Ann Sci For (1993) 50, Suppl 1, 137s-143s

Original article

Results of species hybridization with *Quercus robur* L and *Quercus petraea* (Matt) Liebl

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Summary — *Quercus robur* and *Quercus petraea* can be crossbred. The hybridization rate is affected by the fact that *Q robur* is more easy fertilized with *Q petraea* pollen than *vice versa*, and the fact that individual incompatibilities hinder pollination. The fertilization rate of intraspecific crosses was about 21.6% (with a pollen mixture) and 12.6% (with single-tree pollen) for *Q robur* and 13.7% (pollen mixture) and 17.6% (single-tree pollen) for *Q petraea*. Interspecific crosses had fertilization rates of 6.5% (pollen mixture) and 11.5% (single-tree pollen) for *Q robur* and 9.2% (pollen mixture) and 1.8% (single-tree pollen) for *Q petraea*. After selecting clones that readily accepted pollen from the other species, the fertilization rate increased greatly, especially for the *combination Q petraea* x *Q robur* (single-tree pollen). Dried pollen can be stored at –18 °C.

***Quercus robur L / Quercus petraea* (Matt) Liebl / hybridization / cross breeding**

Résumé — Résultats des hybridations contrôlées entre *Quercus robur* L et *Quercus petraea* (Matt) Liebl. Quercus robur *et* Quercus petraea *sont des espèces compatibles. Cependant le croisement de* Q robur *avec du pollen de* Q petraea *est plus facile que le croisement inverse; d'autre part le taux d'hybridation dépend aussi des phénomènes d'incompatibilité au niveau individuel. Le taux d'hybridation dans les croisements intraspécifiques est de 21,6% (mélange pollinique) et de 12,6% (pollen d'arbres individuels) pour* Q robur. *Ces chiffres sont respectivement 13,7% et 17,6% pour* Q petraea. *Les mêmes taux au niveau des croisements interspécifiques sont de 6,5% (mélange pollinique) et 11,5% (pollen d'arbres individuels) chez* Q robur *et 9,2% (mélange pollinique) et 1,8% (pollen d'arbres individuels) chez* Q petraea. *Ces chiffres augmentent très nettement si on sélectionne les meilleures combinaisons (arbres les plus compatibles) surtout pour le croisement* Q petraea / Q robur. *Le pollen peut être conservé à –18 °C.*

Quercus robur *L* / Quercus petraea *(Matt) Liebl / hybridation / croisement contrôlé*

INTRODUCTION

Both species *Q robur* and *Q petraea* grow in Germany. The geographical range of *Q petraea* includes that of *Q robur.* Their ecology is different, although mixed stands are common and intermediate types have always been found (Krahl-Urban, 1959; Kleinschmit and Svolba, 1979). These forms were regarded as hybrids or as form variations of *Quercus,* mainly *robur* (Burger, 1921; Jovanovic and Tucovic, 1975; Wigston, 1975; Rushton, 1978; Kleinschmit and Svolba, 1979; Aas, 1988).

In 1989 and 1990, a controlled crossing program of *Q robur* and *Q petraea* was initiated on the seed orchards of Berkel, near Hannover. The goals of this program are to obtain further information on the following questions : - How does the crossing technique for these species work? - What is the difference between the intra- and interspecific pollination rates? - What are the growth rate and survival percentage and how do the hybrids look?

MATERIALS AND METHODS

The *Q petraea* and *Q robur* seed orchards in Berkel were established in 1955 and 1957 with grafts from selected plus trees by Krahl-Urban. Isolation of the female strobili began with bud flushing. Male strobili and buds which did not have any female strobili were removed by hand. Branches with at least 5 female flowers (only the flower-bearing stems were counted) were isolated in paper-cellophane bags.

Just before natural pollen shedding, the pollen was collected in paper bags and dried in a *ca* 23°C warm room with low air humidity. After cleaning, the pollen was dried, separated by clone, and placed a second time in a ca 23°C warm room or the desiccator (for 4 h). The pollen was stored for shorter periods (up to 2 wk) at +1°C or, for long-term storage, at −18°C. A pollen sprayer with a rubber bulb, 2 pipes pressed through the rubber stopper into the pollen bottle and a needle to pierce the bag made the pollination unit. Pollination was done when the pistil was large, widely open, glossy and glutinous.

Pollen which was collected in 1989 and not needed for crossing that year was stored in glass bottles at −18°C. It was successfully used for pollination the following year.

RESULTS

In 1989, about 15 000 female strobili were control-pollinated. Table I shows the crossing combinations and the number of successful combinations, the number of acorns produced and the measurements of the acorns. Many acorns were very small and did not germinate in the spring of 1990. Some loss of acorns was due to fungal damage. The hybrid combination *Q robur* x *Q petraea* was more successful (6.5% of the flowers pollinated with a pollen mixture and 11.5% of those pollinated with single-tree pollen produced acorns) than the combination *Q petraea* x *Q robur* (9.2% of the flowers pollinated with a pollen mixture and 1.8% of those pollinated with single-tree pollen produced acorns). The self-pollination rate for *Q robur* was 1.9% and for *Q petraea* it was very small, with only 0.6% acorns of pollinated flowers.

Table II shows the germination rate, growth during the 1st and 2nd years and the survival percentage for each year. Normally, the height of oak seedlings growth depends upon the size of the acorns and of the mother; the bigger the acorn the taller the seedlings, and *Q robur* seedlings are taller than *Q petraea* seedlings. Until now, the hybrids have not shown any significant differences from the pure species. Therefore, each acorn from the 1990 crossing was measured and weighted (table III).

En 1990, a total of 4443 female flowers were isolated. On each mother tree, a pollen mixture and a tester pollen from both species were used for the pollination. In addition pair crossings were made. Table IV shows the 1990 campaign.

Acorns were stored after thermotherapy (42°C water soaking for 2 h) in small bags in a cool house at −1°C over winter. Many acorns were lost due to fungal damage and mice. Before sowing, the acorns were soaked in moderately warm water.

All differences in growth rate between seedlings from different crosses were attributable to the size of the acorns.

Table I. Oak crosses 1989: combinations, rate of successful combinations and acorn measurement data.

Crossing partners	*Combinations (n)*		*Successful (n) combinations*	*Pollinated flowers*	*Acorns (n)*	*Rate (%)*	*Average length (mm)*	*Average diameter (mm)*	*Average weight (g)*
Q robur x pollen mixture *Q robur*	17[a]	(3)	13	1410	306	21.7	25.0	14.2	3.4
Q robur x single-tree *Q robur*	13	(8)	10	1352	170	12.6	24.3	14.0	3.5
Q robur x pollen mixture *Q petraea*	19	(3)	8	2285	145	6.5	25.2	14.5	3.7
Q robur x single-tree *Q petraea*	10	(10)	4	902	104	11.5	25.8	15.5	3.5
Q petraea x pollen mixture *Q petraea*	22	(3)	7	2160	295	13.7	19.7	12.1	2.1
Q petraea x single-tree *Q petraea*	12	(10)	7	941	166	17.6	19.4	11.8	1.9
Q petraea x pollen mixture *Q robur*	19	(3)	3	1972	181	9.2	19.2	12.3	2.2
Q petraea x single-tree *Q robur*	17	(10)	1	1626	29	1.8	23.2	12.2	2.5
Q robur self-pollination	23	(23)	3	1404	27	1.9	24.8	14.1	2.8
Q petraea self-pollination	32	(32)	2	944	6	0.6	20.3	12.0	2.0

[a] *(x)* indicates the number of different pollen used.

Table II. Oak crosses 1989: seedlings 1990 and 1991, growth and survival data compared to pollinated flowers.

Crossing partners	*Seedlings (n) 10/1990*	*Germination (%)*	*% Germination/ flowers*	*Average height (cm) 1990*	*Seedlings 08/1991 (n)*	*Average height (cm)*	*Survival % acorns flowers*
Q robur x pollen mixture *Q robur*	186	60.8	13.2	20.77	185	44.98	13.1
Q robur x single-tree *Q robur*	83	48.8	6.1	17.47	86	35.77	6.3[a]
Q robur x pollen mixture *Q petraea*	48	33.1	2.1	18.58	49	39.63	2.1[a]
Q robur x single-tree *Q petraea*	58	55.8	6.4	14.06	48	38.83	5.3
Q petraea x pollen mixture *Q petraea*	64	21.7	2.9	11.40	64	29.14	2.9
Q petraea x single-tree *Q petraea*	39	23.5	4.1	11.53	37	30.08	3.9
Q petraea x pollen mixture *Q robur*	11	6.1	0.6	10.81	11	25.82	0.6
Q petraea x single-tree *Q robur*	2	6.9	0.1	15.50	4	31.00	0.2[a]
Q robur self-pollination	12	44.4	0.8	17.08	9	23.89	0.6
Q petraea self-pollination	0	0	0	0	0	0	0

[a] Plants considered to be dead had recovered.

Table III. Oak crosses 1990: acorns 1991 data, sowing 1991 seedling growth data.

Crossing partners	*Acorns 4/1991 (n)*	*Average length (mm)*	*Average diameter (mm)*	*Average weight (g)*	*Seedling height 8/1991*	*Seedling 8/1991 (n)*	*% seedlings of acorns sown*	*% seedlings of flowers isolated*
Q robur x pollen mixture *Q robur*	13	26.66	15.47	3.79	11.75	8	61.54	2.75
Q robur x tester pollen *Q robur*	16	26.72	15.38	3.52	14.57	14	87.50	5.13
Q robur x single-tree *Q robur*	34	24.23	16.65	4.53	12.12	26	76.47	5.88
Q robur x pollen mixture *Q petraea*	14	29.24	15.71	4.55	13.07	14	100.00	4.95
Q robur x tester pollen *Q petraea*	8	26.63	16.63	4.60	12.50	4	50.00	1.45
Q robur x single-tree *Q petraea*	18	26.57	16.71	4.15	10.92	13	72.22	2.82
Q petraea x pollen mixture *Q petraea*	35	20.77	13.24	1.88	4.75	4	11.43	1.19
Q petraea x tester pollen *Q petraea*	28	21.79	12.98	2.19	5.36	8	28.57	2.87
Q petraea x single-tree *Q petraea*	28	21.70	12.46	1.90	7.80	5	17.86	0.83
Q petraea x pollen mixture *Q robur*	54	20.15	12.58	1.74	5.50	6	11.11	1.95
Q petraea x tester pollen *Q robur*	19	24.36	12.68	2.18	6.56	9	47.37	3.30
Q petraea x single-tree *Q robur*	10	24.08	14.17	2.31	0	0	0	0

Table IV. Oak crosses 1990: combinations, rate of successful combinations, acorns achieved and rate of acorns compared to pollinated flowers.

Crossing partners	*Combinations (n)*	*Successful combinations (n)*	*Pollinated flowers*	*Acorns 10/1990 (n)*	*Rate (%)*
Q robur x pollen mixture *Q robur*	11	6	291	26	8.94
Q robur x tester pollen *Q robur*	11	5	273	16	5.86
Q robur x single-tree *Q robur*	18	11	442	70	15.84
Q robur x pollen mixture *Q petraea*	11	4	283	21	7.42
Q robur x tester pollen *Q petraea*	11	5	275	24	8.72
Q robur x single-tree *Q petraea*	18	11	461	23	4,99
Q petraea x pollen mixture *Q petraea*	15	7	335	35	10.45
Q petraea x tester pol *Q petraea*	13	8	279	63	22.58
Q petraea x single-tree *Q petraea*	22	8	602	47	7.81
Q petraea x pollen mixture *Q robur*	13	6	308	68	22.08
Q petraea x tester pollen *Q robur*	13	3	273	68	7,69
Q petraea x single-tree *Q robur*	23	3	621	10	1,61

Morphologically, most of the seedlings resembled their mother. As long as the trees are juvenile, no statistical assesments will be made.

At this point, no significant indication for heterosis of interspecific hybrids can be observed, unlike those reported for other crossings in oak (Piatnitsky, 1960). The seedlings with *Q robur* mothers had the bigger and heavier acorns and they grew bigger and faster than the seedlings who had a *Q petraea* mother.

DISCUSSION

The isolation and pollination technique for oak was devised. The main problem was determining the optimal time for pollen collection. After drying, pollen was stored at –18 °C and was successfully used for pollination the following year. Artificial crossing of *Q robur* and *Q petraea* produces fewer acorns (0.2–13.1% of pollinated flowers) than natural pollination (16%; Jovanovic and Tucovic, 1975). *Quercus robur* has higher reproduction rates when pollinated with pollen from *Q petraea* than *vice versa*. Clones selected for their crossability with the other species have high reproduction rates in interspecific crossing. As *Q robur* is morphologically the more variable species, it can only be surmised that the differences in crossability are due to introgression or variation due environmental factors (Ietswaart and Feij, 1989).

Clones selected from their original stands (pure, mixed or intermediate) and their leaf characters should be crossed.

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