Some Characteristics of the Needle Structure and Growth in Hybrids between Austrian Pine and Japanese Red Pine[1])

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Introduction

Trough interspecific hybridization in forest tree species it is possible to obtain hybrids with the phenomenon of heterosis, which in respect to their growth are superior to one of their parents. Hybrids can also display other desirable characters, such as resistance to diseases, frost and drought. Therefore tree breeders show a keen interest in interspecific hybridization. Much has been done. especially in the interspecific hybridization in the genus Pinus. Many interspecific hybrids were produced. More significant morphological features were described as well as the anatomy of needles. Valuable data about the diagnostic characteristics were given by many authors such as KENG and LITTLE (5), WRIGHT and his collaborators (16, 18). Several surveys were published about the individual hybrids that present some of their characteristics (2, 10—14). Other reports have been published by authors such as FOWLER and HEIMBURGER (3), KRIEBEL (6) and MERGEN (7, 8, 9), who demonstrate on examples the possibility of using some methods for the identification of interspecific hybrids of pines, which are based on one or several characters.

Within the framework of our programme of the interspecific hybridization of pines from the subgenus *Diploxylon*, a hybrid of Pinus nigra X Pinus densiflora was produced which might also be of interesting for cultivation in Southern Europe. The first authentic hybrid between Austrian Pine and Japanese Red Pine was produced by BLAKESLEE in 1914 (1). Later this hybrid was produced in many places in the U.S. and Canada. WRIGHT and GABRIEL (18) have described this hybrid. According to these authors the young hybrid plants produce no lammas shoots and are easily distinguished from their parents by the length of needles, size, form and color of buds. MERGEN (8) established in this hybrid that the distribution of its stomata is intermediate in relation to the parent species.

Because when determining hybrids, especially when working with young plants, the forest tree breeder needs as safe diagnostic characteristics as possible, it will be useful in our opinion to review some more characteristics of the structure of needles in young plants of hybrids between the Austrian and Japanese Red Pine. In addition, we shall also say a few words about the growth rates of the hybrid in height and diameter.

Working method

The hybridization was carried out in 1950 and 1961. Five trees of Austrian Pine were chosen as mother trees. These trees were pollinated with the pollen of one tree of P. *densiflora* and with the pollen of hybrids P. densiflora X P. *nigra austriaca* and P. nigra austriaca X P. densiflora. The pollen was obtained from C. HEIMBURGER, Southern Research Station, Maple, Ontario, Canada.[2]) The hybridization was carried out by means of routine pollination methods. Combinations used in the crossing and the number of the isolated shoots are given in Table 1. The measurements were taken on plants in the autumn of 1964, i. e. after the second or third growing period. The diameters of the plants were measured immediately above ground level. The anatomic structure of needles was observed on the cross section of the needles. For each of the presented combination of crossings 12 cross sections of the needles were analysed. In the pure species of P. densiflora needles of two clones were analysed. The cross section was made between the middle and the lower third of the needle. The semidiagrammatic and detailed drawings of the anatomic structure of needles were made by means of a drawing instrument.[3])

Results of investigations and discussion

In 1950 four trees of the Austrian Pine were pollinated with the pollen of two hybrid pines: P. densiflora X P. nigra and P. nigra X P. densiflora, the latter representing at backcrossing. In 1961 two trees of Austrian Pine were pollinated

Table 1.

Symbol of crossing	Combination: ♀ Parent tree P.nigra No.	Crossed	♂ Parent tree	Number of bags set	Year of pollination	Remarks
S 301	126	X	Unknown	—	1960	Open pollination
S 304	126	X	(P. densiflora X P. nigra) + (P. nigra X P. densiflora)	12	1960	Mixed pollen from two hybrid trees
S 307	126	X	P. nigra 126	10	1960	Self fertilized
S 321	221	X	Unknown	—	1960	Open pollination
S 322	221	X	(P. densiflora X P. nigra)	5	1960	
S 323	221	X	P. nigra 127	8	1960	
S 334	127	X	Unknown	—	1960	Open pollination
S 325	127	X	(P. nigra X P. densiflora)	5	1960	
S 326	127	X	P. nigra 126 + 221	11	1960	Mixed pollen from two trees
S 327	45	X	Unknown	—	1960	Open pollination
S 328	45	X	(P. densiflora X P. nigra) + (P. nigra X P. densiflora)	15	1960	Mixed pollen from two hybrid trees
S 329	45	X	P. nigra 127	15	1960	
S 386	126	X	Unknown	—	1961	Open pollination
S 387	126	X	P. nigra 47	10	1961	
S 388	126	X	*P. densiflora*	20	1961	
S 389	126	X	*(P. densiflora* X P. nigra)	5	1961	
S 393	126	X	(P. nigra X P. densiflora)	5	1961	
S 393	47	X	Unknown	—	1961	Open pollination
S 394	47	X	P. nigra 47	10	1961	
S 395	47	X	P. densiflora	30	1961	
S 396	47	X	(P. densiflora X P. nigra)	5	1961	

[1]) The investigations were supported by the Federal Research Work Fund.

[2]) I wish to express my thanks to Dr. C. HEIMBURGER for his kind help in procuring the pollen.

[3]) I am indebted to Miss BRANKA BEVILACQUA, M. Se. for the drawings.

Table 2.

No.	Symbol of crossing	Needles Height μ $\bar{x}$	Needles Height μ σ	Needles Height μ $\sigma_{\bar{x}}$	Needles Breadth μ $\bar{x}$	Needles Breadth μ σ	Needles Breadth μ $\sigma_{\bar{x}}$	Epidermal cells Height μ	Epidermal cells Breadth μ	Number of hypodermis layers Convex side	Number of hypodermis layers Flat side	Number of hypodermis layers In the corners	Resin ducts externally $\bar{x}$	Resin ducts externally σ	Resin ducts externally $\sigma_{\bar{x}}$	Resin ducts medially $\bar{x}$	Resin ducts medially σ	Resin ducts medially $\sigma_{\bar{x}}$	No. of sclerenchyma layers over the phloem
1	*P. nigra* (47 × open poll.)	703.50	83.10	23.99	1538.08	77.94	22.50	(15)17−19(21)	(13)15−17(19)	2−3	(1)2	(2)3	—	—	—	3.75	0 87	0.25	(1)
2	*P. densiflora* V 116	515.42	21.74	6.28	961.41	35.16	10.15	15−17(19)	(13)15−17(19)	1	1	1−2	5.17	2.17	0.63	—	—	—	1(2)
3	*P. densiflora* V 115	596.25	28.54	8.24	1033.41	13.42	3.87	15−19	13−17	1(2)	1	1−2	6.25	0.75	0.22	—	—	—	1−2
4	*P. nigra* 126 × *P. densiflora* S 388	481.83	14.44	4.17	1059.75	43.60	12.58	(11)15−17(21)	(13)15−17	1(2)	1(2)	1−2	1.33	0.78	0.23	0.83	0.84	0.24	(1)
5	*P. nigra* 127 × (*P. nigra* × *P. densiflora*) S 325	655.33	54.82	15.82	1290.08	105.83	30.55	(11)13−17(21)	(13)15−17(19)	(1)2(3)	1−2	2(3)	—	—	—	3.25	1.29	0 33	1(2)
6	*P. nigra* 221 × (*P. densiflora* × *P. nigra*) S 322	698.08	45.73	13.20	1393.08	111.55	32.20	(15)17−19(23)	(13)15−17	1(2)	1	2	1.25	0.87	0.25	2.50	0.52	0.15	1−2

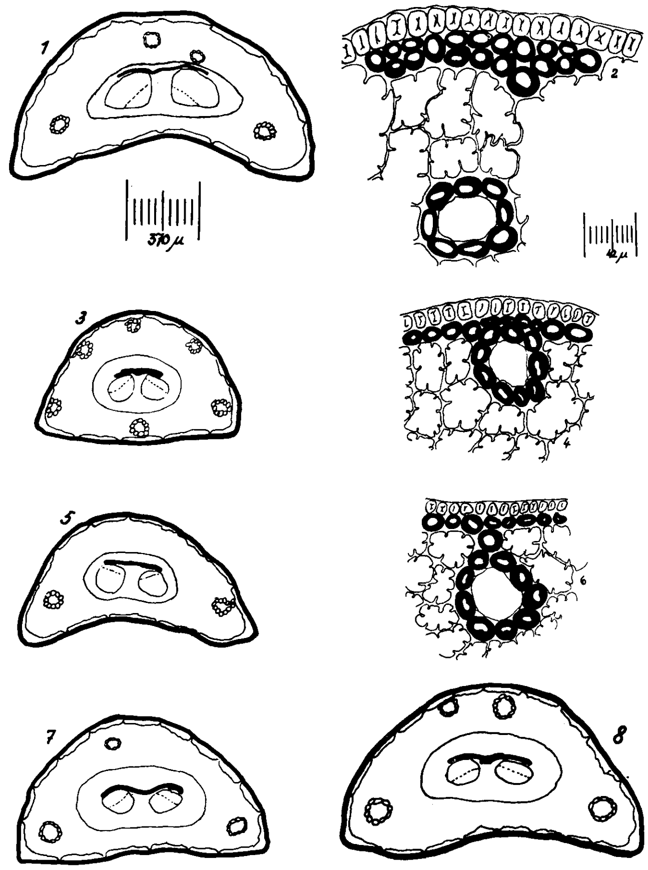
with the pollen of a tree of pure *P. densiflora* species, as well as the pollen of the two hybrids *P. densiflora* × *P. nigra* and *P. nigra* × *P. densiflora*. The backcrossing from 1961 gave poor results (only one plant from each combination) because the pollen in that year was not fresh and had already lost its viability to a great extent.

1. Anatomy of needles

Table 2 presents the anatomic structure of the needles of: *P. nigra, P. densiflora, P. nigra* × *P. densiflora, P. nigra* × (*P. nigra* × *P. densiflora*), and *P. nigra* × (*P. densiflora* × *P. nigra*).

From *Table 2* and Drawings (*Fig. 1, 2, 3, 4*) it can be seen that there is a great difference in the size of the cross section of the needles, number of hypodermal layers, position of resin ducts and number of sclerenchyma layers above the phloem between *P. nigra* and *P. densiflora*. As to the size of the epidermal cells and the number of resin ducts, there are no appreciable differences between these two species. These results of investigations of needle structure coincide in general with the results published by HARLOW (4).

The hybrid *P. nigra* × *P. densiflora* shows a more or less intermediate character in individual elements of its needle structure, as seen in *Table 2* and Drawings (*Fig. 5, 6*). The most conspicuous characteristic is the position of the resin ducts. In the hybrid they are situated medially or externally, i. e. some of them are similar in this respect to the



Figs. 1—8. — Cross section of needles: 1. *P. nigra;* 2. Detail of *P. nigra* (epidermis, hypodermis and resin duct); 3. *P. densiflora;* 4. Detail of *P. densiflora* (epidermis, hypodermis and resin duct); 5. Hybrid *P. nigra* × *P. densiflora;* 6. Detail of *P. nigra* × *P. densiflora* (epidermis, hypodermis and resin duct); 7. Backcross *P. nigra* × (*P. nigra* × *P. densiflora*); 8. Backcross *P. nigra* × (*P. densiflora* × *P. nigra*).

Austrian Pine, while others have a position as in Japanese Red Pine. The width of the needles is likewise intermediate between these two species. As to other characteristics, the hybrids are more related to one or the other parent.

If we observe in the Table and Drawings *(Fig. 7, 8)* the specimens originated through the backcrossing of the hybrids *(P. nigra × P. densiflora* and *P. densiflora × P. nigra)* with the Austrian Pine, we see that they differ from one another. The most pronounced difference is in the position of the resin ducts. In the case where the hybrid *P. nigra × P. densiflora* was taken as the male parent, the resin ducts are always situated medially. In the second combination, where the male parent was the hybrid *P. densiflora × P. nigra,* the resin ducts are situated externally and medially. Consequently, in the first combination the resin ducts are situated as in the Austrian Pine, while in the second combination the position of the resin ducts is the same as in the hybrid *P. nigra × P. densiflora.* The first combination of backcrossing — except in the position of the resin ducts — also has more resemblance to the pure Austrian Pine than the second combination in the structure of the hypoderm and the number of sclerenchyma cells above the phloem portion of the vascular bundles. As to other characteristics, there are no great differences between these two combinations, and they are intermediate between *P. nigra* and *P. densiflora.* On the basis of these results it can concluded that the characteristics of the female parent are expressed to a greater degree when the male parent is the backcross hybrid *P. nigra × P. densiflora* then when the male parent is the hybrid *P. densiflora × P. nigra.* This finding indicates that in crosses of these two species maternal inheritance is more expressed in needle structure than is paternal inheritance.

2. *Plant Height*

Table 3 shows data for the plant heights. In the *Table 4* and in Histogram *(Fig. 9)* we see that in two-year-old plants the hybrids between *P. nigra* and *P. densiflora* do not always have a greater height increment than the Austrian Pine. When Tree No. 126 is taken for the male parent, the hybrid progenies do not show any significant differences. In fact, they are significantly poorer than the pure Austrian Pine. In the second crossing combination, in which Tree No. 47 was used the female parent, the hybrid progenies always

Table 3.

Symbol of crossing	n	$\bar{x}$ cm	σ	$\sigma_{\bar{x}}$
S 301	165	12.93	3.05	0.24
S 304	5	16.50	—	—
S 307	4	7.62	—	—
S 321	125	11.60	2.89	0.25
S 322	20	17.92	4 88	1 09
S 323	76	13 39	2 60	0.29
S 324	224	11.99	4.43	0.29
S 325	47	24.79	6.44	0 94
S 326	120	13.18	2 64	0.24
S 327	200	14.07	4.34	0.31
S 328	130	24.90	5.65	0.50
S 329	193	14.39	3.05	0.22
S 386	72	9.74	2.64	0 31
S 387	91	9.99	2 80	0.29
S 388	16	10.62	3.08	0.77
S 389	1	20.50	—	—
S 390	1	10.00	—	—
S 393	10	10.25	2.30	0.73
S 394	4	8 62	—	—
S 395	43	17.56	3.16	0.48
S 396	1	27.00	—	—

Table 4.

	$\bar{x}_1$	x_2	n_1	n_2	t
S 322 : S 323	17.92500	13.39474	20	76	4.73222***
S 322 : S 321	17.92500	11.60400	20	125	8.11740***
S 325 : S 326	24.78723	13.18333	47	120	11.96280***
S 325 : S 324	24.78723	11.98884	47	224	13.01970***
S 328 : S 329	24.90385	14.38860	130	193	19.25870***
S 328 : S 327	24.90385	14.07000	130	200	18.42490***

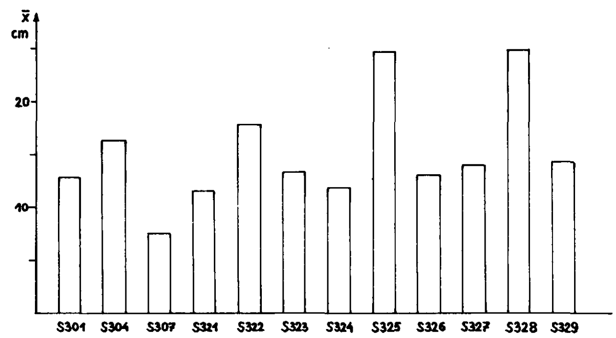


Fig. 9.

exhibited significantly greater heights than the control, i. e. the pure species. This hybrid family likewise differs significantly from the hybrid family in which Austrian Pine No. 126 was taken for the mother tree. Therefore, in the crossing which we carried out between those two species the height growth of the hybrid of the age of two years depends on the combination of the parent trees. Insofar as the female parent is a favourable partner, as is the case with the tree No. 47, the hybrid progenies grows considerably faster than the pure *P. nigra* species. On the other hand, if tree No. 126 is taken as the female parent, the hybrid plants grow more slowly than the pure *P. nigra* plants. Hence, we can not state absolutely that the interspecific hybrid between the Austrian and Japanese Red Pine always grows faster in the juvenile stage than the Austrian Pine. According to Wright and Wright and Gabriel (17, 18) this interspecific hybrid at the age of two years grows more quickly than the mother species *P. nigra austriaca.* Therefore a greater number of individual crossing combinations would be necessary to obtain as safe conclusions as possible to obtain good parents for further work on the production of this interspecific hybrid.

In three-year-old hybrid plants obtained by backcrossing the hybrid with Austrian Pine, we always had greater heights than in the control, i. e. pure *P. nigra (Table 3, Fig. 10).* These differences in heights are significant *(Table 5).* It is necessary to mention that except in one case the female parents were not the same Austrian Pine trees from which

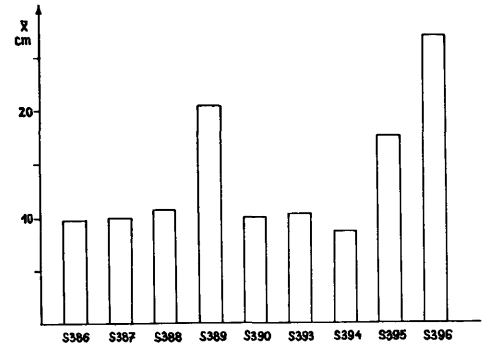


Fig. 10.

Table 5.

	$\bar{x}_1$	$\bar{x}_2$	n_1	n_2	t
S 388 : S 387	10.62500	9.99451	16	91	0.81918
S 388 : S 386	10.62500	9.73611	16	72	1.17000
S 388 : S 393	10.62500	10.25000	16	10	0.32976
S 388 : S 395	10.62500	17.55814	16	43	7.57344***
S 395 : S 393	17.55314	10.25000	43	10	6.83144***
S 395 : S 387	17.55814	9.99451	43	91	13.96010***
S 395 : S 386	17.55814	9.73611	43	72	14.29326***

Fig. 11. — Left: Austrian Pine S_{321}; right: hybrid S_{322} *P. nigra* × (*P. densiflora* × *P. nigra*).

Fig. 12. — Left: Austrian Pine S_{326}; right: hybrid S_{325} *P. nigra* × (*P. nigra* × *P. densiflora*).

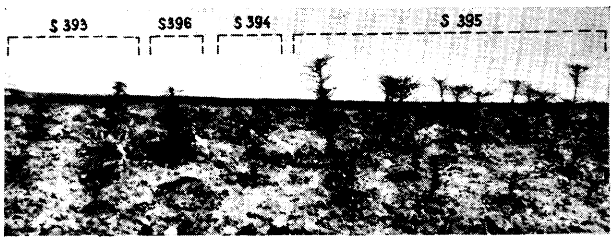


Fig. 13. — From left to right: Austrian Pine S_{393}, hybrid S_{396} *P. nigra* × (*P. densiflora* × *P. nigra*), Austrian Pine S_{394}, hybrid S_{395} *P. nigra* × *P. densiflora*.

the two-year-old hybrid *P. nigra* × *P. densiflora* were obtained.

3. Plant Diameter

Results of study of diameter of two-year-old plants are similar to the results of plant height analysis. The hybrid in which the female parent is Tree No. 126 of Austrian Pine does not exhibit a greater diameter increment than the control, i. e. the pure Austrian Pine species. On the other hand, the hybrids between Austrian Pine and Japanese Red Pine in which Tree No. 47 was taken for the mother tree always shows a greater diameter than the pure species, and even greater than the hybrids in which the mother tree is Tree No. 126. In these cases the differences are significant. Data concerning this are shown in *Table 6 and 7* and Histogram *(Fig. 14)*.

The three-year-old plants originated through backcrossing of the hybrids with Austrian Pine always have significantly greater diameters than the controls obtained from

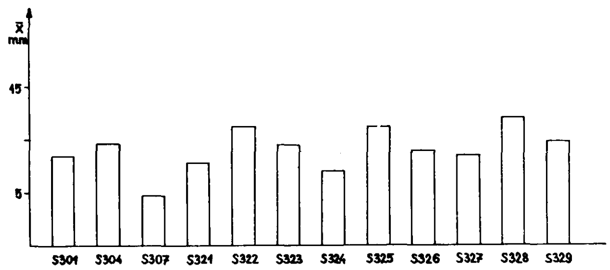


Fig. 14.

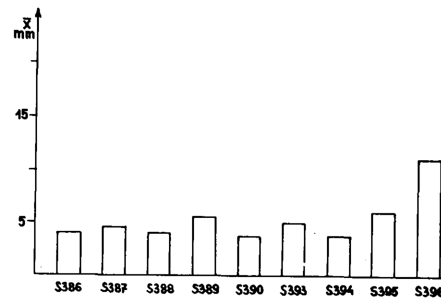


Fig. 15.

various intraspecific crossings of Austrian Pine. In this respect, the analysis of diameter growth of plants from the backcrossing completely coincides with height growth analysis. Data are presented in *Table 5, 6 and 8.* Histogram *(Fig. 15)* illustrates the relationships graphically.

On the basis of what been stated about plant diameter in hybrids between *P. nigra* and *P. densiflora,* we can conclude that diameter growth depends upon the particular tree of Austrian Pine which is chosen for the female parent. Therefore it is necessary to establish in this case as well

Table 6.

Symbol of crossing	n	$\bar{x}$ mm	σ	$\sigma_{\bar{x}}$
S 301	165	8.48	2.23	0.17
S 304	5	9.62	—	—
S 307	4	4.75	—	—
S 321	125	7.78	2.43	0.21
S 322	20	11.28	3.46	0.77
S 323	76	9.44	1.77	0.20
S 324	224	7.05	3.25	0 22
S 325	47	11.18	2.74	0.40
S 326	120	8.92	1.62	0.15
S 327	200	8.50	2.62	0.18
S 328	130	12.00	2.52	0.22
S 329	193	9.85	2.37	0.17
S 386	72	3.96	0.78	0.09
S 387	91	4.53	0.85	0.09
S 388	16	3.93	0.74	0.18
S 389	1	5.50	—	—
S 390	1	3.70	—	—
S 393	10	4.94	0.74	0.23
S 394	4	3.80	—	—
S 395	43	5.95	1.74	0.26
S 396	1	10.90	—	—

Table 7.

	$\bar{x}_1$	$\bar{x}_2$	n_1	n_2	t
S 322 : S 323	11.28500	9.43947	20	76	3.33126**
S 322 : S 321	11.28500	7.78000	20	125	5.63570***
S 325 : S 326	11.18085	8.92250	47	120	4.64680***
S 325 : S 324	11.18085	7.04598	47	224	9.04790***
S 328 : S 329	11.99615	9.85440	130	193	7.70410***
S 328 : S 327	11.99615	8.49950	130	200	12.31210***

Table 8.

	$\bar{x}_1$	$\bar{x}_2$	n_1	n_2	t
S 388 : S 387	3.93125	4.53516	16	91	3.00490**
S 388 : S 386	3.93125	3.96389	16	72	0.15120
S 388 : S 393	3.93125	4.94000	16	10	3.45550**
S 388 : S 395	3.93125	5.95116	16	43	6.38840***
S 395 : S 393	5.95116	4.94000	43	10	2.91350**
S 395 : S 387	5.95116	4.53516	43	91	6.40871***
S 395 : S 386	5.95116	3.96389	43	72	8.35590***

as in plant height which of the individual crossing combinations gives the best results. It can not be considered a general rule that the cross between *P. nigra* and *P. densiflora* always grows faster than Austrian Pine. From these investigations it can be seen that in most but not all cases, this cross grows faster than the Austrian Pine.

Summary

In 1960 and 1961 was performed a hybridization between Austrian Pine and Japanese Red Pine. Obtained were the hybrids *P. nigra* × *P. densiflora* and the backcross *P. nigra* × *(P. nigra* × *P. densiflora)* and *P. nigra* × *(P. densiflora* × *P. nigra)*. When the plants were two or three years old, the structure of their needles and the growth of the plants were examined. Hence the following conclusions:

1. In the anatomic structure of the needles a considerable difference exists between Austrian Pine and Japanese Red Pine in the following elements: height and width of the cross section of the needles, number of hypodermal layers, position of the resin ducts, and number of sclerenchyma cell layers above the phloem.
2. The anatomic structure of the needles of two-year-old plants of the hybrid *P. nigra* × *P. densiflora* is intermediate in the position of the resin ducts and the width of the cross section. In other characteristics the hybrid is more closely related to one or the other parent.
3. In backcrossing, when the hybrid *P. nigra* × *P. densiflora* is chosen for the male parent and *P. nigra* for the female parent, the characteristics of the female parent are more expressed in the anatomic structure of the needles than when the hybrid *P. densiflora* × *P. nigra* is taken for the male parent with the same female parent.
4. Two-year-old hybrid plants of *P. nigra* × *P. densiflora* do not always display a greater height growth than the pure *P. nigra* species. The rate of growth of young hybrid plants depends on the individual tree of the female parent.
5. In the backcrossing of the hybrid with the Austrian Pine, the three-year-old plants show greater heights than the control plants, i. e. pure *P. nigra*, but in this case other trees of Austrian Pine were used for the female parent than those mentioned in point 1.
6. Relationships obtained from a similar study of diameter of hybrids and of Austrian pine control plants agree with those obtained from the plant height analysis.

Résumé

Titre de l'article: *Quelques caractéristiques de la structure des aiguilles et de la croissance chez les hybrides entre le pin noir d'Autriche et le pin rouge japonais.*

En 1960 et 1961 on a effectué l'hybridation entre le pin noir d'Autriche et le pin rouge japonais. On a obtenu les hybrides *P. nigra* × *P. densiflora*, ainsi que l'hybrid *P. nigra* × *(P. densiflora* × *P. nigra)* et *P. nigra* × *(P. nigra* × *P. densiflora)*. Quand les plants ont été agés de deux ou trois ans on a examiné la structure anatomique de leurs aiguilles ainsi que leur croissance. On peut en tirer les conclusions suivantes:

1. Dans la structure anatomique des aiguilles il existe une différence considérable entre le pin noir d'Autriche et le pin rouge japonais *(P. densiflora)* concernant les éléments suivants: la hauteur et la largeur de la section transversale de l' aiguille, le nombre de couches de l'hypoderme, la position des canaux résinifères ainsi que le nombre de couches des cellules de sclérenchyme se trouvant au-dessus du phloème.
2. La structure anatomique des aiguilles provenant des plants hybrides de *P. nigra* × *densiflora* agées de deux ans montre un caractère intermédiare en ce qui concerne la position des canaux résinifères et la largeur de la section transversale des aiguilles. Par rapport aux autres caractéristiques les hybrides sont plus proches à un parent ou à l'autre.
3. Quand on choisit au «backcrossing» pour l'espèce père l'hybride *P. nigra* × *P. densiflora* et pour l'espèce mère *P. nigra,* les caractéristiques maternelles *(P. nigra)* dans la structure anatomique des aiguilles sont plus marquées qu'en cas si pour l'espèce père on a choisi l'hybride *P. densiflora* × *P. nigra,* alors que l'espèce mère a été la même.
4. Les plantes hybrides *P. nigra* × *P. densiflora* agées de deux ans ne montrent pas toujours une croissance en hauteur plus grande que l'espèce pure de *P. nigra.* Le taux d'accroissement de jeunes plantes hybrides dépend de l'arbre particulier du parent femelle.
5. Au «backcrossing» les hybrides du pin noir à l'âge de trois ans donnent un accroissement en hauteur plus grand que les plants témoins, c'est-à-dire, *P. nigra* purs, mais dans ce cas on a choisi pour le parent femelle d'autres tiges du pin noir que celles mentionnées au point.
6. Les relations entre les diamètres des plants hybrides et des plants témoins (étant les pins noirs) coincident avec les résultats obtenus pour les hauteurs des plants.

Zusammenfassung

Titel der Arbeit: *Einige Besonderheiten der Nadelanatomie und des Wachstums der Hybriden zwischen der Schwarzkiefer und der japanischen Rotkiefer.*

Im Jahre 1960 und 1961 wurde die Hybridisierung zwischen der Schwarzkiefer und der japanischen Rotkiefer durchgeführt. Es wurden die Hybriden *P. nigra* × *P. densiflora* und *P. nigra* × *(P. nigra* × *P. densiflora)* und *P. nigra* × *(P. densiflora* × *P. nigra)* gewonnen. Als die Pflanzen zwei oder drei Jahre alt waren, wurden der anatomische Aufbau ihrer Nadeln und das Wachstum der Pflanzen untersucht. Daraus können folgende Schlüsse gezogen werden:

1. Es besteht ein beträchtlicher Unterschied im anatomischen Bau der Nadeln zwischen der Schwarzkiefer und der japanischen Rotkiefer *(P. densiflora)*, und zwar in den folgenden Bauelementen: Höhe und Breite des Nadelquerschnitts, Anzahl der Hypodermisschichten, Lage der Harzgänge und Anzahl der über dem Phloëm vorkommenden Bänder von sklerenchymatischen Zellen.
2. Der anatomische Bau der Nadeln der zweijährigen Hybridpflanzen von *P. nigra* × *P. densiflora* weist in Bezug auf die Lage der Harzgänge und die Breite des Nadelquerschnitts einen intermediären Charakter auf. In den übrigen Merkmalen sind die Hybriden dem einen oder dem anderen Elter näher verwandt.

3. Bei der Rückkreuzung, wobei als väterlicher Elter der Hybrid *P. nigra* × *P. densiflora* und als Mutter *P. nigra* gewählt wurde, kommen bei dem anatomischen Bau der Nadeln mehr die Merkmale der Mutter *(P. nigra)* zum Ausdruck, als in dem Fall, bei dem als väterlicher Elter der Hybrid *P. densiflora* × *P. nigra* ausgewählt worden ist und die Mutter dieselbe blieb.
4. Die zweijährigen Hybridpflanzen von *P. nigra* × *P. densiflora* zeigen nicht immer ein größeres Höhenwachstum als die reine Art *P. nigra*. Die Wuchsleistung der jungen Hybridpflanzen hängt von den einzelnen Individuen des weiblichen Elters ab.
5. Bei der Rückkreuzung des Hybrids mit der Schwarzkiefer weisen dreijährige Pflanzen größere Höhen als die Kontrollpflanzen auf, d. h. als die reine Art *P. nigra*. In diesem Falle wurden aber als weibliche Eltern andere Schwarzkiefernstämme als die unter Punkt 1 angeführten ausgewählt.
6. Die Verhältnisse zwischen den Durchmessern der Hybridpflanzen und denen der Kontrollpflanzen der Schwarzkiefer stimmen mit den Ergebnissen überein, welche für die Höhen der Pflanzen erhalten worden waren.

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Breeding Blister Rust Resistant Western White Pine

III. Comparative Performance of Clonal and Seedling Lines from Rust-Free Selections

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In 1950, the Forest Service began its program in breeding western white pine *(Pinus monticola* DOUGL.) resistant to blister rust caused by *Cronartium ribicola* J. C. FISCH. ex. RABENH. Progress has been reported in this journal and elsewhere (BINGHAM *et al.* 1953, 1960; and BINGHAM 1963).

During the 15 years through 1964 more than 400 phenotypically resistant selections have been located in rust-decimated, natural western white pine stands of northern Idaho and adjacent States. These remarkable trees, completely rust-free or with few infections, their branches often interlaced with those of neighboring trees bearing thousands of rust cankers, comprise the basic plant material for a practical breeding program aimed toward mass production of resistant planting stock.

Presently, the only economical means for mass producing resistant western white pine stock is by seed. Consequently, each of the field selections is under test to determine its ability to transmit resistance via seed. Some selections exhibit general combining ability for resistance (i. e., they transmit an above-average level of resistance to several test progenies). These are considered to have the greatest breeding value and are entered in the long-range breeding and seed orchard programs (BINGHAM *et al.* 1960).

Other experimentation is also underway. To gain insight into the efficacy of phenotypic selection for resistance and into the mode of inheritance of resistance, a representative group of field selections has been under study as grafted clonal lines exposed to heavy, natural blister rust infection. Comparative performance of these clonal lines and of related seedling progenies is the subject of this paper.

Materials and Methods

Clonal lines. — In early December of 1950 and 1951, scionwood from 36 rust-free selections was collected, often in remote localities in the mountains, packed with snow in polyethylene bags, and stored in an accessible snowbank. Greenhouse grafting began about 2 months later *(Fig. 1)* on well-established, actively growing, 4- to 5-year-old western white pine seedlings of a single Coeur d'Alene National Forest nursery seed lot. In early May of 1951 and 1952, susceptible rootstock foliage was removed by pruning all branches below successful graft unions. Grafted plants were then transferred to an outdoor coldframe for hardening-off. In early June of the same year grafts were planted in three 5-acre field plots, located in areas of heavy, natural blister rust infection. Plots were at Elk River, Idaho; at Tepee Creek near Coeur d'Alene, Idaho; and at Randolph Creek near Saltese, Montana.

Each field plot contained six grafts (ramets from each of the 36 canker-free parent trees [ortets]), the total number of 216 ramets being subdivided into six randomized, complete blocks, each block containing one ramet of each ortet. Grafts were row-planted at 30 × 30 feet, but with planting spots of adjacent rows shifted 15 feet to increase spacing

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