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

By L. E. MEJNARTOWICZ and A. SZMIDT

Institute of Dendrology, Polish Academy of Sciences
Kórnik, Poland

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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 Columbien 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 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.

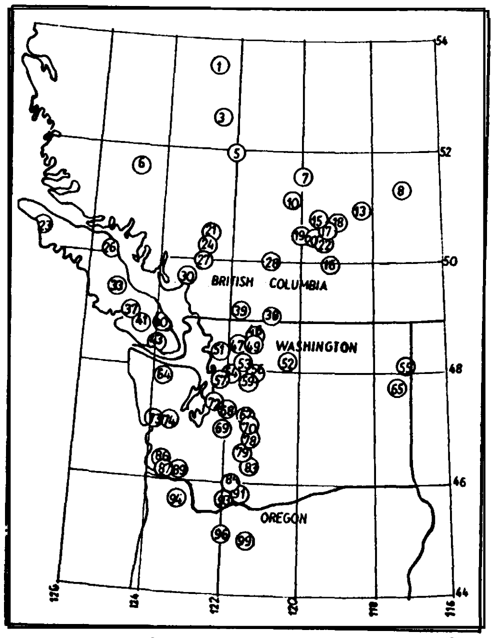


Fig. 1. — Distribution of 59 investigated provenances of Douglas fir in Northern America.

SCHWENKE (1972) and TEUCHER (1955a, 1955b, 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 X 2.0 m. spacing. The data on height, diameter, number of branches and other characters are presented in the study by MEJNARTOWICZ (1976), while the geographical coordinates of the populations are given in BIALOBOK and MEJNARTOWICZ'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-

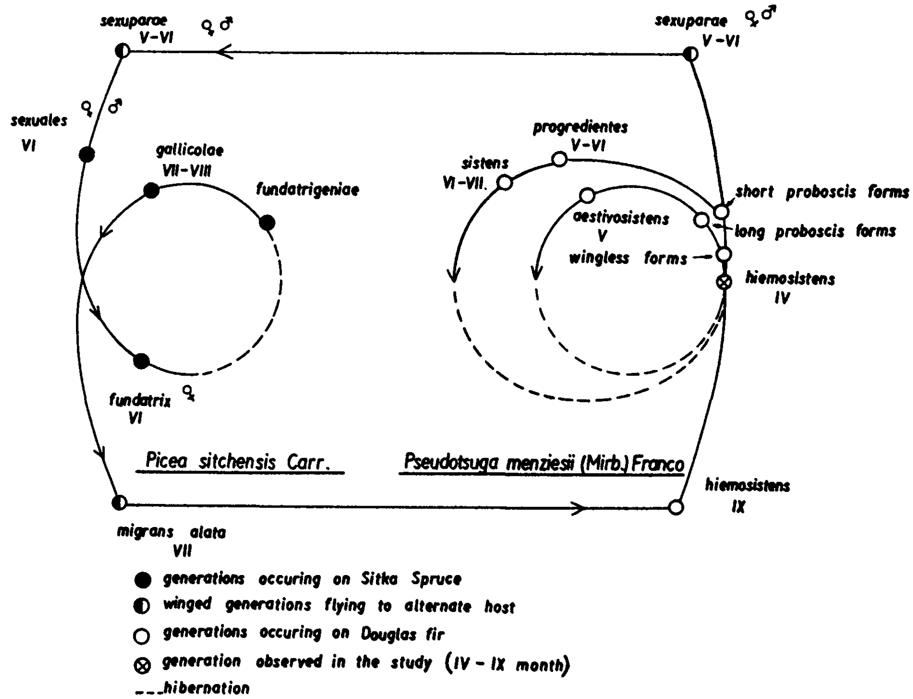


Fig. 2. — Outline of the life cycle of *Gilletteella cooleyi* Gill. (Compiled from Schwenke 1972).

significant numbers so that there were no visible foliage injuries.

Those specimens were regarded as attacked on which large numbers of the representatives of hiemosistens and aestivalis generations were found causing conspicuous injuries and deformations of needles. The hiemosistens 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 hiemosistens 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 (Mosteller 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.

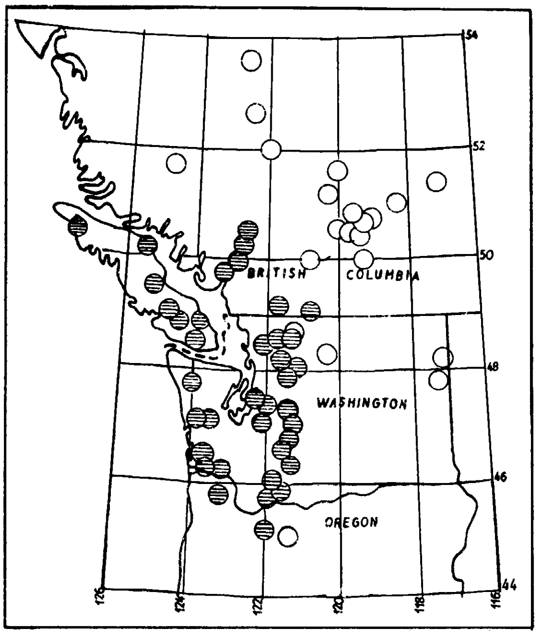
Table 1. — Analysis of variance for the estimate of *Gilletteella cooleyi* attack on 59 Douglas-fir provenances in 1976 and 1977.

Source of Variation	Degrees of freedom	Mean Square	F
Total	353		
Years	1	1777	40.2***
Populations	58	2252	50.9***
Blocks	2	14646	331.3***
Popl. × Blocks	116	363	8.2***
Popl. × Years	58	46	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 tests

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



○ - less than 50% attacked trees
⊖ - more than 50% attacked trees

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 × 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 (MEJNARTOWICZ, 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 (MEJNARTOWICZ, 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 (MEJNARTOWICZ, 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 scare occurrenec 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 occurence with suitable insecticides.

Literature

BIALOBOK S., and MEJNARTOWICZ, L.: Provenance differentiation among Douglas fir seedlings. Arboretum Kórnickie 15: 196—219 (1970). — CHRYSTAL, R. N.: Galls of Adelges *Gilletteella cooleyi* Gillette Hem. Adelgidae on Sitka Spruce in Cumberland. Ent. mon. Mag. 79: 233 (1943). — CHRYSTAL, R. N.: The Douglas-Fir Adelges. Rep. Imp. For. Inst. Oxf. 1948—9, 1950: 15—16 (1950). — DUNCAN, D. B.: Multiple Range and Multiple F Tests. Biometrics 11: 1—42 (1955). — HEITMÜLLER, H. H.: Beobachtungen über individuelle Resistenz gegen *Gilletteella cooleyi* GILL. an Douglasie. Z. Forstgenet. 3 5: 99—100 (1954). — JONES, B. L.: The interrelationships among *Chermes* cooleyi GILL. fungi and the foliage of *Pseudotsuga menziesii* FRANCO. Abstr. of thesis in Dissert. Abstr. 1967 28B 6: 2218 (1967). — LARSEN, C. S.: Studies of diseases in clones of forest trees. Hereditas 39 1-2: 179—192 (1953). — LUNDERSTÄDT, J.: Isolation and analysis of plant phenolics from foliage in relation to species characterization and to resistance against insects and pathogens. Modern Methods in Forest Genetics. Miksche J. P. (ed.) Springer Verlag, Berlin-Heidelberg-New York. chapt. 7: 158—164 (1976). — MEJNARTOWICZ, L.: Genetic investigations on Douglas-fir *(Pseudotsuga menziesii* (MIRB.) FRANCO) populations. Arboretum Kórnickie 21: 126—187 (1976). — MOSTELLER, F., and YOUTZ, C.: Tables of the Freeman-Tukey transformation for the Binomial and Poisson distributions. Biometrika 48 3—4: 433—440 (1961). — MÜLLER, H.: Die Douglasienwollaus, *Gilletteella cooleyi* GILL. und ihre Bekämpfung. Anz. Schädlingsk. 17: 121—125 (1941). — PETERSEN, B. B., and SØEGAARD, B.: Studies on resistance to attacks of *Chermes cooleyi* GILL. to *Pseudotsuga taxifolia* POIR. Britt. Forstl. Forsøgsv. Danm. 25 1: 35—45 (1958). — SCHWENKE, W.: Die Forstschädlinge Europas. Band 1. Paul Parey, Hamburg und Berlin (1972). — TEUCHER, G.: Die Anfälligkeit der Douglasienrassen gegenüber der Douglasien-Wollaus *Gilletteella cooleyi* GILL. C. B. Forst u. Jagt. 5 7: 297—299 (1955 a). — TEUCHER, G.: Die Anfälligkeit der Douglasienrassen gegenüber der Douglasien-Wollaus *Gilletteella cooleyi* GILL. C. B. Forst u. Jagt 5 8: 337—342 (1955 b). — TEUCHER, G.: Über die Anfälligkeit von Douglasien und Strobenherkünften gegenüber der Douglasienwollaus *Gilletteella cooleyi* GILL. C. B., bzw. der Strobenwollaus *Pineus strobi* Htg. in Deutschland. 12-th Congr. Int. Union For. Res. Organ., Oxford 1956 No. IUFRO 56 24 18 (1956).

Effect of growth regulators on the flowering of Scots pine (Pinus sylvestris L.) grafts

By W. CHALUPKA

Institute of Dendrology, 63-120 Kórnik, Poland

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Summary

Application of $GA_{4/7}$ made thrice in May 1976 at weekly intervals has significantly increased the percentage of Scots pine shoots that flowered male in 1977. This result was independent of method application and over and above substantial clonal variation. Application of CCC had no measurable effect. The girdling of branches has significantly increased both male and female flowering. There was no interaction between the $GA_{4/7}$ and the girdling treatments indicating that the responses are additive rather than synergistic. There are indications that the applied gibberellins also migrate to adjacent untreated twigs causing similar flowering responses there.

Key words: Pinus sylvestris L., flowering, gibberellins, girdling.

Zusammenfassung

Durch die Anwendung von Gibberellinsäure im Mai 1976 konnte bei *Pinus sylvestris* im folgenden Frühjahr 1977 eine signifikant verstärkte Ausbildung männlicher Blüten beobachtet werden. Das Ergebnis war unabhängig von der Anwendungsmethode und unabhängig von den einzelnen Klonen. Die Anwendung von Chlorcolinchlorid hatte keinen meßbaren Effekt. Das Ringeln der Zweige verstärkte die Ausbildung sowohl männlicher Blüten als zugleich weiblicher Blüten.

Introduction

Interest in the role of growth regulators in the regulation of flowering in coniferous trees is on the increase. In the fifties and sixties most investigators concentrated their work on the study of species from the families Cupressaceae and Taxodiaceae in view of the positive responses that were being obtained following treatments, particularily with gibberellic acid (GA_3). This same gibberellin however proved completely inadequate or only minimally so for the induction of flowering in the representatives of the Pinaceae family. In recent years other gibberellins were being investigated and it turned out that some of them could also stimulate flowering in the Pinaceae. A detailed review of achievements in this field has been recently published by PHARIS and KUO (1977). In addition to the results quoted there one should also mention those of BLEYMÜLLER (1976) which were not mentioned in that review. He has applied gibberellic acid (GA_3) as sprays on 16-year old grafts of *Picea abies* and then followed the treatment 4 and 8 weeks later with a dose of CCC [(2-chloroethyl) trimethylammonium chloride]. This treatment favoured the induction of female flowers, and reduced male flowering. The idea behind BLEYMÜLLER's method was to give the promoter in the early phase of vegetation and then to inhibit the growth processes with a retardant during the final stage of extension growth, thus to divert the built up potential towards reproductive functions.

In 1976 studies were begun in the Institute of Dendrology of the Polish Academy of Sciences in Kórnik on the effect of growth regulators on flowering of Norway spruce and Scots pine. In the case of spruce GA_3 was used at a concentration of 100 ppm and CCC at a concentration of 2000 ppm in order attempt a confirmation of the result BLEYMÜLLER obtained. Unfortunately this experiment has not provided any meaningful results. A similar method was tried on Scots pine, but in this case instead of GA_3 the $GA_{4/7}$ mixture was used. The results presented below concern this latter experiment.

Materials and Methods

In the spring of 1976 on a 15-year old seed orchard of Scots pine in Kórnik 5 clones were selected each represented by 12 ramets. Individual grafts within a clone were treated either with $GA_{4/7}$, CCC, $GA_{4/7}$ + CCC or not at all (control). Thus there were 3 grafts (replicates) per treatment. For the treatments in the central part of the crown two branches were selected from adjacent whorls, one of which was given a full girdle 5 mm wide close to the base of the branch. On both the branches three more or less uniform 2-year old twigs were selected from the same whorl, and these were given the same hormonal treatment but the method of application to each twig was different. Three methods of application were tried: 1° in lanoline onto a longitudinal 4—5 cm slit in the stem, 2° by spraying aqueous solution and 3° by dipping in an aqueous solution. The