAITS ASSESSED ONLY AT THE SECOND ASSESSMENT

The results of the ANOVA's are presented in table 7.30.

Table 7.30 ANOVA for epicormic branches, protuberant buds, relative pilodyn penetration (wood density), relative bark thickness and buttressing

Trial: IP038	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait:	F	Pr>F	F	Pr>F	F	Pr>F
Epiconnics	**1.79**	**0.033**	**3.36**	**0.019**	1.03	0.437
Protuberant buds	**1.98**	**0.016**	2.36	0.071	1.39	0.166
Relative pilodyn	**2.84***	**0.001 ***	0.96	0.480	**3.01**	**0.001**
Relative bark thickness	1.61	0.068	-	-	-	-
Buttressing	1.29	0.201	-	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Significant differences are found in **epicormics and protuberant buds**. The two traits are seen to be highly correlated (figure 44).

Differences in **relative pilodyn penetration (wood density) and bark thickness** were found to be almost significant though small (figure 45). No significant differences were found in **buttressing**.

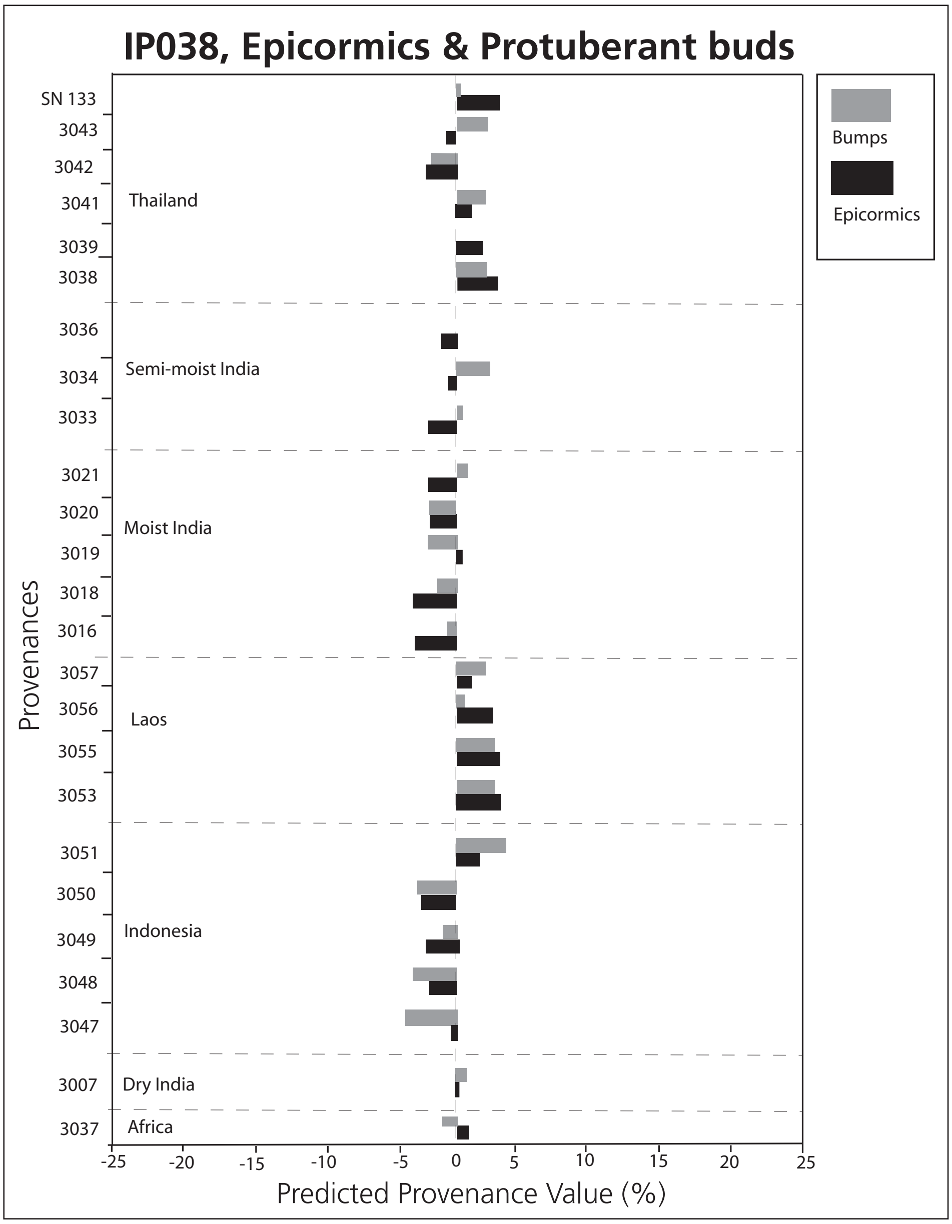

Figure 44. Epicormics and Protuberant Buds in IP038, Pah Nok Kau, Thailand. (Note: Positive values signify small number of epicormics and bumps).

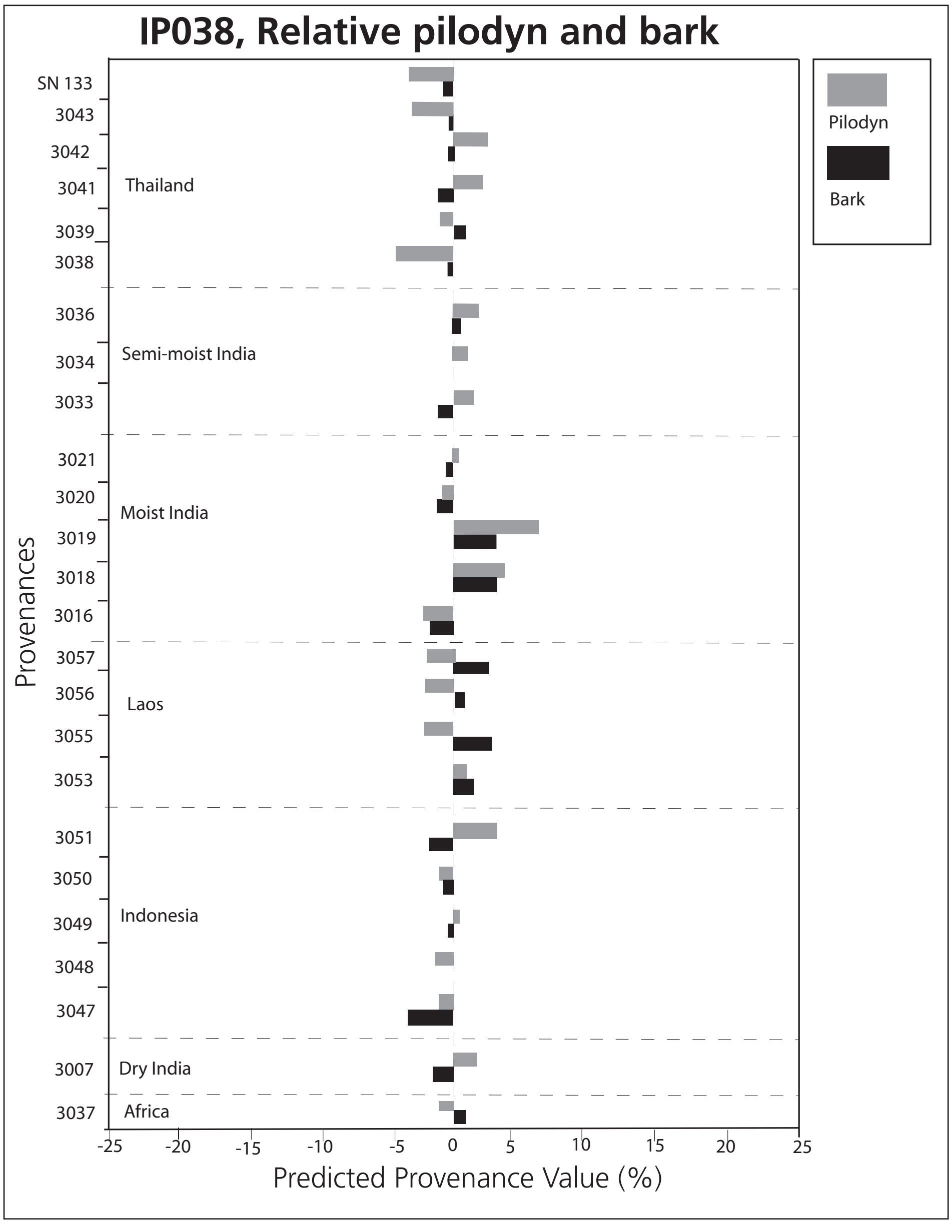

Figure 45. Relative Pilodyn and Bark in IP038, Pah Nok Kan, Thailand. (Note: Positive values signify small penetration and high wood density).

7.4.3 Production and growth rate

The diameter of all living trees was recorded at age 9 and 17. The average basal area per tree and basal area per ha. were calculated. The results of the ANOVA's and ANOCOV's are presented in table 7.31-7.32. Correlations between provenance averages at age 9 and 17 are presented in table 7.24.

Table 7.31 ANOVA for basal area per tree (Ba/tree) and basal area per ha (Ba/lha) in IP038.

TRIAL: IP038	**Model I**		**Model II**			
Differences between:	**Provenances**		**Provenance regions**		**Provenances within regions**	
Trait (age):	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Ba / tree (9)	1.45	0.120	-	-	-	-
Ba / tree (17)	**1.84**	**0.028**	1.64	0.191	1.57	0.096
Ba / ha. (9)	1.57	0.079	-	-	-	-
Ba / ha. (17)	1.31	0.194	-	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in model I marked with an asterisk are also significant according to the sequential Bonferroni procedure (see section 5.2).

Table 7.32 ANOCOV for development from first to second assessment.

IP038	**Model I**		**Model II**		
Effect of:	**Provenances**	**Covariate: Age 9 value**	**Provenance regions**	**Provenances within regions**	**Covariate: Age 9 value**
Development of:	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**	**Pr>F**
BA / tree	0.223	0.187	-	-	-
BA / ha	0.599	**0.001**	-	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances in model I marked with an asterisk are also significant according to the sequential Bonferroni procedure (see section 5.2).

Production - expressed as basal area per hectare - does not differ significantly at any of the two assessments. The correlation between the basal area per ha at age 9 and 17 is intermediate, rp=0.42. The differences found at age 9 and age 17 are presented in figure 46, but it should be recalled that they are not significantly different. The figure does, however, give some indication that for example provenances from Thailand and Laos are slow growing compared to provenances from Semi-moist India and Indonesia.

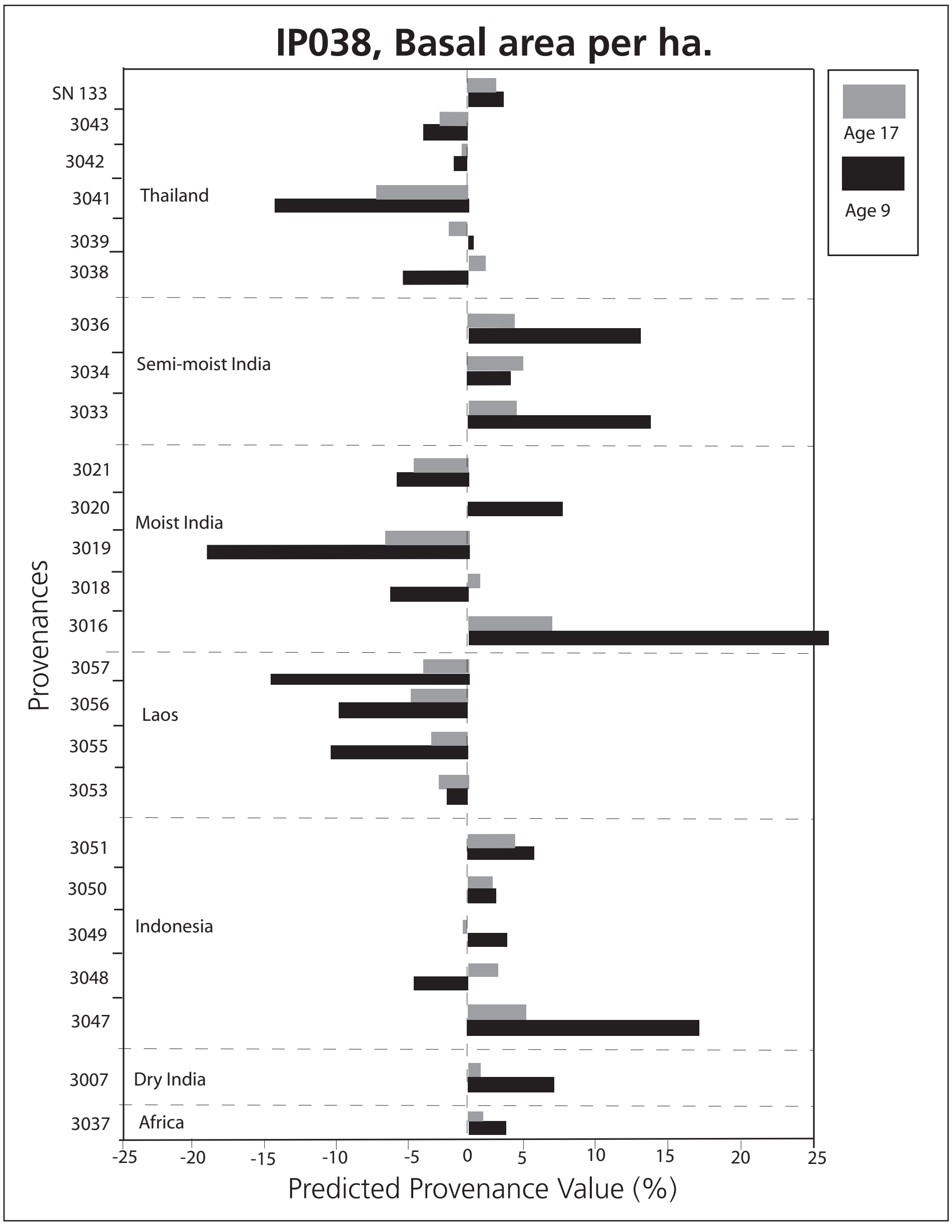

Figure 46. Basal area per hectare in IP038, Pah Nok Kan, Thailand

The differences in the **average size of trees** - expressed as basal area per tree - were significant only at the second evaluation. The differences in increment from age 9 to 17 are not significant. The correlation between the two assessments is fair, rp=0.59. The provenances from Indonesia are all above average. Trees from Semi-moist India are also relatively large on an average, as are trees of the African provenance SC3037. Provenances from Laos have all grown slower than average at age 17 (figure 47). The provenances from Moist India and Thailand are fairly slow growing on average.

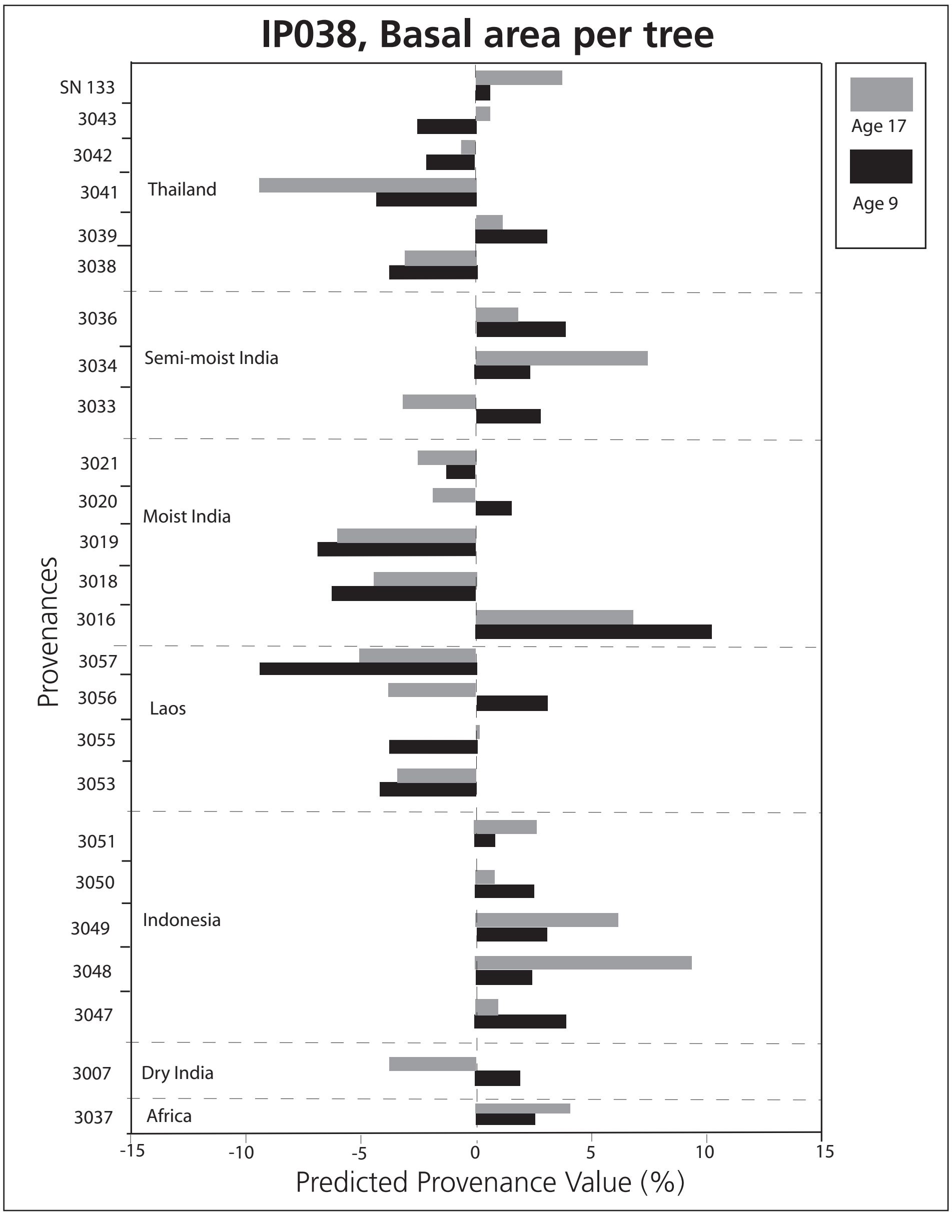

Figure 47. Basal area per tree in IP038, Pah Nok Kan, Thailand.

CONCLUSIONS CONCERNING PRODUCTION

The differences in IP038 in terms of production per ha are not significant. Significant differences are, however, found in average tree size. Differences in this trait suggest that provenances from Indonesia, and to a lesser extent from Semi-moist India, are more productive than provenances from Laos, Thailand and Moist India. The single African landrace is seen as fast growing. This is exactly the same picture as was seen for the South East Asian origin at age 9 (Keiding *et al.* 1986, p.37). That result was based on four trials in the South East Asian trial region, and the three other trials not assessed at age 17 all showed higher levels of significance than IP038.

7.4.4 General recommendations for trial region South East Asia

Thai and Laotian provenances are found to be of good quality, but especially provenances from Laos are less productive than the average of the tested provenances.

Indonesian provenances are more productive, but are on the average of a slightly lower quality. SC3047 is, however, of very good quality.

The Moist Indian provenances are in general found to be of lower productivity and quality than Indonesian provenances, especially due to low axis persistence. Branches are generally fine.

These results are in dose concordance with the results from the first assessments with the exception that the Moist Indian provenances have lost in quality in comparison to the other provenance regions.

7.5 Trial region : Central America

This trial region was represented by four trials in the first assessment, IP022 (Mexico), IP045, IP046 (Puerto Rico) and IP047 (St. Croix). All four trials were reassessed at age 17. Unfortunately the largest trial (IP022) suffered from very high mortality, and had to be abandoned in this analysis. The two trials from Puerto Rico and the trial from St. Croix were analyzed, but all provenance differences in characters assessed in IP046 were highly insignificant, Table 7.36-7.42. This is probably due to a high site variability, as the trial is placed in a tract exposed to wind. Only results from IP045 and IP047 will therefore be discussed further in this section. One provenance, SC3041 (Thailand) has a poor representation in IP045 compared to the other provenances in this trial.

Five provenances were tested in both IP045 and IP047 and were used for an analysis of interaction between the trials within the region. IP046 is not included in this analysis. The results are presented in table 7.33. Correlations between average provenance performance at the two trials are presented in 7.35.

Table 7.33 Analysis of interaction across the two trials in the trial region.

	TRIAL		PROVENANCE		TRIAL*PROVENANCE	
Trait (age)	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Survival (7)	6.84	0.011	1.26	0.379	1.97	0.106
Survival (17)	4.73	0.033	0.43	0.781	1.91	0.106
Health (17)	159.63	0.001	5.88	0.057	0.75	0.558
Persist. (7)	1.07	0.328	1.14	0.440	1.77	0.141
Persist. (17)	17.56	0.011	0.11	0.974	8.46	0.001
Stemform (7)	2.94	0.120	0.32	0.912	0.76	0.552
Stemform (17)	17.39	0.005	0.46	0.765	2.62	0.040
Br. size (7)	7.78	0.018	14.70	0.003	1.04	0.392
Br. size (17)	2.07	0.211	0.14	0.960	13.53	0.001
Epicormics	-	-	-	-	-	-
Protub.Buds	-	-	-	-	-	-
Buttressing	-	-	-	-	-	-
Ba ltree (7)	79.46	0.001	1.51	0.331	2.68	0.037
Ba ltree (17)	5.49	0.067	0.42	0.792	8.93	0.001
Ba !ha (7)	432.01	0.001	0.51	0.787	2.12	0.081
Ba!ha (17)	5.39	0.081	0.76	0.653	5.56	0.001

Table 7.34 Correlation (within trial) between provenance performance at age 7 and 17.

	IP045		IP047	
Trait	r_p	r_g	r_p	r_g
Survival	0.44	-	0.77	1.02
Health	-	-	-	-
Persistence	0.34	-	-0.93	-1.61
Stem form	0.41	-	0.18	-
Branch size	0.57	0.63	-0.85	-1.10
Ba /tree	0.95	0.99	0.79	0.80
Ba /ha	0.77	0.97	0.67	0.73

The »genetic correlation« is only estimated for traits where significant differences are found at both ages (see section 5.1.3. for details).

Table 7.35 Correlation between provenance performance in IP045 and IP047.

	Age 7		Age 17	
Trait	r_p	r_g	r_p	r_g
Survival	0.04	-	-0.56	-
Health	-	-	0.68	-
Persistence	0.14	-	-0.99	-1.62
Stem form	-0.41	-	-0.58	-
Branch size	0.92	1.06	-0.76	-0.99
Ba /tree	0.19	-	-0.42	-
Ba /ha	0.58	-	0.19	-

The »genetic correlation« is only estimated for traits where significant differences are found at both ages (see section 6.1.2. for detaiis). Only five provenances are tested in IP047, and the estimates of correlation should therefore be interpreted with some caution.

7.5.1 Adaptation

Survival and health were assessed at age 7 and 17. Results of the ANOVA's and ANOCOV's are presented in table 7.36. Correlations between provenance averages at age 7 and 17 are presented in table 7.34. Analysis of interaction between the two trials are presented in table 7.33, and correlation between trials in table 7.35.

Table 7.36 ANOVA for adaptive traits in IP045, IP046 and IP047.

IP045	**Model I**	
Differences between:	**Provenance**	
Trait (age):	**F**	**Pr>F**
Survival (7)	0.34	0.936
Survival (17)	1.81	0.102
Health (7)	-	-
Health (17)	3.20	0.006*
IP046	Model I	
Differences between:	Provenances	
Trait (age):	F	Pr>F
Survival (7)	1.61	0.138
Survival (17)	1.23	0.293
Health (7)	-	-
Health (17)	1.28	0.271
IP047	Model I	
Differences between:	Provenances	
Trait (age):	F	Pr>F
Survival (7)	**4.55**	**0.003***
Survival (17)	2.12	0.093
Health (7)	-	-
Health (17)	1.33	0.275

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects in marked with an asterisk are also significant according to the sequential Bonferroni procedure (see section 5.2).

Table 7.37 ANOCOV for development from first to second assessment.

IP045	**Model I**	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development in:	**Pr>F**	**Pr>F**
Survival	**0.028**	0.091
Health	-	-

IP046	**Model I**	
Effect of:	**Pcovenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
Survival	0.997	**0.001**
Health	-	-

IP047	**Model I**	
Effect of:	**Pcovenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
Survival	0.136	0.430
Health	-	-

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of pcovenances marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

There were no significant differences in **survival** in **IP045**. At age 7 survival was high for all provenances, higher than 95%. Some differences can be measured at age 17, and an F-ratio of 1.81 (Pr>F = 0.102) suggests that the differences may have some interest. The PPV's are therefore presented in figure 48 for this age. It should be recalled that the differences are non-significant. The increase in mortality from age 7 to age 17 was significantly different for the provenances. Especially the Thai provenances SC3040 & SC3041 and the Moist Indian SC3021 have had **relatively** high mortality from age 7 to 17. This development is reflected in the performance at age 17, figure 48, and is probably a result of lower adaptability of these provenances in the period after the initial establishment phase. At age 17, only one provenance, SC3041, had a survival of less then 85%. The survival of this provenance was 60%. The correlation between average performance at age 7 and 17 is rp=0.44.

The differences in survival in **IP047** were significant only at age 7. The differences in increased mortality in the period between the two assessments were not significant, and the correlation between the results of the two assessments is high: rp=0.84, rg=1.01. All provenances had 95-100% survival at age 7, except SC3017 (Moist India), which had a survival of 85%. At age 17 SC3017 still has the lowest survival, but SC3049 (Indonesia) has also experienced relatively high mortality compared to the other provenances. More than 80% of the trees have survived in all the provenances, and the differences may therefore be without any practical importance.

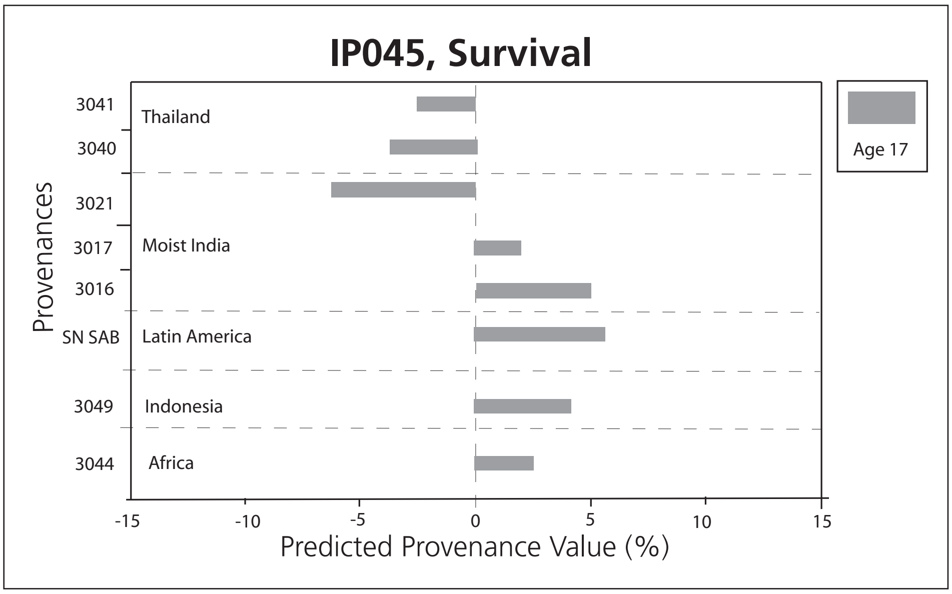

Figure 48. Survival in IP045, Rio Abajo, Puerto Rico.

The standard assumptions for the ANOVA were only partly fulfilled for the analysis of survival at both ages in both trials, and the inference on levels of significance should therefore be interpreted with some caution.

No significant interaction was found in survival between the two trials, but the F-ratios for the interaction are higher than the F-ratios for the provenance differences at both ages. Interaction can therefore not be said to be without importance. The correlation between the performance at the two trials was found to be low at age 7 and even negative at age 17, rp = 0.04 at age 7 and rp = -0.56 at age 17. The provenances have thus performed quite differently.

It was not possible to analyze **health** at age 7 in **IP045** or **IP047** due to large deviations from standard ANOVA assumptions and little variance. Health was analyzed at age 17, and here significant differences were found in **IP045**. The results are shown in figure 49. 25-30 per cent of the trees were classified as not healthy in the Moist Indian SC3017, SC3021 and the Thai SC3040 provenances. The other provenances had less than 10 per cent trees classified as not healthy. Almost no unhealthy trees were found in the Indonesian (SC3049) and African (SC3044) provenances.

GENERAL CONCLUSIONS CONCERNING ADAPTATION

The trials reveal a tendency to lower adaptation of Moist Indian and Thai provenances compared to tested landraces from Africa and Latin America.

It should be remembered that the provenance representation is fairly poor in this trial region. Reference is made to Conclusions concerning the quality traits assessed at both ages (see page 97).

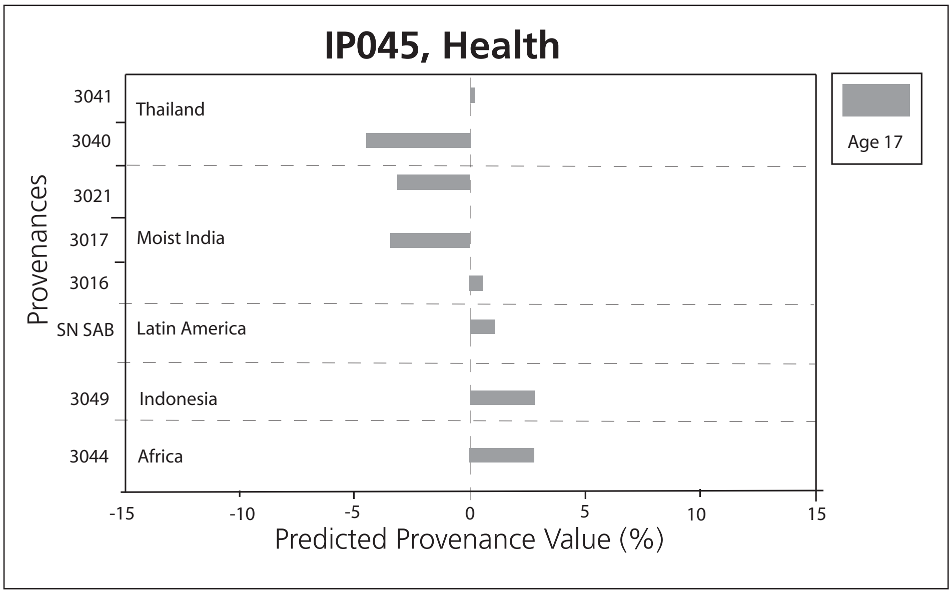

Figure 49. Health in IP045, Rio Abajo, Puerto Rico.

7.5.2 Stem quality

Three characters were assessed at both ages: Persistence of the axis, stem-form and branch size. Pilodyn (wood density), epicormic branches, and bark thickness were assessed for the first time at age 17.

TRAITS ASSESSED AT BOTH AGES

Results of the ANOVA's and ANOCOV's are presented in table 7.38. Correlations between provenance averages at age 7 and 17 is presented in table 7.34. Analysis of interaction between the two trials are presented in table 7.33, and correlation between trials in table 7.35.

Table 7.38 ANOVA for persistence, stemform and branch size.

Trial: IP045	**Model I**	
Differences between:	**Provenance**	
Trait (age):	**F**	**Pr>F**
Persistence (7)	0.25	0.972
Persistence (17)	**2.97**	**0.010**
Stemfonn (7)	0.70	0.674
Stemfonn (17)	**2.34**	**0.035**
Branch size (7)	**6.38**	**0.001 ***
Branch size (17)	**8.34**	**0.001 ***
Trial: IP046	**Model I**	
Differences between:	**Provenance**	
Trait (age):	**F**	**Pr>F**
Persistence (7)	0.75	0.644
Persistence (17)	1.21	0.305
Stemfonn (7)	-	-
Stemfonn (17)	0.60	0.778
Branch size (7)	-	-
Branch size (17)	0.37	0.931
Trial: IP047	**Model I**	
Differences between:	**Provenance**	
Trait (age):	**F**	**Pr>F**
Persistence (7)	**3.84**	**0.009**
Persistence (17)	**3.66**	**0.012**
Stemfonn (7)	0.70	0.595
Stemfonn (17)	1.77	0.155
Branch size (7)	**7.05**	**0.003***
Branch size (17)	**4.71**	**0.003***

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects marked with an asterisk are also significant according to the sequential Bonferroni procedure (see section 5.2).

Table 7.39 ANOCOV for development from first to second assessment.

IP045	**Model I**	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
Persistence	**0.008**	0.621
Stemform	**0.012**	**0.001**
Branch size	**0.001**	**0.026**
IP046	**Model I**	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
Persistence	0.652	**0.004**
Stemform	-	-
Branch size	-	-
IP047	**Model I**	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
Persistence	**0.008**	**0.003**
Stemform	**0.025**	0.114
Branch size	**0.021**	**0.001**

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

The **persistence of axis** was not significantly different at age 7 in **IP045**, but significant differences have evolved in the period between the two assessments. The Moist Indian provenances are all of better persistence than the tested provenance from Indonesia (SC3049), and especially better than the African SC3044 (figure 50).

Significant differences were found in **IP047** at both ages. The ranking were reversed dramatically between the assessments (figure 51), and the correlation between the first and second assessment is therefore very negative, rp= -0.93. At age 7 the results of the two trials are in acceptable concordance without any significant interaction. At age 17 this picture has changed, and there is a significant interaction between the trials. This is mainly due to the dramatic changes in IP047. It is difficult to explain these changes. IP047 is the smaller of the two trials, and most emphasis should probably be put on the differences found in IP045, although the diverging results make the conclusion for this trial region very weak.

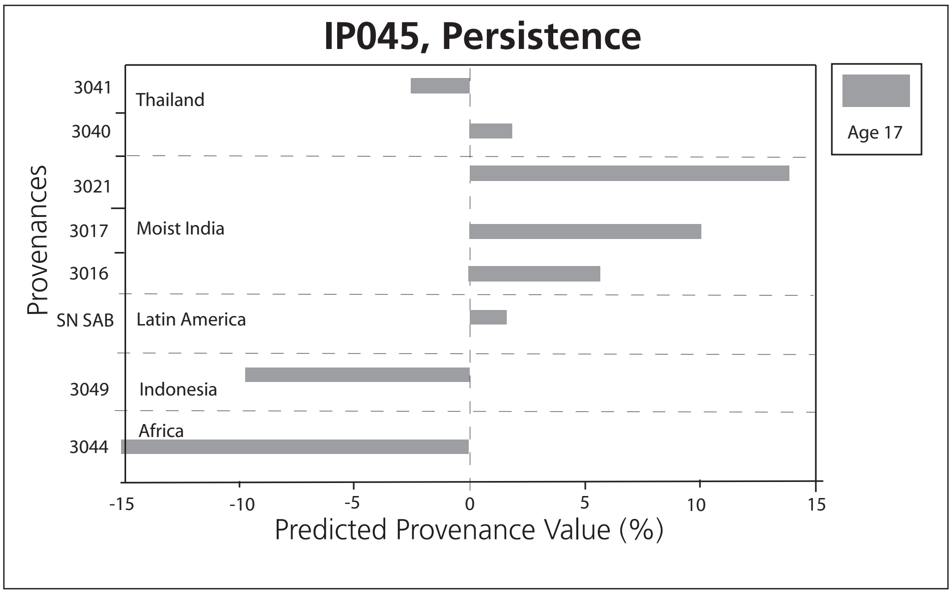

Figure 50. Persistence in IP045, Rio Abajo, Puerto Rico.

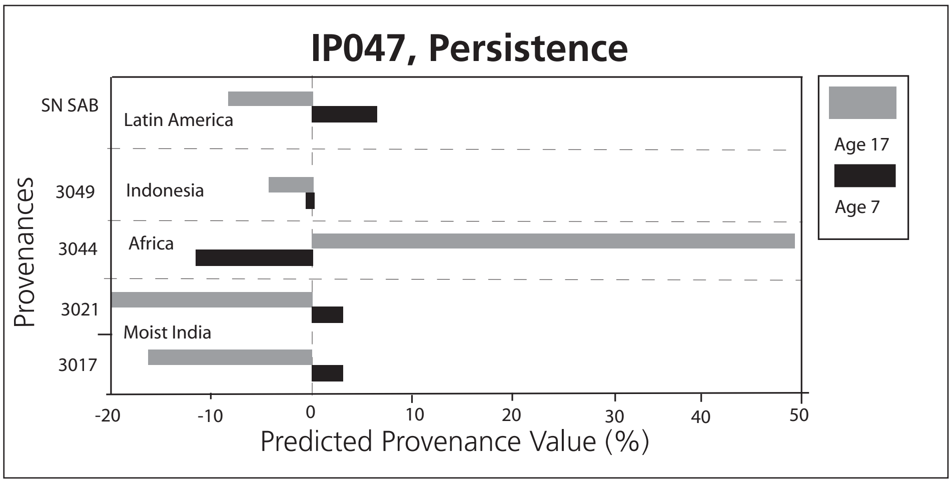

Figure 51. Persistence in IP047, St. Croix, Puerto Rico.

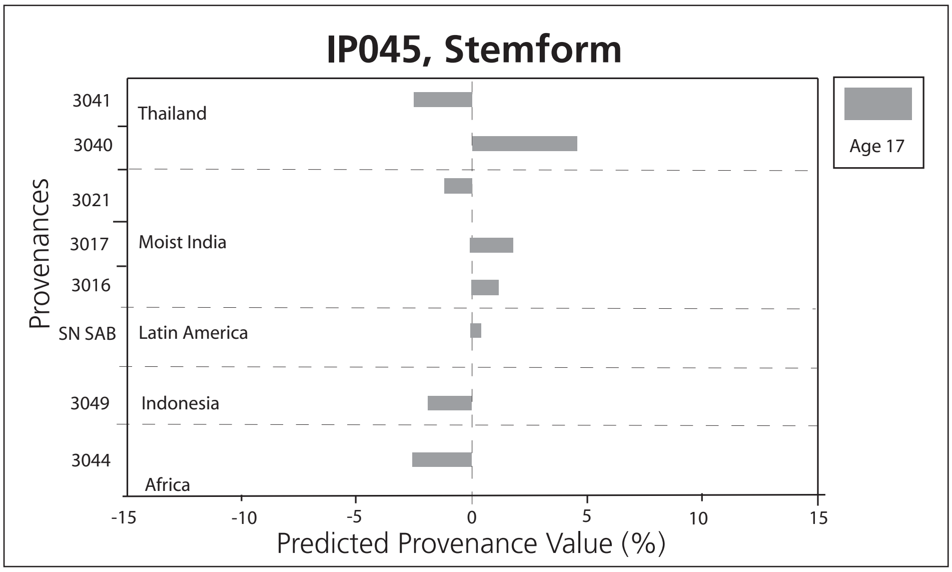

Figure 52. Stemform in IP045, Rio Abajo, Puerto Rico.

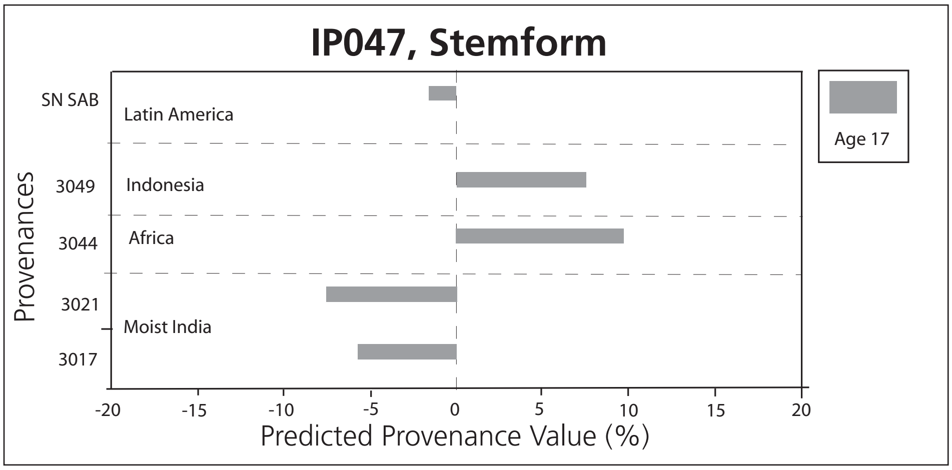

Figure 53. Stemform in IP047, St. Croix, Puerto Rico.

Differences in **stemform** in **IP045** were not significant at age 7, but have developed into significant differences at age 17. The correlation between the performance at the two ages is intermediate, rp= 0.41. At age 17 the differences are still small (figure 52).

Differences were also insignificant at age 7 in **IP047** (F=0.70, Pr>F=0.595). The differences were also non-significant at age 17, although the F-ratio has increased to F=1.77 (Pr>F=0.155). The PPV's are therefore presented in figure 53. It should be recalled that the differences are not significant, but the results indicate a deve10pment parallel to persistence ofaxis: The African SC3044 and Indonesian SC3049 are of above average quality in this trial at age 17.

Significant interaction between IP045 and IP047 was found at age 17.

Differences in **branch size** were highly significant at both ages in **IP045**. The changes from the first to second assessment are, however, also significant. The correlation is still relative high, rp=0.75 & rg=0.61. The differences are large and presented in figure 54. It is clear that the significant changes from the first to the second assessment are due to the two Thai provenances, which both have changed their rank dramatically. For the other provenances the performance at age 17 is merely an increase of the differences already found at age 7. The Indonesian provenance (SC3049) and African landrace (SC3044) have much larger branches than the fine branched provenances from Moist India.

In **IP047** the differences in branch size are significant at both ages. The results are presented in figure 55. It is obvious that dramatic changes in the ranking have also taken place for the branch size in this trial analogous with persistence. The differences are small at age 7, the African SC3044 and Indonesian provenance having larger branches than the provenances from Moist India. At age 17 this picture has changed completely, the African SC3044 and Indonesian SC3049 now having finer branches than the Moist Indian provenances. The correlation between the first and second assessment, rp=-0.85, clearly reveals that the ranking has been reversed.

Significant interaction between **IP045** and **IP047** was found in branch size at age 17, but not at age 7. The correlation has changed completely from being close to 1.00 at age 7, rp=0.92, rg=1.06, to being close to -1.00 at age 17, rp=-0.76, rg=-0.99.

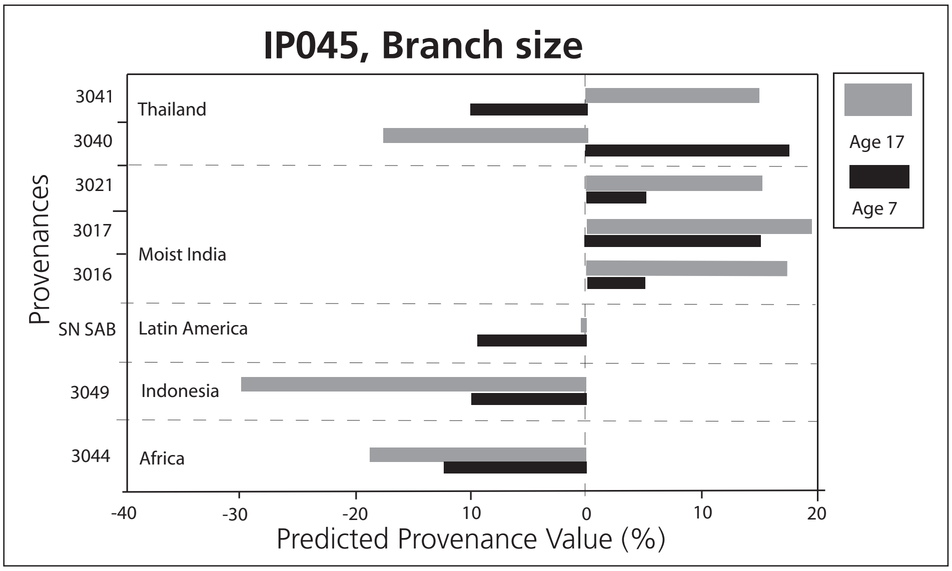

Figure 54. Branch size in IP045, Rio Abajo, Puerto Rico. (Note: Positive values signify fine branches).

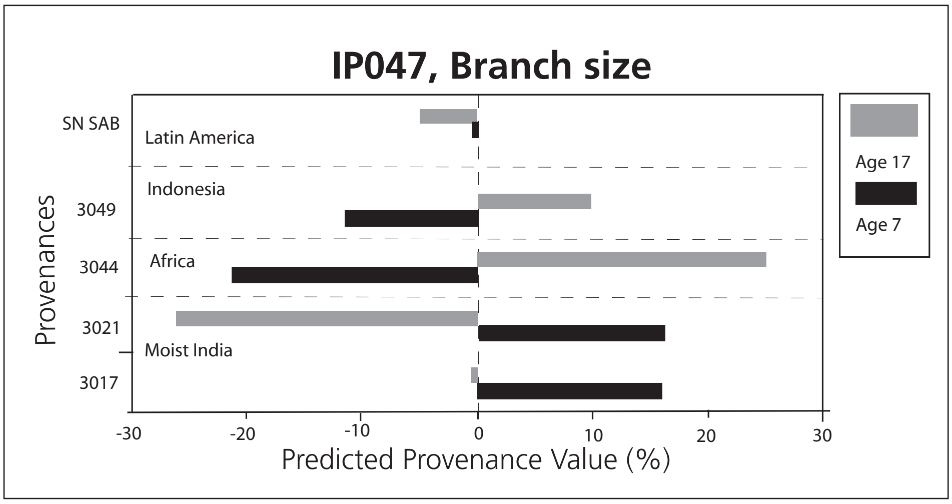

Figure 55. Branch size in IP047, St. Croix, Puerto Rico. (Note: Positive values signify fine branches).

CONCLUSIONS CONCERNING THE QUALITY TRAITS ASSESSED AT BOTH AGES

It has generally been possible to observe larger differences in stem quality at the later age than at the younger. For one of the trials, **IP045**, the results at age 17 are generally an increase of differences already found at age 7. The provenances from Moist India and Thailand are of better quality than the tested provenance from Indonesia and the African landrace.

In the other trial, **IP047** (St. Croix) the results are much more complicated. The ranking has changed completely. The African landrace has changed from being of relatively inferior quality to being the provenance of best quality. The African landrace has not in fact improved its quality absolutely, the change in ranking has taken place because the provenances from Moist India and Thailand have developed into stands of very poor quality. The most likely explanation is therefore that the differences in development are caused by a better long term adaptation of the African landrace. The Indonesian (SC3049) and Latin American (SN SAB) provenances are intermediate being of poorer quality than Moist Indian provenances but better than the African provenances at age 7, changing to being better than the Moist Indian provenances and inferior to SC3044 at age 17 in this trial.

Unfortunately it has not been possible to find significant differences in the third trial assessed in this region, **IP046**. The analysis does, however, show that the plot means at the two ages are well correlated. This means that this trial has experienced no changes comparable to those found in **IP047**. Results from **IP046** indicate, although not significantly, that the Moist Indian provenances are of good persistence at age 17.

The annual rainfall is 2400 mm at **IP045** (Puerto Rico), but only 1500 mm per year at **IP047** (St. Croix). The soils are also poorer at **IP047** compared to**IP045**. The two Moist Indian provenances tested in both **IP045** and **IP047,** SC3017 and SC3021, both originate from regions with more than 2000 mm rainfall per year. The dramatic decrease in the quality of these two provenances in **IP047** may therefore be interpreted as a result of using the Moist Indian provenances in sites with too little annual rainfall. This is supported by the fact that the age 7 -age 17 correlations in the more moist **IP046** trial are much more comparable with the findings in **IP045**. The actual growth, in terms of basal area, has however, not decreased in **IP047** as will be shown below. It is therefore not a question of simple mal-adaptation of the Moist Indian provenances.

The significant interaction between **IP045** and **IP047** suggests that they cannot be considered as belonging to the same trial region in terms of quality traits.

QUALITY TRAITS ASSESSED ONLY AT THE SECOND EVALUATION

Results of the ANOVA's are presented in table 7.40.

Table 7.40 ANOVA for epicormic branches, protuberant buds, relative pilodyn penetration (wood density), relative bark thickness and buttressing.

Tria1: IP045	**Model I Provenance**	
Differences between:		
Trait:	**F**	**Pr>F**
Epiconnics	**7.56**	**0.001 ***
Protuberant buds	-	-
Relative pi10dyn	**8.99**	**0.001 ***
Relative bark thickness	**15.39**	**0.001 ***
Buttressing	-	-

Trial: IP046	**Model I Provenance**	
Differences between:		
Trait:	**F**	**Pr>F**
Epiconnics	0.23	0.983
Protuberant buds	1.83	0.122
Relative pilodyn	0.77	0.631
Relative bark thickness	0.93	0.50
Buttressing	-	-

Trial: IP047	**Model I Provenance**	
Differences between:		
Trait:	**F**	**Pr>F**
Epiconnics	**3.94**	**0.008***
Protuberant buds	1.69	0.170
Relative pilodyn	**3.94**	**0.008***
Relative bark thickness	**4.91**	**0.003***
Buttressing	-	-

Notes: Effects significant on a simple 5%level are typed in bold. Significant effects marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

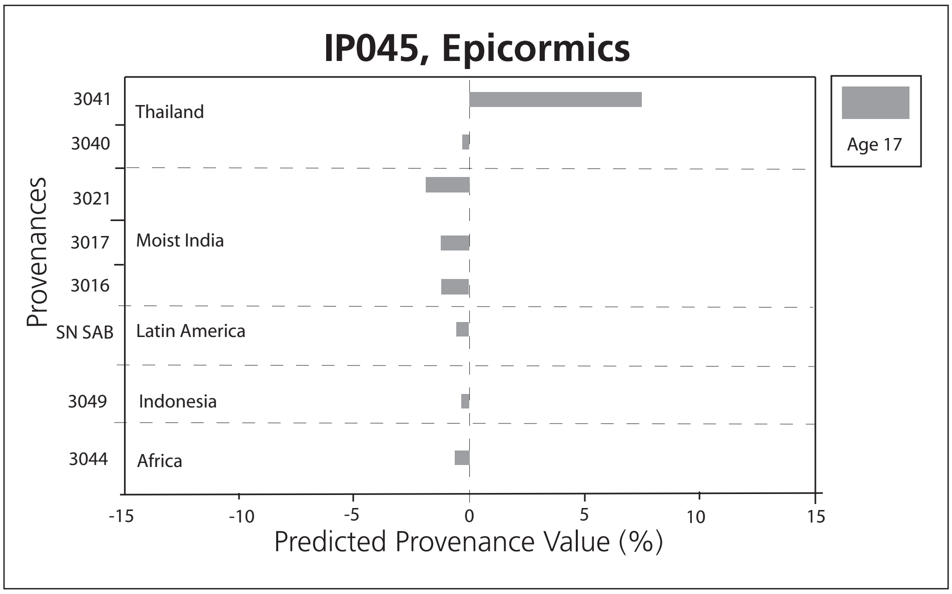

Figure 56. Epicormics in IP045, Rio Abajo, Puerto Rico. (Note: Positive values signify small number of epicormics).

Significant differences were found in **epicormics** in **IP045**, but not in **IP047**. Results from IP045 are presented in figure 56. The differences are smal!. There was no significant interaction between **IP045** and **IP047** in this trait.

No significant differences were found in protuberant buds in any of the trials.

Significant differences in relative bark thickness were found in both trials. The Moist Indian provenances have higher relative bark thickness in both trials (figure 57, 58). There was no significant interaction between **IP045** and **IP047** in this trait.

Significant differences were found in relative pilodvn penetration in both trials (figures 57 and 58). The differences are large in these two trials compared to those generally found, but the practical importance is still questionable.

No significant differences were found in **buttressing** in any of the trials.

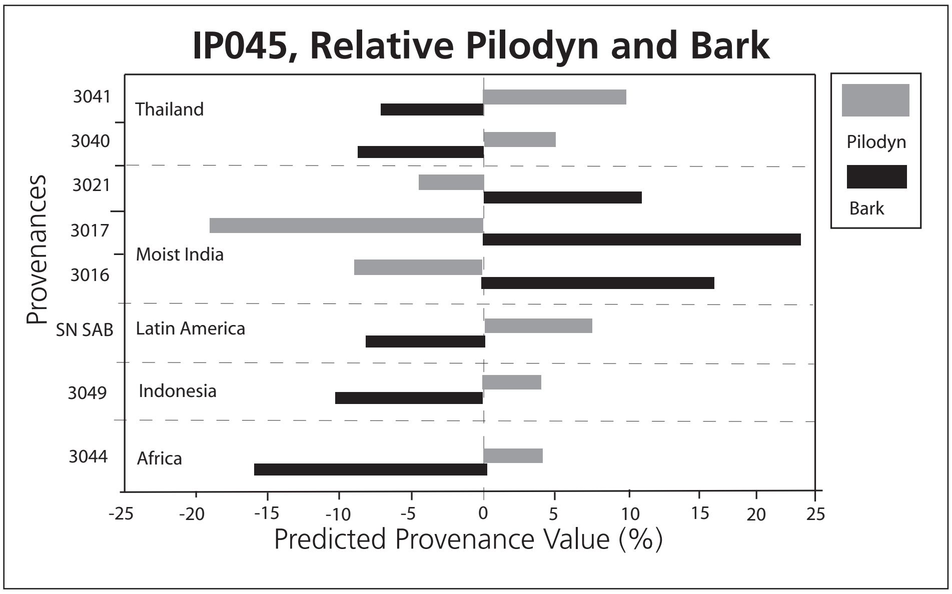

Figure 57. Relative Pilodyn and Bark in IP045, Rio Abajo, Puerto Rico. (Note: Positive values signify small penetration or high wood density)

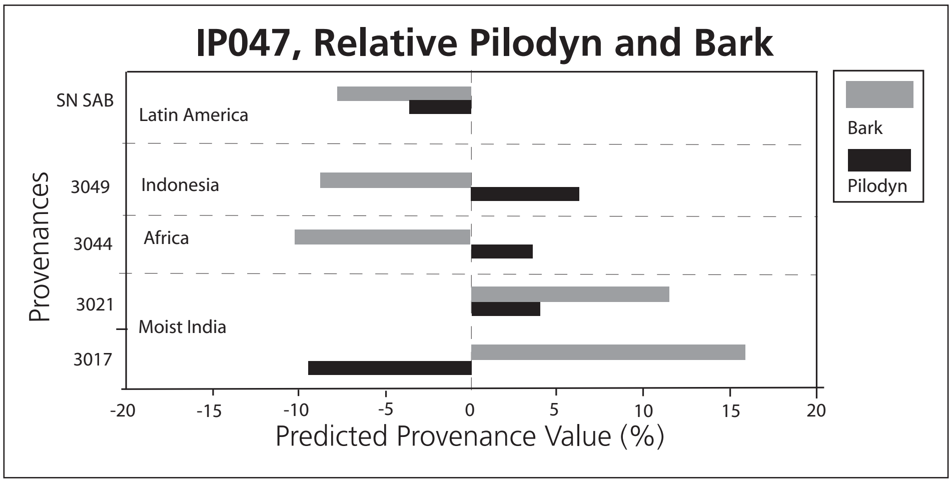

Figure 58. Relative Pilodyn and Bark in IP047, St. Croix, Puerto Rico. (Note: Positive values signify small penetration or high wood density). (This figure is a modification of theoriginal print of 1995).

7.5.3 Production and growth rate

The diameter was recorded of all living trees at age 7 and 17. The average basal area per tree and basal area per ha. were ca1culated. Results of the ANOVA's and ANOCOV's are presented in tab1e 7.41. Correlations between provenance averages at age 7 and 17 are presented in table 7.34. Analysis of in teraction between the two trials is presented in tab le 7.33, and correlation between trials in table 7.35.

Table 7.41 ANOVA for basal area per tree (Ba/tree) and basal area per ha (Ba/ha).

TRIAL: IP045		**Model I**
Differences between:		**Provenance**
Trait (age):	**F**	**Pr>F**
Ba / tree (7)	**5.16**	**0.001 ***
Ba / tree (17)	**4.66**	**0.001 ***
Ba / ha. (7)	**4.99**	**0.001***
Ba / ha. (17)	**6.14**	**0.001 ***
TRIAL: IP046		**Model I**
Differences between:		**Provenance**
Trait (age):	**F**	**Pr>F**
Ba / tree (7)	0.99	0.455
Ba / tree (17)	1.01	0.438
Ba / ha. (7)	0.38	0.926
Ba / ha. (17)	1.27	0.276
TRIAL: IP047		**Model I**
Differences between:		**Provenance**
Trait (age):	**F**	**Pr>F**
Ba / tree (7)	1.93	0.126
Ba / tree (17)	**7.64**	**0.001 ***
Ba / ha. (7)	1.93	0.126
Ba / ha. (17)	**2.74**	**0.034**

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Table 7.42 ANOCOV for development from first to second assessment.

IP045	**Model I**	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
BA I tree	0.511	0.001
BA I ha	0.224	0.001

IP046	**Model I**	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
BA I tree	0.468	0.001
BA I ha	0.126	0.001

IP047	Model I	
Effect of:	**Provenances**	**Covariate: Age 7 value**
Development of:	**Pr>F**	**Pr>F**
BA I tree	0.001 *	0.001
BA I ha	0.001 *	0.001

Notes: Effects significant at a simple 5%-level are typed in bold. Significant effects of provenances marked with an asterisk are also significant according to the sequential Bonferonni procedure (see section 5.2).

Production - expressed as basal area per hectare - differs significantly at both ages in **IP045**. The correlation between the basal area per ha at age 7 and 17 is high, rp=0.77, rg=0.97, and no significant difference in relative increment were found. The predicted provenances values estimated at age 7 and age 17 are presented in figure 59. The differences are very large compared to differences found in other trials: Provenances from Thailand, and SC3021 from Moist India, have grown slowly compared to especially the Indonesian SC3049. The African SC3044 and the Moist Indian SC3016 have also been fast growing.

The differences in the **average size of trees** - expressed as basal area per tree - were also significant at both age. The differences correspond to the differences in production per ha, but are smaller (figure 60). The differences' in relative increment from age 7 to 17 is nonsignificant, and the correlation between provenance performance at age 7 and 17 is fairly high, rp=0.67, rg=0.73.

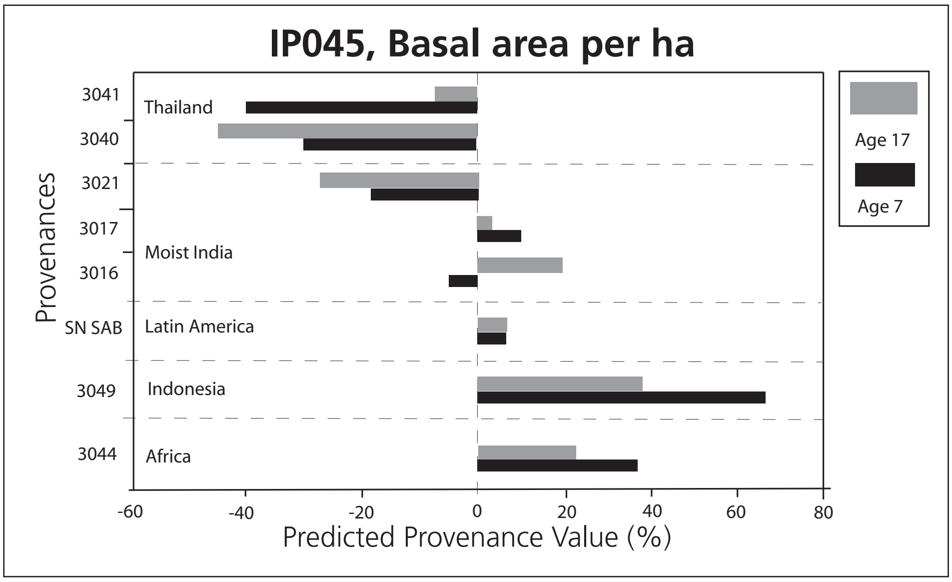

Figure 59. Basal area per ha. in IP045, Rio Abajo, Puerto Rico.

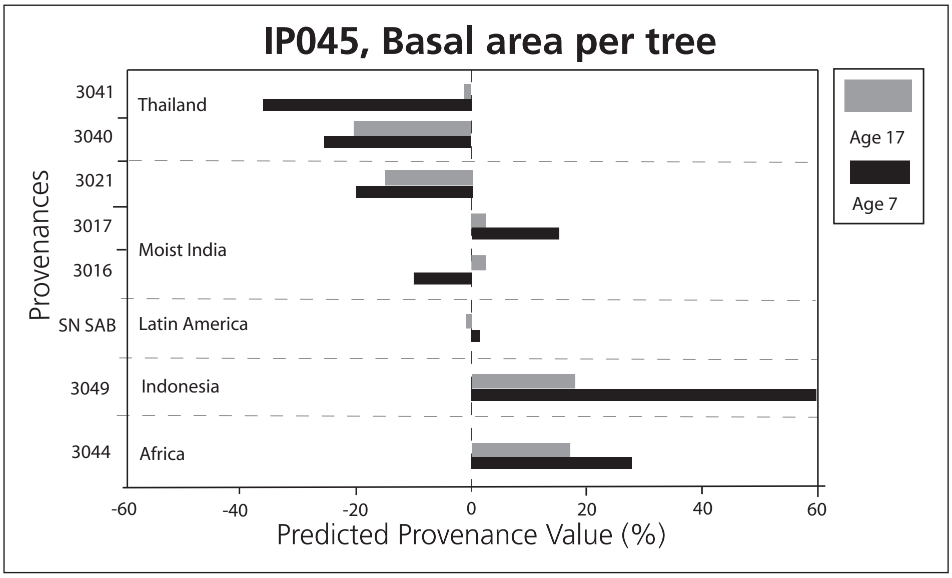

Figure 60. Basal area per tree in IP045, Rio Abajo, Puerto Rico.

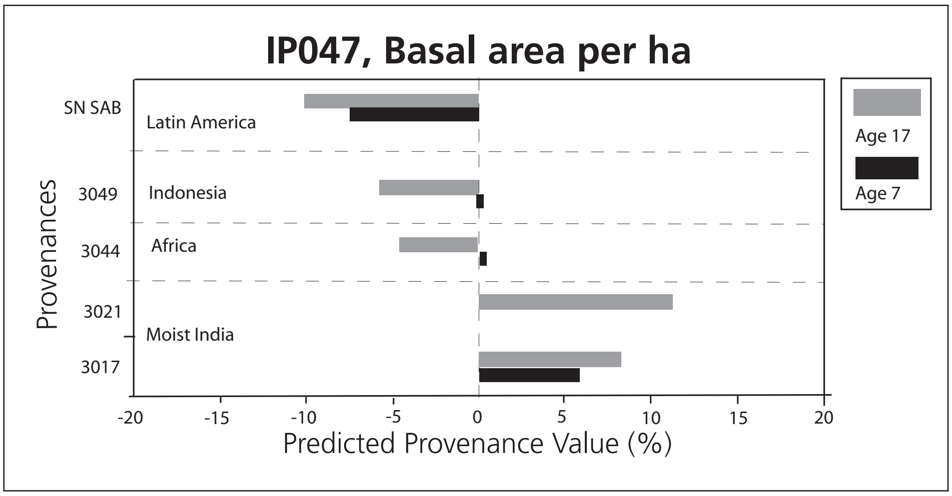

Figure 61. Basal area per ha in IP047, St. Croix, Puerto Rico.

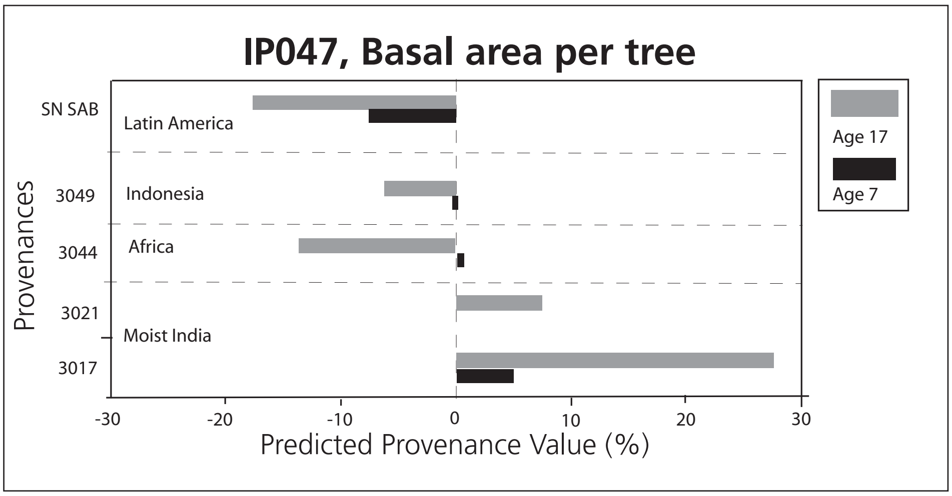

Figure 62. Basal area per tree in IP047, Rio Abajo, Puerto Rico.

Production - expressed as basal area per hectare - differs significantly in **IP047** at age 17. Significant differences were found in the relative increment from age 7 to age 17, and a new development was thus revealed. The correlation between average performance at age 7 and 17 is fair, rp=0.67, rg=0.73. The predicted provenance values are presented in figure 61 for both ages, although the differences are only significant at age 17. The two moist Indian provenances, SC3017 and SC3021, have produced considerably better than the two landraces, SC3044 (Africa) & SN SAB (Latin America) and the Indonesian provenance (SC3049). SN SAB were found to be the poorest at both ages.

The differences in average size of the trees in **IP047** - expressed as **basal area per tree** correspond closely to the differences in production per ha (figure 62). The correlation between performance at age 7 and 17 is a little higher than for IP045, rp=0.79, rg=0.80.

There is highly significant interaction in production between provenances and trials at age 17.

CONCLUSIONS CONCERNING PRODUCTION

The second assessment has revealed an increased provenance variation in productivity compared to age 7, but the ranking already found at age 7 in general holds. Significant interaction between the two reassessed trials has however been revealed, and it is questionable whether the two trials can be said to belong to the same trial region. The Moist Indian provenances (SC3017 & SC3021) have outgrown the Latin American landrace (SN SAB), the Indonesian provenance (SCJ049) and the African (SC3044) in **IP047**, whereas the opposite picture is found in IP045. The Thai provenance (SC3040) has been the least productive provenance.

7.5.4 General recommendations for trial region Central America

The provenance representation is low at the second assessment because of the loss of an important trial **IP022** (Mexico).

The trials reveal a tendency to lower adaptation of Moist Indian and Thai provenances compared to tested landraces from Africa and Central America. Generally, the adaptation of all the provenances does however seem acceptable.

It has generally been possible to observe larger differences in stem quality at the second assessment than at the first. The results from the two trials are very different. In one of the trials the provenances from Moist India and Thailand are of better quality than the tested provenance from Indonesia and the African landrace, which corresponds to the findings in the first assessment. In the other trial - with conditions less suitable for teak - the ranking has changed completely. The Moist Indian provenances have experienced a severe reduction in quality, and the African landrace has therefore changed from being of inferior quality to being the provenance of best quality.

Significant interaction between the trials in productivity was found at the second assessment. This interaction could, opposite to the interaction in the quality traits, already be observed at age 7, although the differences between the trials are larger at age 17. The ranking found at age 7 in general holds within each of the two trials.

Based on these results it is difficult to give general recommendations, as the provenance representation is so poor at the second assessment. Future recommendations must therefore to a large extent be based on local experience and the findings from the first assessment (see Keiding *et al.* (1986) for details).

Some deductions can be made based on the second assessment:

The Thai provenance (SC3040) in general still seems less attractive due to below average growth and adaptation. The quality of the Moist Indian provenances may to some extent have been over-estimated at the first assessment, and the very poor quality of the African landrace found in the first assessment may have been under-estimated. The Indonesian provenance (SC3049) together with the Moist Indian provenances still seem a good choice.

8. RESULTS FROM ANALYSIS ACROSS REGIONS

The data from all the eight evaluated trials is analyzed in a joint ANOVA in order to examine the amount of interaction between trial regions (details are given in section 6.2).

The results are presented in table 8.1. The analysis is only performed for age 17.
Table 8.1 Analysis across all trials at age 17

	TRIAL-REGION		**TRIAL**		**PROV.REGION**		**TRIAL.REG.*PROV.REG.**	
Trait	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**	**F**	**Pr>F**
Surviva1	4.22	0.093	**11.29**	**0.001**	**2.83**	**0.007**	1.49	0.118
Health	0.26	0.849	**60.53**	**0.001**	**5.04**	**0.001**	**2.62**	**0.002**
Persistence	0.72	0.589	**33.20**	**0.001**	**0.47**	**0.859**	**3.80**	**0.001**
Stemform	0.44	0.737	**20.96**	**0.001**	**3.98**	**0.001**	1.20	0.278
Epicorrnics	**7.05**	**0.046**	**18.08**	**0.001**	**6.55**	**0.001**	**3.05**	**0.001**
Protub.Buds	**8.16**	**0.030**	**11.88**	**0.001**	**5.28**	**0.001**	**2.38**	**0.004**
Buttressing	**30.36**	**0.001**	**38.64**	**0.001**	**3.66**	**0.007**	3.01	0.001
Branch size	5.37	0.077	**8.01**	**0.001**	**4.91**	**0.001**	1.12	0.341
Ba Itree	4.14	0.098	**32.27**	**0.001**	**5.22**	**0.001**	**3.90**	**0.001**
Ba /ha	4.02	0.105	**44.82**	**0.001**	**3.52**	**0.001**	**2.83**	**0.001**

The ANOVA across the trial regions c1early reveals significant interaction between trial region and provenance region for all traits but stemform, branch size and survival.

The significant interactions suggest that it is only possible to recommend provenance regions separately for each trial region.

Significant interaction can occur if the size of the provenance differences is significantly different in the different trial regions - even if the ranking is the same in all regions. It is therefore valuable to accompany the test with a graphical presentation. The average values of each provenance region in each trial region are therefore estimated and presented in figures 63-72. The values here are estimated averages for each provenance region in each trial region (not reduced with provenance heritabilities).

The purpose of the figures is mainly to describe the nature of the interaction. The results presented in section 7 have shown that the variance between provenances in many situations cannot be described as simple differences between provenance regions. With this serious limitation - and recalling the unbalanced nature of the worldwide analysis - some interesting trends can be seen.

Important interaction - in terms of serious change in rank - is for example seen in persistence at age 17 (figure 65). The Moist Indian provenances are on the average poor performers in South East Asia (Thailand) and Brazil, but the best in the Latin American and Ghanian trials.

The interaction found for growth at age 17 is also important (figures 71-72). Provenances of Moist Indian origin are superior in Brazil and West Africa (semi moist - dry), but les s productive in South East Asia (Thailand) and Latin America. The Indonesian provenances seem to be productive everywhere.

The general conclusion is therefore that the provenances still perform so differently in the different trial regions that it is not possible to recommend any one »universal« provenance for use in all trial regions.

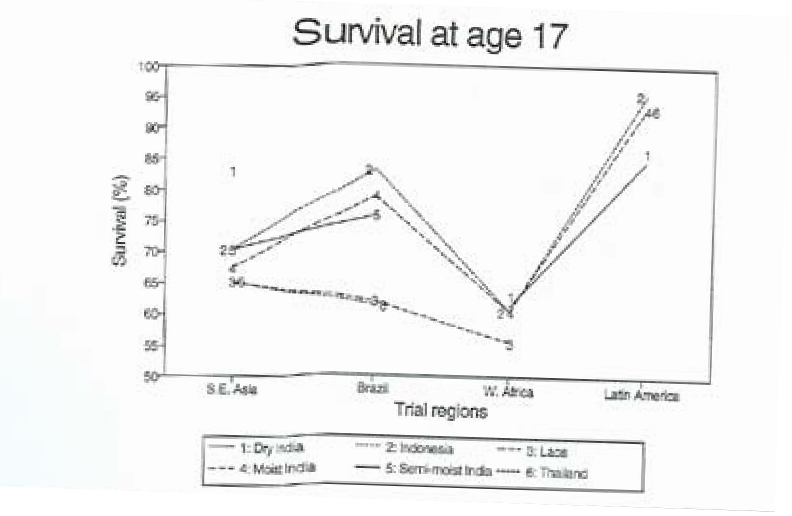

Figure 63. Survival at age 17.

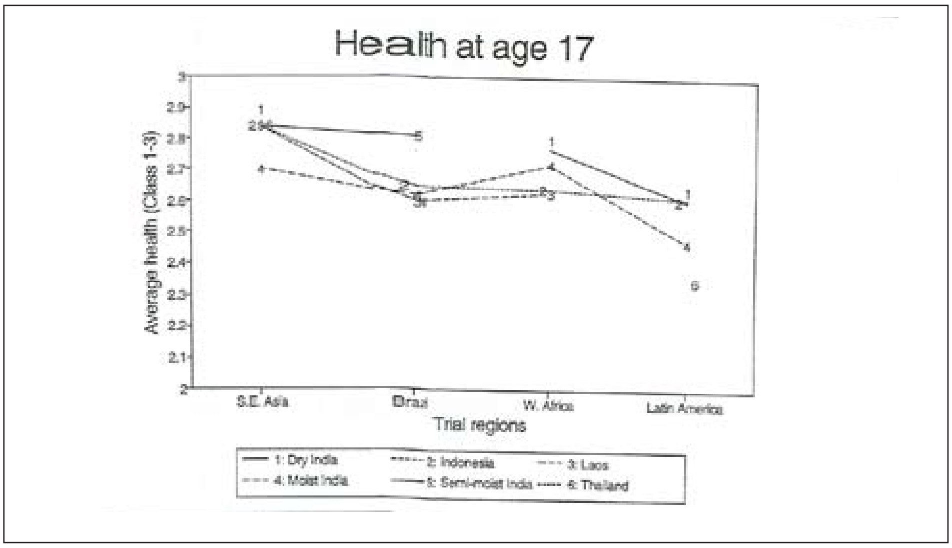

Figure 64. Health at age 17.

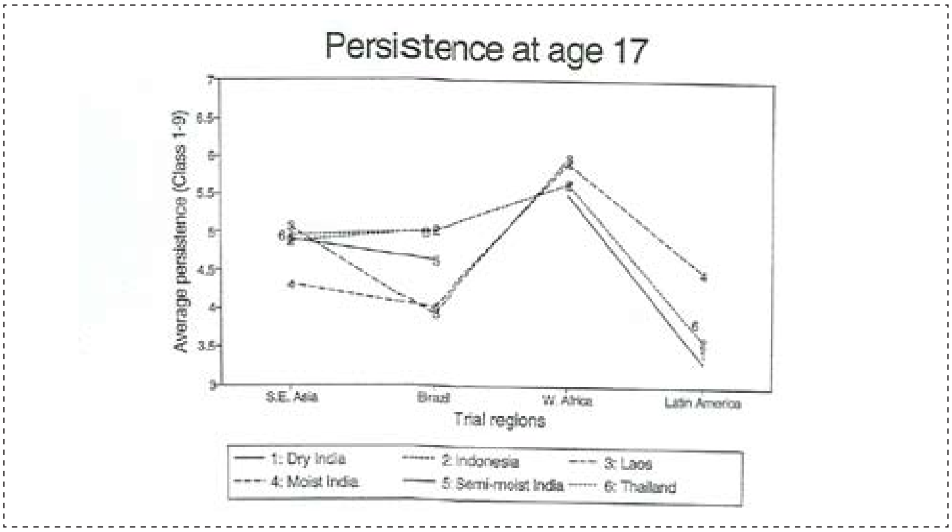

Figure 65. Persistence at age 17.

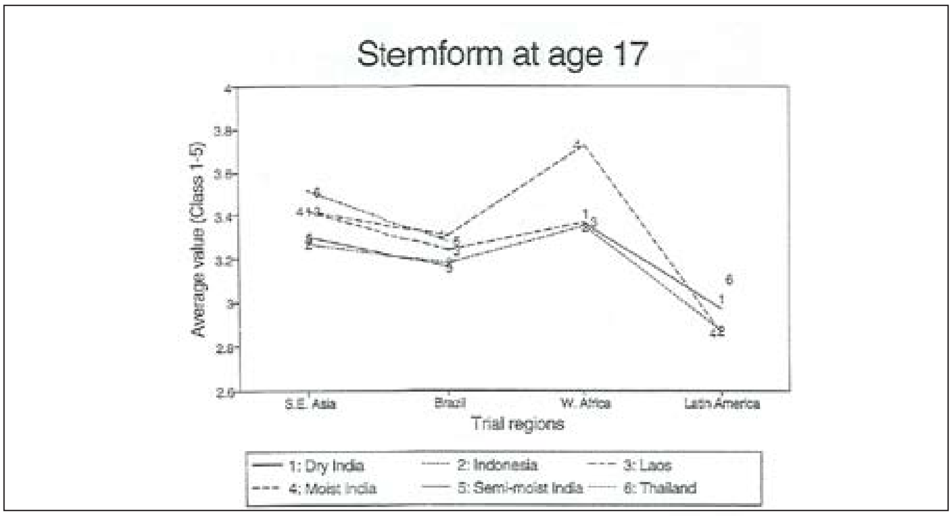

Figure 66. Stemform at age 17.

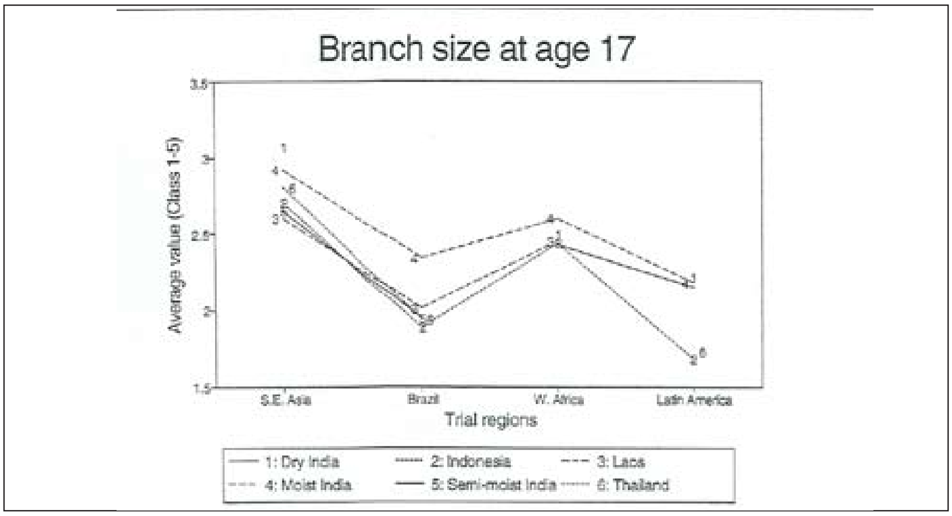

Figure 67. Branch size at age 17.

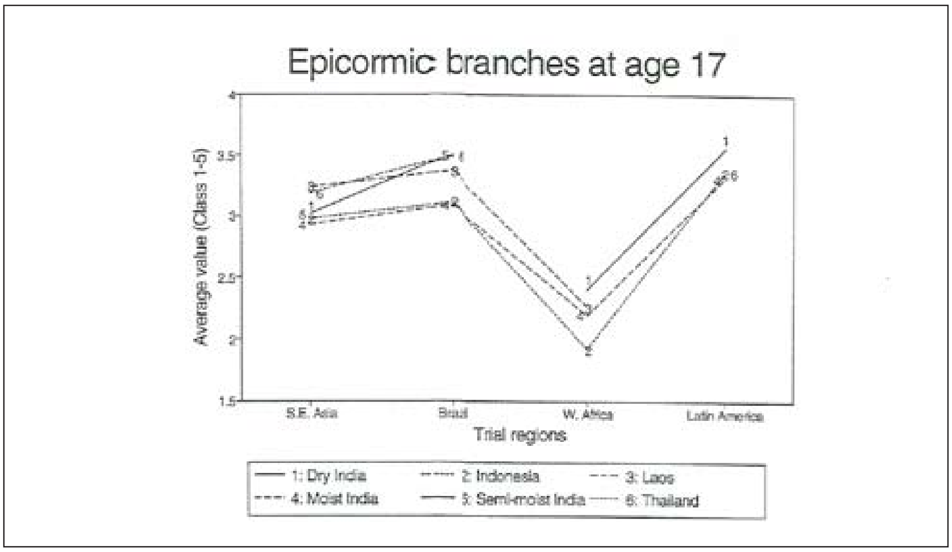

Figure 68. Epicormic branches at age 17.

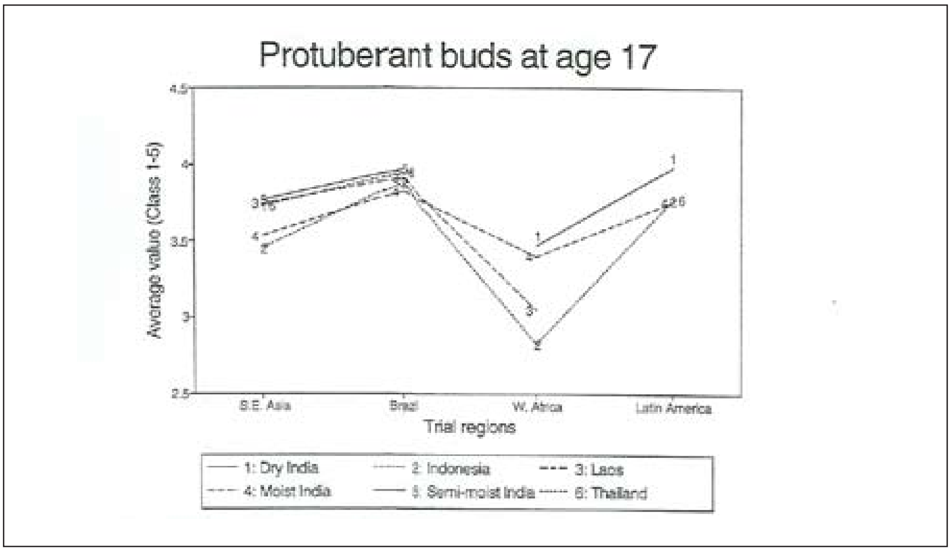

Figure 69. Protuberant buds at age 17.

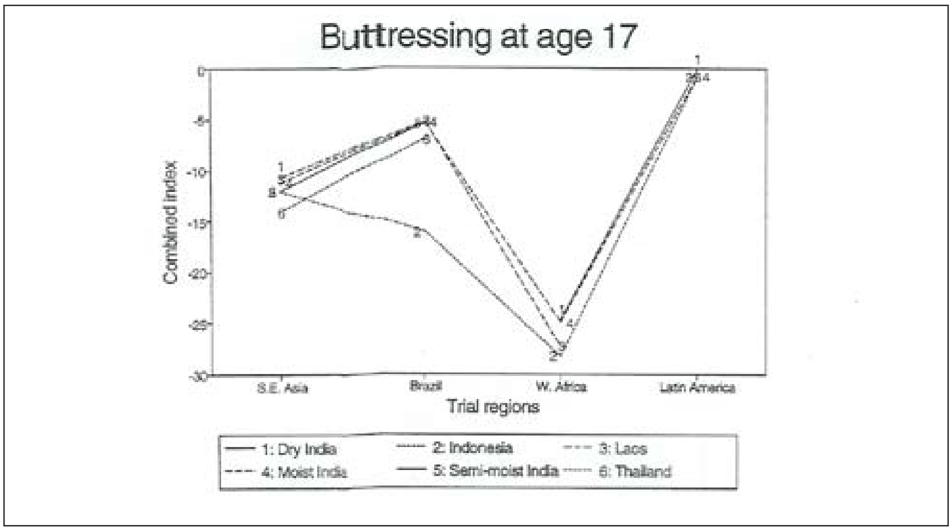

Figure 70. Buttressing at age 17.

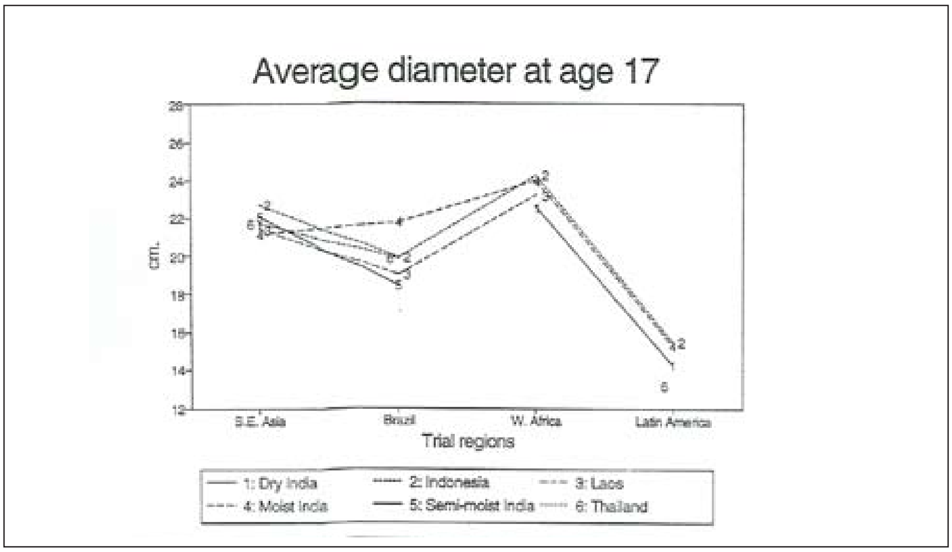

Figure 71. Average diameter at age 17.

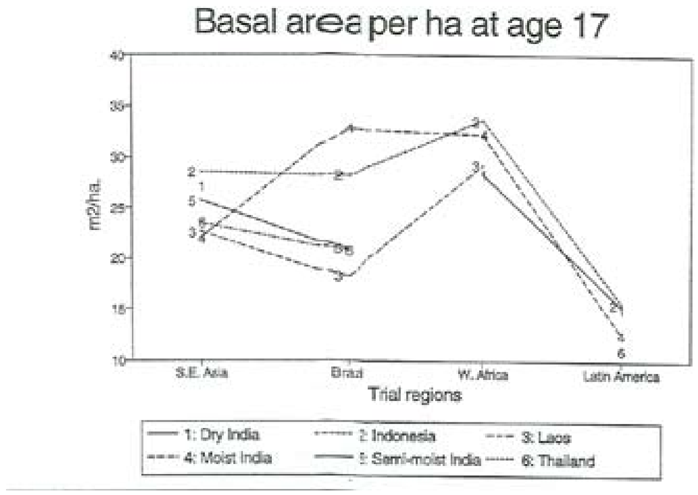

Figure 72. Basal area per ha at age 17.

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