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INFESTATION LEVEL OF THE EUROPEAN PINE SHOOT MOTH

(Rhyacionia buoliana Schiff.)

ON SOME PROVENANCES OF LODGEPOLE PINE

(Pinus contorta Loud.)

ANGREB AF FYRREVIKLEREN I NOGLE PROVENIENSFORSØG MED CONTORTAFYR

BY

PETER ESBJERG AND LARS FEILBERG

During about 150 years the damage caused by the European Pine Shoot Moth (Rhyacionia buoliana Schiff.) has given rise to comments in Danish literature on forestry. This pest attacks Scots Pine (*Pinus sylvestris L.*), Mountain Pine (*Pinus Mugo Turra.*), Austrian Pine (*Pinus nigra Arnold*), and Lodgepole Pine (*Pinus contorta Loud.*) *Butovitch* (1936), *Esbjerg* (1969) — in other words all the more important species of pine found in Danish forestry. *Pinus contorta* has, however, suffered in particular from severe attacks. The steadily increasing use of this tree species on light soils — especially in western Jutland — made it desirable that further studies should be made of the European Pine Shoot Moth.

The special preference which the Pine Shoot Moth shows for *Pinus contorta* may be illustrated by some countings of attacks from 1966 in Sonnerup Skov (Odsherred state forest district). (Table 1).

Table 1.

Comparisons of Pine Shoot Moth infestation in a mixed pine stand 6 years after planting. The stand consists of 70 % *Pinus contorta*, and 30 % *Pinus sylvestris* and *Pinus nigra*. Tree height 1.5—3 m, (mainly 2—2.5 m). All trees in 4 out of the 34 rows present were examined.

Optalte fyrreviklerangreb i blandet fyrrekultur 6 år efter plantning. Kulturen består af 70 % Pinus contorta og 30 % Pinus sylvestris og Pinus nigra. Trærnes højde var 1,5—3 m (overvejende 2—2,5 m). Alle træer i 4 ud af 34 rækker blev undersøgt.

Row No. *Række nr.*	Number of trees per row *Antal træer pr. række*						
	Pinus contorta		*Pinus nigra*		*Pinus sylvestris*		
	infested *angrebne*	not infested *ikke angrebne*	infested *angrebne*	not infested *ikke angrebne*	infested *angrebne*	not infested *ikke angrebne*	total *ialt*
4	5	8	0	5	0	4	22
8	17	31	0	16	1	5	70
12	14	18	0	10	0	4	46
16	12	8	0	14	0	3	37
total *ialt*	48	65	0	45	1	16	175

Of 62 trees of *Pinus nigra* and *Pinus sylvestris* examined, only one tree was infested (1.6 %). Of 113 *Pinus contorta* examined 48 were infested (42.5 %).

The natural range of *Pinus contorta* is rather wide both with regard to climate, geography and soil conditions. A correspondingly large number of provenances are under cultivation.

As regards the conditions in NW-Europe the interest is focused on the northern part of the natural range of *Pinus contorta*. Here two groups of provenances are recognized 1) coastal types and 2) inland types, *Jeffers* and *Muir Black* (1963), *Chritchfield* (1957). In Denmark mainly the coastal types have come into use. Respecting their value to forestry the most relevant characteristics are their more rapid growth but coarser form in comparison to the inland types.

The contorta stem is often heavily deformed as a result of attacks by the Pine Shoot Moth while the trees are still young. It is the generally accepted view among foresters that this applies to a greater extent to the coastal type than to the inland type.

The provenance trials on, *Pinus contorta,* of the Danish Forest Experiment Station (H): B.No.23, have given the opportunity for a quantitative study of the relation between provenances and Pine Shoot Moth damage.

Such a study has been carried out at the Zoological Institute, Royal Veterinary and Agricultural University (supported by the Danish State Research Foundation). The results are given below.

MATERIAL AND METHODOLOGY

The study is based on provenance trials on *Pinus contorta*. These experiments were established in 1960, and are thoroughly described by *Løfting* (1966). The present study is based on countings of the trees infested by Rhyacionia buoliana in the following 5 provenances:

Coastal types:	Long Beach
	Klosterheden
Inland types:	Cascadia
	Manning Park
	Stuart Lake

The countings have taken place at the 4 localities mentioned in table 2. The provenances occur in a block design with 3 replications and 1 plot containing single rows of all the provenances

used *Løfting* (1966). The replications but not the single row plot are included in the counting. *Feilberg* (LF) has examined each tree in every second row, while *Esbjerg* (PE) has examined every third tree in each row.

Table 2.
Year and locality of the countings.
År og lokaliteter for optællinger.

	Silkeborg Nordskov	Vejers Plt.	Valskov Plt.	Klosterheden Plt.
1965	LF	LF	LF	LF
1966	LF	LF	LF	PE
1967	—	—	PE	PE
1968	—	—	PE	PE

The countings have taken place in June-July when the infestations can be recognized with certainty.

The figures from 1965 and 66 include the number of infested trees irrespective of the place of infestation. In 1967 and 68 only trees with infestation in the terminal shoot, and first and second whorl are counted (figure 1) because the infestations almost exclusively occur in this part of the tree.

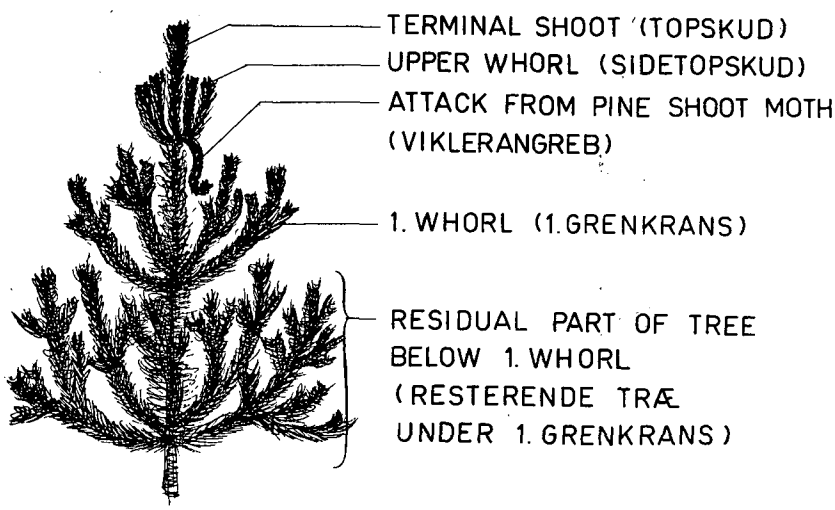


Fig. 1. Tree divided in regions for investigation.
Inddeling af træ i regioner til undersøgelse.

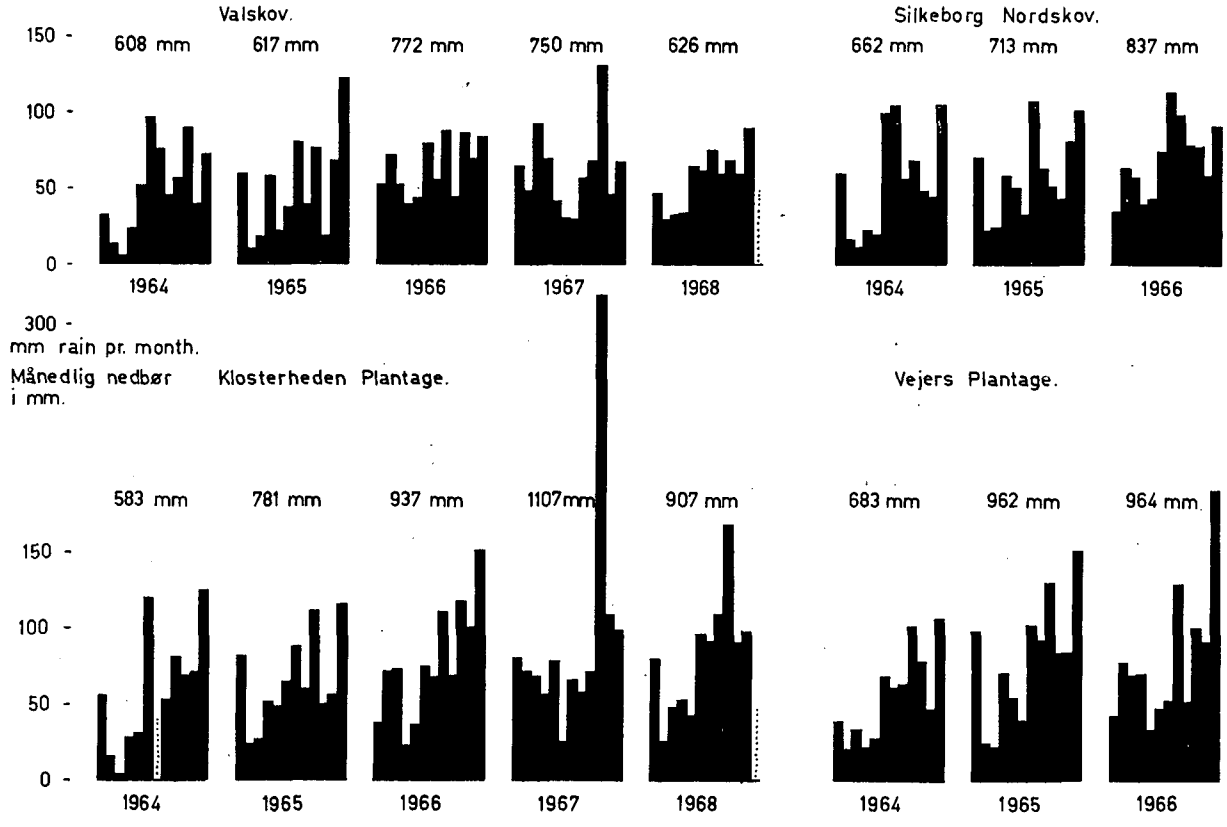


Fig. 2. Diagrams showing monthly precipitation in mm on research localities.
Diagrammer over månedlig nedbør på forsøgslokaliteterne.

DESCRIPTION OF THE PROVENANCE TRIALS

A description of the soil of the 4 localities is seen from establishment reports of the Danish Forest Experiment Station. The trial at Vejers is established on a fairly level drift sand area, the other 3 on more or less podsolated heath sand. The trial at Klosterheden seems to be the most uniform as regards terrain and soil.

The trial at Vejers has suffered from growing under nurses of mountain pine, which were removed in 1966.

The trial at Silkeborg Nordskov is situated in a rather irregular terrain with some frost threatened hollows at the North end.

As regards the Valskov trial there are differences obvious in the soil and also some variation of the terrain.

Figure 2 and 3 give an impression of the climate of the 4 localities by showing the monthly average temperature and precipitation. The figures were taken from the local stations of the Meteorological Institute. With regard to 3 of the localities the

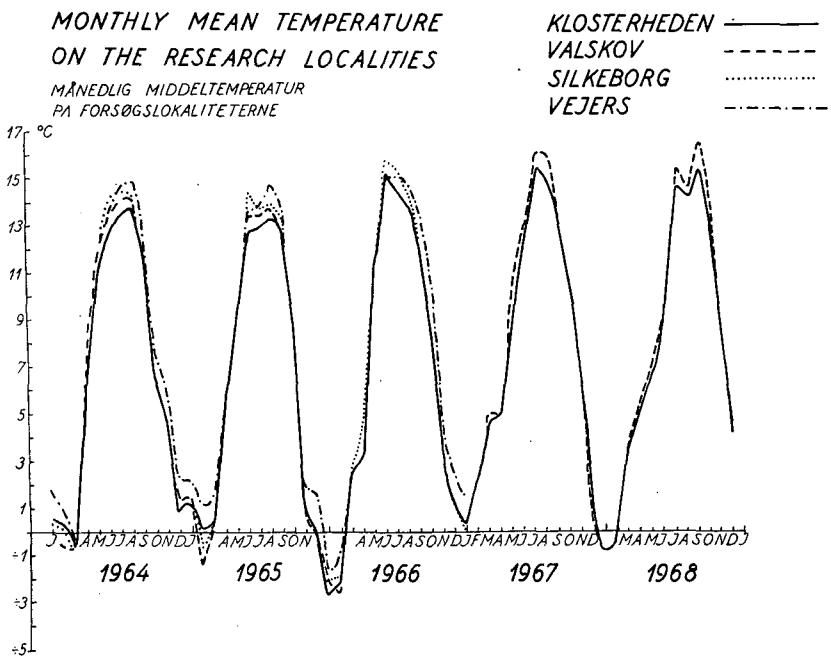


Fig. 3. Monthly meantemperature on research localities.
Månedlige middeltemperaturer på forsøgslokaliteterne.

stations are situated within a distance of a few kilometres from the trials. At the fourth, Valskov, the station is situated at Avning (about 16 kilometres away). The figures from Silkeborg Nordskov must be used with some caution in view of the above mentioned occurrence of frost hollows.

Table 3.
Result of Countings.
Optællingsresultater.

A is the number of trees examined (comprising the 3 replications).
A er antallet af undersøgte træer i alle tre gentagelser.
B is the number of infested trees.
B er antallet af angrebne træer.
$C = \frac{B \times 100}{A}$ %.

Locality *Lokalitet*		Silkeborg Nordskov		Vejers Plt.		Valskov Plt.				Klosterheden Plt.			
Year *År*		1965	1966	1965	1966	1965	1966	1967	1968	1965	1966	1967	1968
Series No. *Serie Nr.*		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Stuart Lake	A	275	238	306	296	240	246	141	173	499	345	353	351
	B	9	15	22	5	13	45	18	29	22	21	21	87
	C	3.3	6.3	7.2	1.7	5.4	18.3	12.8	16.8	4.4	6.1	6.0	24.8
Cascadia	A	—	231	199	206	250	256	176	173	497	345	334	341
	B	—	15	9	5	5	43	15	34	35	37	36	79
	C	9.6	6.5	4.5	2.4	2.0	16.8	8.5	19.7	7.0	10.7	10.8	23.2
Manning Park	A	—	300	223	218	275	247	172	189	508	—	342	339
	B	—	38	13	6	15	59	31	36	51	—	45	106
	C	11.5	12.7	5.8	2.8	5.5	23.9	18.0	19.0	10.0	11.8	13.2	31.3
Long Beach	A	201	193	303	303	217	224	146	160	482	805	345	350
	B	20	63	26	32	28	61	13	37	110	89	29	97
	C	10.0	32.6	8.6	10.6	12.9	27.2	8.9	23.1	22.8	11.1	8.4	27.7
Klosterheden	A	257	208	255	280	249	228	165	206	489	805	345	350
	B	31	57	16	32	20	93	23	31	154	77	40	91
	C	12.1	27.4	6.3	11.4	8.0	40.8	13.9	15.0	31.5	9.6	11.6	26.0

NB. A few countings are missing in series no. I and X, and here the percentage of infestation is therefore calculated from the mean of the vertical and horizontal means at the place in question in the table.
Enkelte tællinger mangler i serierne I og X. De hertil svarende angrebsprocenter er beregnet som gennemsnit af horisontale og vertikale gennemsnit for de pågældende lokaliteter og år.

EXPERIMENTAL RESULTS

The result of the countings of infestations appears in table 3.

Already from Series No. II it appears that there are important differences between the provenances as regards the level of attacks caused by Rhyacionia buoliana. The table shows, however, that in some cases there are also wide variations found both within each year and within each locality. This is illustrated in figure 4 and 5, which are diagrams of the C's of table 3.

A further investigation of the variation between provenances, which seems to appear from figure 4 and 5, is given in the analysis of variance (table 4). The series numbers refer to those mentioned in table 3.

Moreover it should be noticed that the observations do not strictly comply with the normal distribution of observations required for an analysis of variance. The analysis does, however, give a strong indication of the relative position of the provenances as regards the infestation caused by Rhyacionia buoliana.

The observations used in the analysis of variance are the infestation percentages (C) from table 3.

The analysis indicates a considerable interaction between trials and provenances; but in spite of this the difference between the infestations of the 5 provenances is significant.

A subdivision of the analysis of variance (shown with dotted line in table 4) proved the differences between provenances to be especially great when the infestations were heavy.

A special economic interest is connected with the stem form. Therefore the number of trees with infestations in the terminal shoot or in one or more shoots of the upper whorl (compare figure 1) is calculated as a percentage of all infested trees. The result is shown in table 5.

Experience while counting showed that a very high percentage of the trees with infestations somewhere either in the terminal shoot or the first whorl were in fact infested within the terminal shoot itself. When this information is related to the percentages of infestation in either the first whorl or the terminal shoot

Table 4.

Analysis of variance on the infestation percentages (C) from table 3.
Variansanalyse af angrebsprocenterne (C) i tabel 3.

Series No. *Serie Nr.*	Provenances *Provenienser* Stuart Lake	Cascadia	Manning Park	Long Beach	Kloster-heden	Sum of Series *Sum af serie*
IV	1.7	2.4	2.8	10.6	11.4	28.9
III	7.2	4.5	5.8	8.6	6.3	32.4
V	5.4	2.0	5.5	12.9	8.0	33.8
XI	6.0	10.8	13.2	8.4	11.6	50.0
VII	12.8	8.5	18.0	8.9	13.9	62.1
IX	4.4	7.0	10.0	22.8	31.5	75.7
II	6.3	6.5	12.7	32.6	27.4	85.5
VIII	16.8	19.7	19.0	23.1	15.0	93.6
VI	18.3	16.8	23.9	27.2	40.8	127.0
XII	24.8	23.2	31.3	27.7	26.0	133.0
Sum of all Series *Sum af alle serier*	103.7	101.4	142.2	182.8	191.9	722.0

From the information given above we may compute:

(SS. = sum of squares
f = degrees of freedom
n = number of observations).

$S^2 : n = 722.0^2 : 50 = 10425.7$

1) S.S.(total) $= (1.7^2 \ldots . + 26.0^2) - 10425.7$
$= 4407.0$

2) S.S.(provenances) $= (103.7^2 \ldots . + 191.9^2) : 10 - 10425.7$
$= 724.1$

3) S.S.(series) $= (28.9^2 \ldots . + 133.0^2) : 5 - 10425.7$
$= 2575.0$

4) S.S.(residual) = S.S.(total) — S.S.(provenances) — S.S.(series)
$= 1107.9$

Variation	S.S.	f	s^2	F	P.100
1) Total *Ialt*	4407.0	49	—	—	—
2) Between provenances *Mellem provenienser*	724.1	4	181.0	5.9	99
3) Between series *Mellem serier*	2575.0	9	286.1	9.3	99.9
4) Residual *Restvariation*	1107.9	36	30.8	—	—

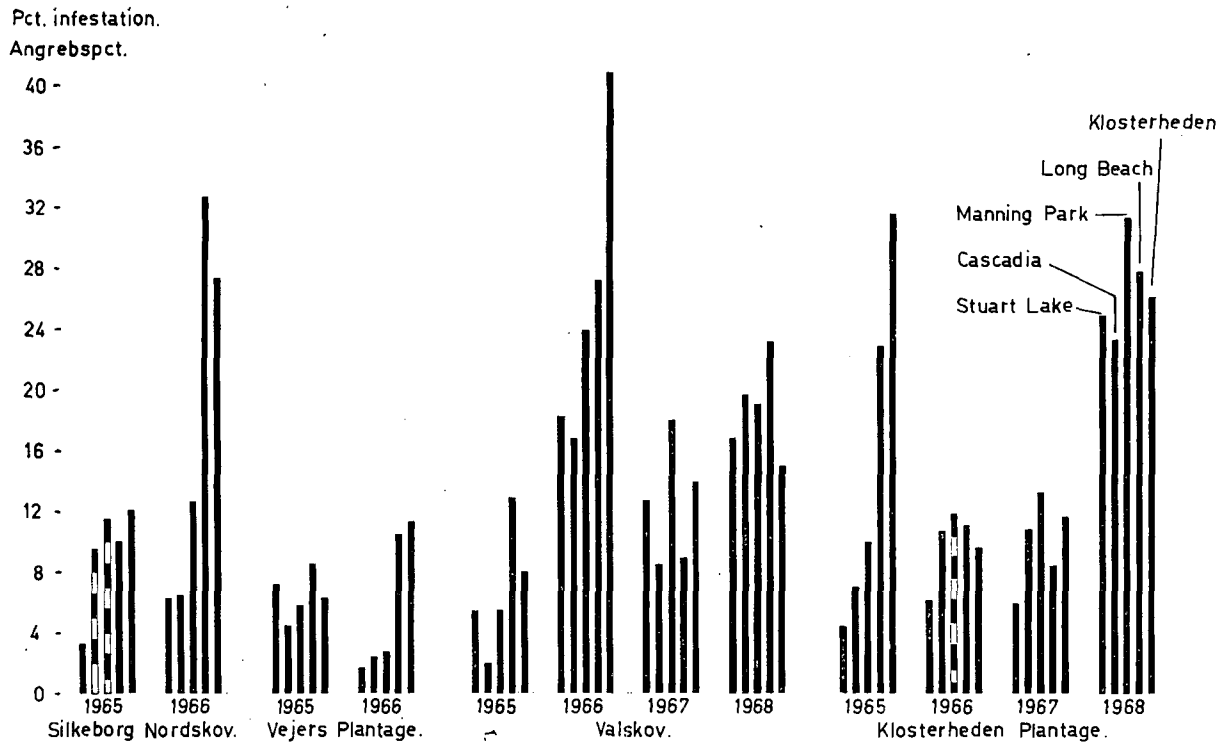


Fig. 4. Percent infested trees (as table 1.) in the investigated provenances grouped in localities.
Angrebsprocenter (jvfr. tabel 1.) på de undersøgte provenienser grupperet efter lokaliteter.

Table 5.
Trees with infestations in the terminal shoot and the upper whorl as a percentage of the total number of infested trees.
Træer med angreb i topskud og sidetopskud i procent af det samlede antal angrebne træer.

Stuart Lake	45.2 %
Cascadia	55.7 %
Manning Park	52.4 %
Long Beach	46.0 %
Klosterheden	47.9 %

(table 5) it is seen that about 50 % of all infested trees are also infested in the terminal shoot itself. This does not, however, imply that the percentage of permanent stem deformations is also 50, as some of the trees outgrow the injury. Also the possibility of a varying ability of regeneration within the different provenances should not be excluded.

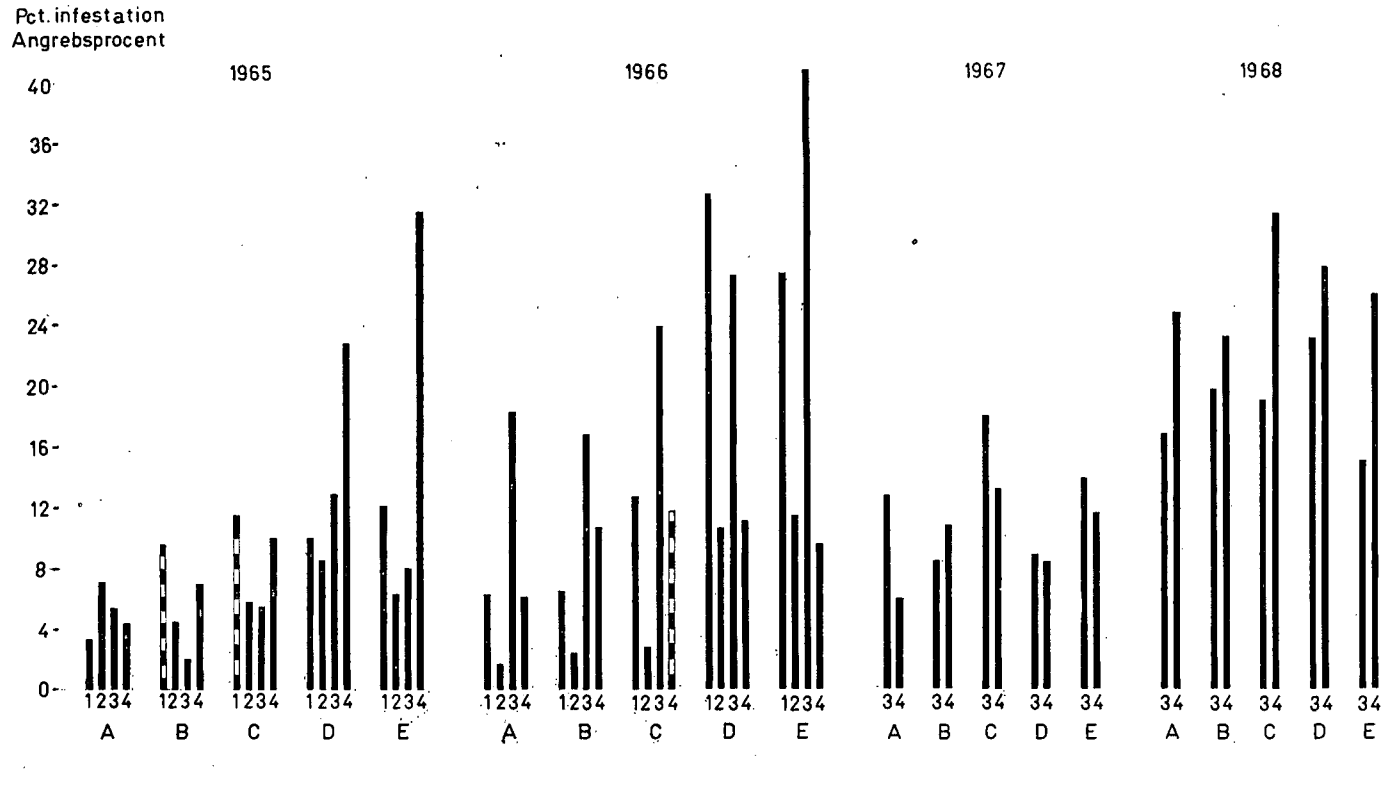
It has not been investigated whether there is a correlation between tree height and percentage of infested trees or between tree height and population density of Rhyacionia bouliana. As regards infestations by Rhyacionia bouliana on *Pinus sylvestris* the last mentioned correlation has been found in Belgium, *Nef* (1966). The possible existence of the first mentioned correlation is indicated by the relation between tree age and percentage of infested trees found in Sweden, *Butovitsch* (1936).

It is not out of the question that the differences found between *Pinus contorta* provenances with regard to infestation by Rhyacionia bouliana are primarily due to variations in tree height. The range of material in the present investigation is, however, not sufficient to answer this question.

Fig. 5. Percent infested trees (as in table 1.) in the investigated provenances grouped in years.
Angrebsprocenter (jvfr. tabel 1.) på de undersøgte provenienser grupperet efter år.

A = Stuart Lake
B = Cascadia
C = Manning Park
D = Long Beach
E = Klosterheden

1 = Silkeborg Nordskov
2 = Vejers Plantage
3 = Valskov Plantage
4 = Klosterheden Plantage


Pct. infestation
Angrebsprocent
1965
1966
1967
1968
40
36
32
28
24
20
16
12
8
4
0
1234 A
1234 B
1234 C
1234 D
1234 E
1234 A
1234 B
1234 C
1234 D
1234 E
34 A
34 B
34 C
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34 A
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34 C
34 D
34 E

DISCUSSION

The result of this investigation supports the view that differences in the intensity of Rhyacionia bouliana infestation occur between provenances. These differences are especially marked in years with heavy infestations.

The differences found in intensity of infestation may be caused by favourable or unfavourable conditions for the trees or for the insects or, most likely, by a combination of both.

The considerable residual variation of the analysis of variance may indicate an interaction between provenances and environment in relation to infestation by Rhyacionia bouliana.

It is unfortunate for Danish forestry that the slow growing inland provenances are the more resistant to infestation by Rhyacionia bouliana. This might recommend their use as partners for hybridization between provenances.

On account of the economic interests involved it would be advisable after some years to re-examine the provenance trials with special regard to permanent stem deformations.

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SUMMARY

In Danish provenance trials with *Pinus contorta* there were 5 provenances, repeated in 4 localities, which were investigated for infestations of Rhyacionia bouliana Schiff.. The trials contain 3 randomized blocks in each locality.

33—50 % of the trees in all blocks were counted.

Table 2 gives the names of the localities, the initials of the investigator and the years of investigation.

The result of the counting is found in table 3 and in the diagram (figure 5).

An analysis of variance (table 4) showed significant differences between provenances and between (locality + year). A considerable residual variation suggests the presence of an interaction between provenance and (locality + year).

It was found that the leader was attacked in appr. 50 % of the infested trees.

The level of infestation was found to be higher in the coastal than in the inland provenances. Unfortunately the inland *Pinus contorta* has a rather low production level in Denmark, and therefore the idea of provenance hybrids is suggested.

DANSK RESUME

Undersøgelsens grundmateriale er en serie proveniensforsøg med *Pinus contorta* udplantet af Statens Forstlige Forsøgsvæsen i 1960. Angreb af fyrrevikleren, Rhyacionia bouliana, blev optalt i følgende 5 provenienser gentaget på 4 lokaliteter:

Long Beach, Washington, U.S.A.	(Kysttype)
Klosterheden, Danmark.	(—)
Cascadia, Oregon, U.S.A.	(Indlandstype)
Manning Park, B.C., Canada.	(—)
Stuart Lake, B.C., Canada.	(—)

Proveniensforsøget er udlagt med 3 randomiserede blokke på hver lokalitet. 33—50 % af træerne i hver blok er blevet undersøgt. I tabel 2 er anført navnene på de 4 lokaliteter, iagttagerens forbogstaver og iagttagelsesår.

Resultatet af tællingerne fremgår af tabel 3 og figur 4 og 5. Variansanalysen i tabel 4 viser signifikante forskelle mellem provenienser og mellem (lokalitet + år). En betydelig restvariation antyder tilstedeværelsen af vekselvirkninger mellem proveniens og (lokalitet + år).

Hos ca. 50 % af de angrebne træer var topskuddet angrebet.

Der blev fundet en større angrebsprocent hos kystprovenienserne end hos indlandsprovenienserne. De sidste er desværre ret langsomt producerende i Danmark. Muligheden for fremstilling af proveniens-hybrider nævnes.

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