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Provenance contribution to genetic composition of progeny from outbreeding seed orchard of *Picea abies*

Abstract: The abundant flowering, observed in 2004 in a model outbreeding seed orchard established in Kórnik, Poland, promoted crossing between clones of five geographically distant populations of Norway spruce. The clones were selected from a group of ca. 1100 provenances participating in the international IUFRO 1964/68 experiment and performing best in terms of growth traits and adaptability. In the seed orchard, 91.3% of clones and 64.1% of grafts produced female and/or male strobili. Statistically significant differences between the clones were only found in the number of mature cones produced. The mean number of mature cones in individual clones was also significantly correlated with the latitude of the place of origin of maternal populations ($r = 0.88$, $p = 0.047$). The nearly equal percentages of clones representing each of the five populations in the outbreeding seed orchard (from 23.2 to 17.5%) resulted finally in the highly unequal production of full seeds by each population (from 62.9 to 0.7%). These data provide evidence to suggest that the level of genetic diversity in the progeny, expected from the number of growing clones, diverges from the level resulting from the contribution of clones to the full seed production which is an effective measure of the genetic composition of progeny. To avoid this divergence, an outbreeding seed orchard could be established with unequal proportions of clones from different provenances, considering the knowledge of their flowering phenology, and individual variation in flowering and cone production.

Additional key words: Norway spruce, genetic composition of progeny, cone yield, seed production

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Introduction

One of the main principles of seed orchard management is to promote genetic diversity in the orchard progeny. For this reason, when laying out a seed orchard, it has been common practice to use very similar or even equal initial numbers of grafts of each clone with the aim of ensuring an adequate and proportional contribution of clones to the genetic composition of the progeny. It has been found, however, that there is a great clonal variation in the production of female strobili (Eriksson et al. 1973; Skrøppa and Tutturen 1985; Kjaer 1996; Nikkanen and Ruotsalainen 2000), and nearly all seeds in Norway spruce seed orchards are frequently produced by only part of clones (ca. 25 to 50% of their total number) which thus contribute to the seed crop composition (Chałupka 1988; Misiorny and Chałupka 2006). As a consequence, the level of genetic diversity in the seed orchard progeny expected from the proportion of planted clones could be quite different from the level of genetic diversity resulting from the effective contribution of clones to the seed crop.

The aim of the present study was to test the hypothesis that the clones of each of five Norway spruce provenances make an equal maternal contribution to

the genetic composition of seed crop from a model outbreeding seed orchard, by analysing the data on flowering, and cone and seed production.

Material and methods

The outbreeding seed orchard of Norway spruce (*Picea abies* (L.) Karst) was established by M. Giertych in Kórnik in 1981, based on five geographically distant populations (Fig. 1, Table 1) which proved to perform best in various countries and site conditions in terms of growth traits and adaptability among the 1095 European provenances included in the international IUFRO 1964/68 experiment (Giertych 1978). Such a model seed orchard was assumed to produce a genetically highly diverse offspring of geographically distant populations exhibiting high adaptability (Giertych 1993, 1999). The layout of the seed orchard is presented in Fig. 2, and the number of clones and grafts from each population in 2004 is shown in Table 2.

In 2004, a year of good flowering, the abundance of female flowering was estimated in early May. In mid-November, all mature cones were collected separately from each graft. Then, seeds were extracted from the cones and examined for several traits. The results were evaluated statistically using non-orthogonal and hierarchical analysis of variance.

Results

Strobili and cone bearing

As found by Misiorny and Chałupka (2006), 80.6% of all clones and 53.1% of all grafts in the outbreeding seed orchard formed female strobili in the flowering year 2004. However, the percentage of clones and grafts with mature cones, measured in November (68.0 and 36.4%, respectively; Table 3), declined as compared to the percentage of those with female strobili in May, mostly due to the flower and/or immature cone abortion.

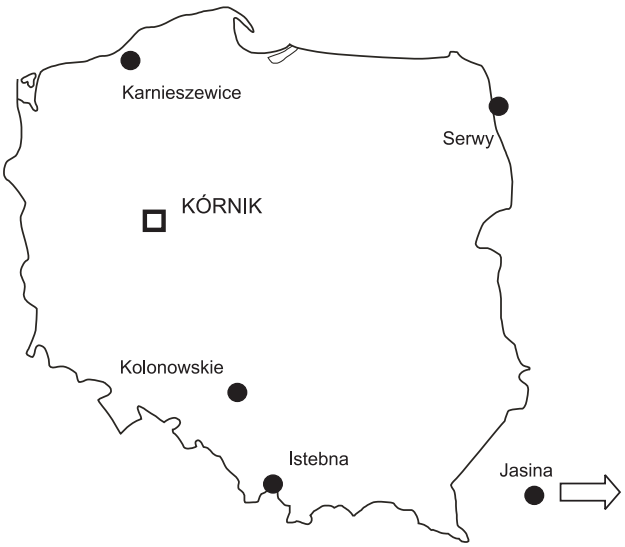

Fig. 1. Origin of Norway spruce provenances (●) and location of outbreeding seed orchard (□)

The abundance of cone crop for each provenance, calculated as the mean number of mature cones per graft, was positively significantly correlated with the latitude of provenance origin (Misiorny and Chałupka 2006).

Seed crop composition

The provenances showed quantitative differences in seed traits (Table 4). For most traits, the differences were statistically significant for provenances and much less significant for clones within provenances (Table 5).

In 2004, the percentages of clones representing each provenance were more or less the same, ranging from 23.2% for Serwy to 17.5% for Kolonowskie (Table 2). The percentages of clones that produced female strobili broadly mirrored those values (21.4 to 13.6%; Table 6). The production of mature cones showed a different pattern, with the percentages for three provenances (Kolonowskie – 9.7%, Istebna – 11.6%, Jasina – 8.7%) being much lower than for the other two. When the number of full seeds produced was taken into account, the picture changed dramatically: the final contribution to the seed crop composition varied widely among the provenances, from 62.9% for Serwy to 0.7% for Jasina (Table 6).

Discussion

As mentioned earlier, when planning the layout of a regular seed orchard, the same or very similar initial numbers of grafts of each clone are planted with the hope of obtaining more or less equal contribution of the clones to the genetic composition of the offspring. This was not the case, however, with our outbreeding model seed orchard of Norway spruce in the flowering year 2004. The nearly equal percentages of clones of five provenances, from 23.2 to 17.5%, used in the orchard, resulted in the highly unequal production of full seeds by the clones, with the contribution of each provenance ranging from 62.9 to 0.7% (Table 6). This demonstrates that the level of genetic diversity in seed orchard progeny, expected from the proportion of planted and cone-bearing clones of five provenances, differed substantially from the effective genetic diversity which resulted from the contribution of provenances to the final crop of full seeds. A new research project has recently been initiated to better understand the reproduction processes in the same outbreeding seed orchard by using molecular analyses.

In summary, the results obtained so far indicate that the number of full seeds produced by clones of different provenances, planted in an outbreeding seed orchard, provides an effective quantitative measure of

Table 1. Origin of five populations of Norway spruce in outbreeding seed orchard in Kórnik (after Misiorny and Chałupka 2006)

IUFRO No.	Population (provenance) name	Geographic location			Clone symbols
		latitude	longitude	altitude (m)	
0253	Serwy	N 53°50'	E 23°02'	120	04-106 to 04-129
0266	Karnieszewice	N 53°20'	E 15°50'	150–200	04-150 to 04-170
0293	Kolonowskie	N 50°39'	E 18°23'	150–200	04-130 to 04-149
1045	Istebna	N 49°34'	E 18°51'	540	04-83 to 04-105
1062	Jasina	N 48°18'	E 24°20'	800–1000	04-171 to 04-189

Table 2. Plant material in outbreeding seed orchard in Kórnik; italics is used for percentages

Provenance	Number of clones	Number of grafts
Serwy	24	110
	23.3	*24.5*
Karnieszewice	21	104
	20.4	*23.2*
Kolonowskie	18	57
	17.5	*12.7*
Istebna 148–149	21	86
	20.4	*19.2*
Jasina	19	91
	18.4	*20.3*
Total	103	448
	100.0	*100.0*

their contribution to the genetic composition of the orchard progeny. Therefore, if an equal or close to equal contribution of provenances or clones into the genetic composition of progeny is needed, the outbreeding seed orchard could be established with unequal proportions of clones of each provenance, based on the knowledge of their flowering phenology, and on the recognised individual variation in flowering and cone production. The above suggestions may also to some extent apply to laying out a new generation of commercial seed orchards.

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Table 3. Cone yield in outbreeding seed orchard in 2004 (after Misiorny and Chałupka 2006); italics is used for percentages

Total No. of clones	Clones with female strobili	Clones with mature cones	Total No. of grafts	Grafts with female strobili	Grafts with mature cones
103	94	70	448	238	163
100	*80.6*	*68.0*	*100*	*53.1*	*36.4*

Table 4. Mean provenance values of seed traits

Provenance	Lat.	Long.	Alt.	Weight of 1000 seeds (full + empty)	Weight of 1000 full seeds	% of full seeds	Mean No. of seeds per cone (full + empty)	Mean No. of full seeds per cone
Serwy	N 53°50'	E 23°02'	120	7.28	8.73	75	189.6	143.2
Karnieszewice	N 53°20'	E 15°50'	150–200	7.42	9.56	62	205.3	122.9
Kolonowskie	N 50°39'	E 18°23'	150–200	8.29	10.26	70	198.9	145.3
Istebna	N 49°34'	E 18°51'	540	7.55	9.42	68	221.1	143.4
Jasina	N 48°18'	E 24°20'	800–1000	7.81	9.15	73	113.5	98.0

Table 5. Results of ANOVA (significance levels)

Variables	Weight of 1000 seeds (full + empty)	Weight of 1000 full seeds	% of full seeds	Mean No. of seeds per cone (full + empty)	Mean No. of full seeds per cone
Provenances	0.0010	0.0412	< 0.0001	0.0004	< 0.0001
Clones in provenances	0.1306	0.2146	0.0203	0.0079	0.0052

										04-187	04-159	04-86	04-117	04-118		04-154	04-127	04-84	04-128	04-129	04-155	04-87	04-90	04-110	04-92	04-99	04-159	04-162	04-164	04-94	04-97	04-91	18
											04-122	04-88	04-95	04-98	04-103	04-106	39-05	04-89	04-111	04-124	04-126	04-150	04-152	04-153	04-176	04-181	04-183	04-108	31-08	04-158	04-165	38-09	17
									04-166		04-167	04-127	04-138	26-07	04-168	04-140		04-125		04-163		26-02			04-125		04-116			26-04	04-187	04-159	16
								04-155	04-87	04-90	04-110	04-92	04-99	04-159	04-162	04-164	04-94		04-91		04-172	04-173	04-174		04-101	04-187	04-102	04-120		29-01	04-119	04-122	15
								04-126	04-150	04-152	04-153	04-176	04-181	04-183	04-108		04-158	04-165	38-09	31-05	39-02	04-112		04-161	04-175	04-179		04-188	04-189	04-169	04-185	04-167	14
							04-163		26-02	04-186	37-16	04-125	04-180	04-116				04-187	04-159	04-86	04-117	04-118	04-151	04-154			04-128	04-129	04-155	04-87	04-90	04-110	13
							04-123	04-172	04-173	04-174	29-03	04-101	04-187	04-102	04-120			04-119	04-122	04-93	04-95	04-100	04-103	04-107	39-05	04-89	04-111	04-124	04-126	04-150	04-152	04-153	12
						38-09				04-157	04-160	04-175	04-179	04-182	04-188	04-189	04-169	04-185	04-184	04-127	04-138			04-140	04-178	04-125	04-180	04-163	04-177		04-186		11
						04-159	04-86	04-117	04-118	04-151	04-154	04-127		04-128	04-129	04-155	04-87	04-90	04-110	04-92	04-99	04-159	04-162	04-164	04-94		04-91	04-123	04-172			29-03	10
					04-119	04-122	04-93		04-100	04-104	04-107		04-89	04-114	04-124	04-126	04-150	04-152	04-153	04-176	04-181	04-183	04-109	31-08	04-158	04-165	24-01	31-09	39-03	04-113	04-157	04-160	9
						04-184	04-127	04-138		04-168	04-170	04-178	04-125	04-180	04-163			04-186	37-16	04-125	04-180	26-17			26-04	04-187	04-159	04-86	04-117	04-118	04-151	04-154	8
				04-87	04-90	04-110	04-92	04-99	04-159	04-162	04-164	04-94	04-97	04-91	04-123	04-172	04-173	04-174	29-03	04-101	04-187	04-102	04-120	04-121	29-01	04-119	04-122	04-93	04-95	04-100	04-104	04-107	7
			04-126	04-150	04-152	04-153	04-176	04-181	04-183	04-108	31-08	04-158		24-01	31-09	39-02	04-112	04-156	04-160	04-175	04-179	04-182	04-188	04-189	04-166	04-171	04-167	04-127	04-138	26-06	04-168	04-170	6
			04-177	26-02	04-186	37-16	04-125	04-180	04-116		26-16	26-04	04-187	04-159	04-86	04-117	04-118	04-151	04-154	04-127	04-84	04-128	04-129	04-155	04-87	04-90	04-110	04-92	04-99	04-159	04-162	04-164	5
		04-123	04-172	04-173	04-174	29-03	04-101	04-187	04-102	04-120	04-121	29-01	04-119	04-122	04-88	04-95	04-98	04-103	04-106	39-05	04-83	04-111	04-124	04-126	04-150	04-152	04-153	04-176	04-181	04-183	04-109	31-08	4
		31-05	39-03	04-112	04-157	04-161	04-175	04-179	04-182	04-188	04-189	04-166	04-171	04-167	04-127	04-138	26-07	04-168	04-170	04-178	04-125		04-163	04-177	26-02	04-186	37-16	04-125	04-180	26-17		26-16	3
	04-159	04-86	04-117	04-118	04-151	04-154	04-127	04-84	04-128	04-129	04-155	04-87	04-90	04-110	04-92	04-99	04-159	04-162	04-164	04-94	04-97	04-91	04-123	04-172	04-173	04-174	29-03	04-101	04-187	04-102	04-120	04-121	2
04-119	04-122	04-88	04-95	04-98	04-103	04-106	39-05	04-89	04-111	04-124	04-126	04-150	04-152	04-153	04-176	04-181	04-183	04-109		04-158	04-165	24-01	31-05	39-03	04-113	04-156	04-161	04-175	04-179	04-182	04-188	04-189	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	

Fig. 2. Layout of outbreeding seed orchard of Norway spruce in Kórnik

Table 6. Provenance contribution (%) to genetic composition of outbreeding seed orchard progeny

Provenance	Clones with female strobili	Clones with mature cones	Clones producing seeds (full + empty)	Total No. of seeds produced (full + empty)	Total No. of full seeds produced
Serwy	21.4	21.4	20.4	50.3	62.9
Karnieszewice	18.4	16.5	16.5	35.9	20.6
Kolonowskie	13.6	9.7	7.8	3.5	5.2
Istebna	19.4	11.6	10.7	9.8	10.6
Jasina	18.4	8.7	8.7	0.5	0.7

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