

Investigations into the Resistance of Douglas Fir (*Pseudotsuga menziesii* (Mirb.) Franco) Populations to the Douglas Fir Wolly Aphid (*Gilletteella cooleyi* Gill.)

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Summary

On a Douglas fir provenance experiment established from 1 + 2 stock in 1971 in Kórnik, nr. Poznan, numerous occurrences of the Douglas fir woolly aphid *Gilletteella cooleyi* GILL. were observed in 1976 and mass occurrences in 1977. Assessment of the proportions of severely infested trees in 59 populations showed great variation from nil to 94% infestation and a considerable resistance to this pest was found in trees from populations originating east of the Cascadian Mts. These differences appear to be under genetic control.

Key words: *Pseudotsuga menziesii* (MIRB.) FRANCO., provenance, resistance, *Gilletteella cooleyi* GILL.

Zusammenfassung

Auf der internationalen Douglasien-Provenienzversuchsfläche der IUFRO vom Jahre 1971 mit 1 + 2 Sämlingen, gegründet in Kórnik bei Poznan (Polen), hat man Forschungen über die Widerstandsfähigkeit von 59 Douglasien-Populationen gegen Befall der Douglasien-Wollaus durchgeführt. Aufgrund zweijähriger Observationen (1976—77) hat man festgestellt, daß einige Provenienzen aus dem Terrain der Mitte der Staaten Washington, Oregon und British Columbia viel widerstandsfähiger sind als Bäume von anderen Populationen, welche von der Pazifikküste derselben Staaten stammen. Die Widerstandsfähigkeit der Douglasien gegen Befall durch die Douglasien-Wollaus ist ein genetisches Merkmal.

Introduction

In 1968 a provenance experimental area with Douglas fir was established at the Kórnik Institute of Dendrology of the Polish Academy of Sciences. These were North American provenances 1966 IUFRO collection — Fig. 1. The North American Douglas fir woolly aphid was first observed in the trials in 1974 and spread rapidly.

In view of the fact that a considerable differentiation as to the degree of its attacks on particular populations could be seen, an attempt was made to determine whether the above-mentioned event was the result of varying resistance of those populations to the pest.

Survey of Literature

The Douglas fir woolly aphid (*Gilletteella cooleyi* GILL.) is a two-host aphid of the family Adelgidae in the suborder Homoptera. It made its first appearance in Europe as early as the beginning of the XX-th c. following the introduction of Douglas fir (*Pseudotsuga menziesii* (MIRB.) FRANCO), into forest lands (CHRYSTAL, 1943, MÜLLER, 1941). Sitka spruce, and less commonly the blue spruce (*Picea pungens* ENG.) or ENGELMANN spruce (*P. engelmanni* ENG.), are the alternate hosts of Douglas fir woolly aphid.

The Douglas fir woolly aphid inflicts injuries by sucking this year's and older needles, causing characteristic yellowing and curling. The aphid may also be contributive to infection induced by fungal pathogens that penetrate into needles through the injured parts (JONES, 1967).

CHRYSTAL (1950) and also HEITMÜLLER (1954) gave an account of the occurrence of individual resistance of Douglas

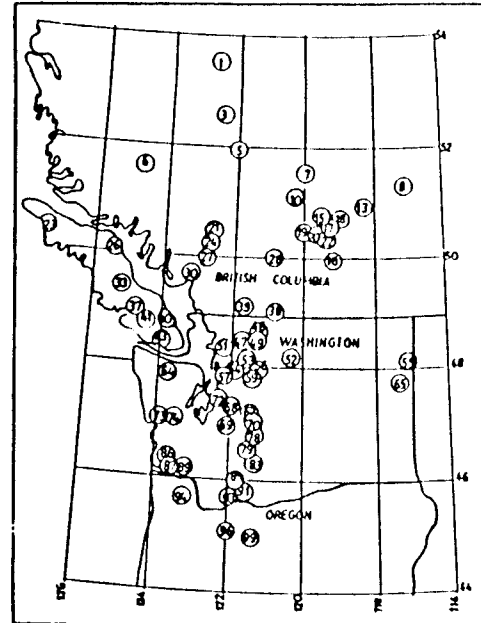


Fig. 1. — Distribution of 59 investigated provenances of Douglas fir in Northern America.

fir to *Gilletteella cooleyi*. LARSEN (1953) as well as PETERSEN and SØEGAARD (1958) established large differences in resistance among several clones of Douglas fir that they had investigated, which suggested a genetic basis of this character.

SCHWENKE (1972) and TEUCHER (1955 a, 1955 b, 1956) report that the *glauca* variety is resistant and *f. viridis* susceptible to the Douglas fir woolly aphid. HEITMÜLLER (1954), on the other hand, thinks that no differences exist among Douglas fir varieties with respect to resistance to this insect.

Plant Material and Methodology

The provenance experiment with Douglas fir was established at Kórnik nr. Poznan in 1968. Of the initial 104 provenances early losses resulted in only 59 being fully represented in 3 blocks.

For our investigations into the degree of resistance of particular populations to *Gilletteella cooleyi*, we took these 59 populations randomly distributed in three blocks. Each population occupied a separate plot of ground, where initially 25 trees grew in a 1.5 × 2.0 m. spacing. The data on height, diameter, number of branches and other characters are presented in the study by MEINARTOWICZ (1976), while the geographical coordinates of the populations are given in BIALOBOK and MEINARTOWICZ's study (1970).

The observations of attacks were carried out at the turn of April in two consecutive years, 1976 and 1977, separately for each tree. Because there were very pronounced differences in the severity of attack on particular trees, only a two-level scale was adopted: 1. attacked tree, and 2. unattacked tree. Trees were considered as unattacked when the pest was found to be totally absent or occurred in in-

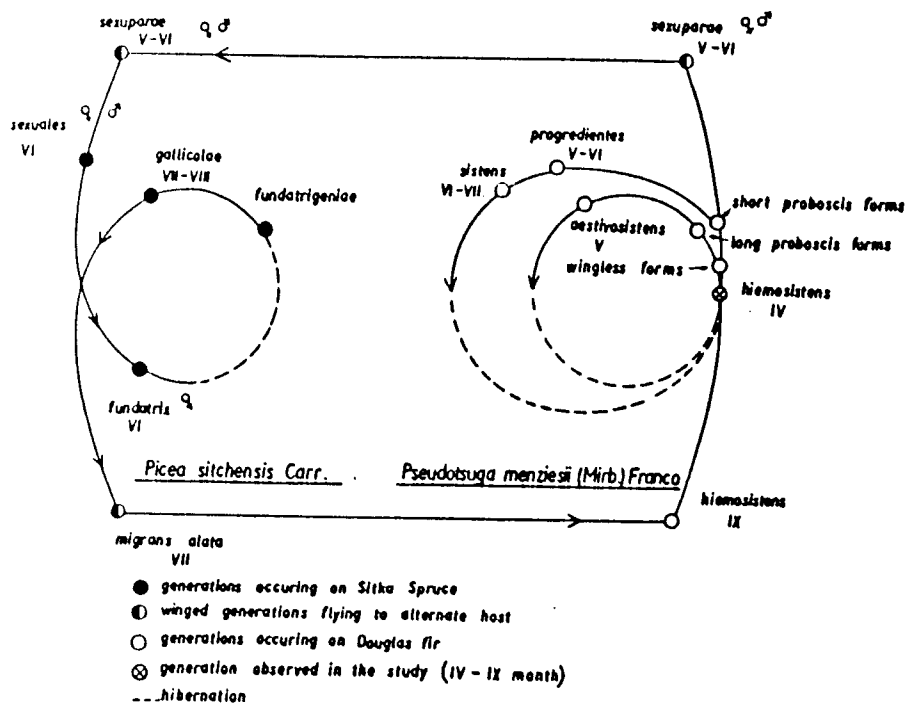


Fig. 2. — Outline of the life cycle of *Gilletteella cooleyi* GILL. (Compiled from SCHWENKE 1972).

significant numbers so that there were no visible foliage injuries.

Those specimens were regarded as attacked on which large numbers of the representatives of hiemastens and aestivalis generations were found causing conspicuous injuries and deformations of needles. The hiemastens generation is the parthenogenetic line hatched from eggs laid by the pest specimens migrans alata that fly over from Sitka spruce or other alternate host. In contrast, the aestivalis generation is also a parthenogenetic line hatched from the eggs laid on Douglas fir by the hiemastens generation. The description of the pest's complex life cycle is presented in fig. 2 following SCHWENKE (1972).

On completing the appraisal of the degree of attack, the number of attacked trees was calculated for each plot of the Douglas-fir populations under investigation in 1976 and 1977. Because some populations had fewer than 25 specimens per plot the obtained data were subsequently transformed to the Freeman's — Tukey values of θ for binomial proportions (MOSLELLER and YOUTZ, 1961). On the θ values analysis of variance and interpretation in terms of the DUNCAN's multiple range test were performed (DUNCAN, 1955).

Results

The results of the analysis as presented in table 1 show that at the 0.001 level of significance there existed differences between Douglas-fir populations in the degree of attack by aphids.

Table 1. — Analysis of variance for the estimate of *Gilletteella cooleyi* attack on 59 Douglas-fir provenances in 1976 and 1977.

Source of Variation	Degrees of freedom	Mean Square	F
Total	353		
Years	1	1777	40.2***
Populations	58	2252	50.9***
Blocks	2	14846	331.3***
Popl. × Blocks	118	383	8.2***
Popl. × Years	58	48	1.0NS
Error	118	44	

*** Statistically significant ($p > 0.999$).

NS Statistically non significant ($p < 0.95$).

Table 2. — Division of 59 investigated Douglas fir populations into homogeneous groups on the basis of Duncan's multiple range test

No	IUFRO No of Populat.	Results of Duncan's test and mean % of attacked trees in 1976-77
1	1003	1,3
2	1001	1,5
3	1005	1,7
4	1055	2,4
5	1008	2,4
6	1010	7,0
7	1020	9,2
8	1006	10,6
9	1007	10,8
10	1028	15,3
11	1017	16,2
12	1015	18,1
13	1052	19,0
14	1019	21,6
15	1018	22,9
16	1022	22,9
17	1016	23,5
18	1065	36,6
19	1046	41,4
20	1099	45,3
21	1013	46,2
22	1083	52,2
23	1089	52,5
24	1021	53,7
25	1068	55,1
26	1023	55,4
27	1030	55,6
28	1027	57,3
29	1078	57,7
30	1037	61,6
31	1024	63,6
32	1043	63,6
33	1084	64,1
34	1033	64,5
35	1069	66,5
36	1091	66,8
37	1064	67,3
38	1040	67,7
39	1074	68,4
40	1059	70,4
41	1073	71,0
42	1049	73,3
43	1070	74,6
44	1039	75,3
45	1087	75,9
46	1093	76,3
47	1067	77,9
48	1086	77,9
49	1051	79,3
50	1056	79,5
51	1094	81,3
52	1072	81,5
53	1041	82,3
54	1096	82,6
55	1079	86,9
56	1026	88,9
57	1038	90,3
58	1047	91,6
59	1053	96,4

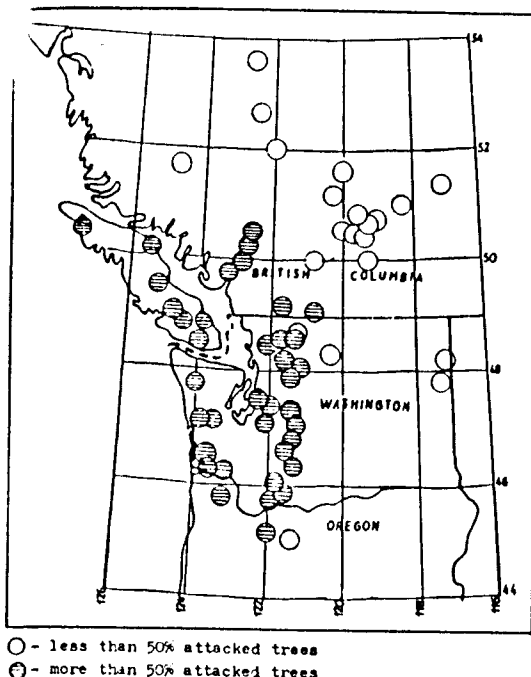


Fig. 3. — Degree of attack of Douglas fir provenances by the Douglas fir woolly aphid.

Very significant differences between blocks and years of observations are probably the result of the fact that the initial infection center was in block I and it is from that block that the invasion spread into the other blocks during the years of observation. When spreading, the aphids attack various populations in successive blocks with relatively similar intensities, thus the population \times years interaction was not significant (Table 1).

Using the DUNCAN multiple range test, we have allocated the populations into 13 internally undifferentiated groups (Table 2). In the first most resistant group there were 17 of the 59 studied populations. They had less than 24% of trees affected by the aphids. All the populations of that group originate from the interior of British Columbia and Washington State. On the other hand the 13th group of most susceptible populations had 60–100% of trees attacked. These were populations from coastal regions of British Columbia, Washington and Oregon. If we should split the studied populations into two groups with either more or less than 50% of trees attacked we obtain a geographical split up as shown in fig. 3, which follows the Cascadian watershed. To the east of that line resistant populations are to be found and west of it susceptible ones.

Discussion

The provenance area with Douglas fir did not see any occurrences of pests or diseases till the trees were seven years old; the only exception being injuries done to their roots by cockchafer grubs (*Melolontha melolontha* L.), which injuries, however, were not associated with Douglas fir's geographical variation (MEINARTOWICZ, 1976).

The occurrence of the Douglas fir woolly aphid was in evidence on several trees when they were six years old. During the next two years the insect made its massive appearance throughout the experimental area. Trees from provenances located in western parts of Oregon and Washington, and in Vancouver Island, were far more affected than those from the interior. Massive appearance of the insect was very much in evidence, among others, on trees

from provenances: 1053-Darrington and 1047-Concrete, which were grouped among the fastest growing ones under conditions existing in western Poland (MEINARTOWICZ, 1976).

The severity of attacks of aphids against particular populations was distinctly modified by environmental conditions, as is evident from the significant interaction between populations and blocks. The observed differences in attacks on trees in particular populations are hereditary, however, since population variance is much greater, as they were for Douglas-fir clones in a prior account (PETERSEN and SØEGAARD, 1958). Populations 1001-Stoner or 1005-Williams Lake from British Columbia which were least attacked were free of the aphid in all blocks, even if they were surrounded by populations whose trees were 100% attacked.

Although varying response of Douglas fir populations to *Gilletteella cooleyi* can surely be considered a proven phenomenon, yet little is known about its mechanism and immediate causes. PETERSEN and SØEGAARD (1958) asserted that despite the presence of the pest's larvae on some trees the aphid could not have persisted on them. These authors considered that the event they have described was presumably caused by certain anatomical characters of the needles. Another reason why plants can be resistant to insects might be the presence of certain chemical compounds, e.g. phenols, in their assimilating organs which are responsible for the fact that a given plant is not attractive food for an insect (LUNDERSTÄDT, 1976).

Differential response of Douglas fir to the pest under discussion may also be conditioned by physical factors, such as, e.g. exposure to light of the tree crown.

The populations which on investigation proved to be resistant to the pest were in the majority of cases derived from eastern or northern regions. In the light of previous investigations (MEINARTOWICZ, 1976), these populations are characterized by relatively more slender crowns and a smaller number of first-order branches in comparison with the coastal populations. The characters just mentioned render possible a greater light penetration into the crown interior, which in turn may be a cause of a more occurrence of the pest on trees from such populations.

Conclusions

The investigations we have carried out demonstrate in effect that there are substantial differences in the resistance of particular Douglas fir populations to attacks to the Douglas fir woolly aphid. The most resistant populations proved to be those from the eastern parts of Washington, Oregon and British Columbia.

The resistance of some Douglas fir populations to aphid attacks seems to have a genetic basis.

Since to Douglas fir woolly aphid first occurs in small numbers at one or several spots on a plantation and makes its massive appearance all over the place two years later, attention should therefore be directed to early detection and control of the foci of its occurrence with suitable insecticides.

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