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Selection of Dwarfing Pear Rootstock Clones from *Pyrus betulaefolia* and *P. calleryana* Seedlings

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A rootstock trial has been established to develop dwarfing pear rootstock clones from *Pyrus* species. Seedlings that were raised from the open-pollinated seeds of *P. betulaefolia* Bunge (PB) and *P. calleryana* Decne (PC); and showed significant genetic dwarfing growth and good traits based on ease of clonal propagation were screened. Among those, four seedlings of PB named SPRB1, SPRB13, SPRB15, and SPRB22 (SPRB = Shinshu University Pear Rootstock *P. betulaefolia* clone) and six seedlings of PC named SPRC3, SPRC5, SPRC8, SPRC13, SPRC15, and SPRC20 (SPRC = Shinshu University Pear Rootstock *P. calleryana* clone) were selected. Clones that were generated from the selected seedlings had significantly higher rooting ability by softwood cuttings compared with the control during an 8-year test. Japanese pear 'Kosui' and European pears 'La France' and 'Conference' revealed a dwarfing growth habit when grafted onto the selected clones. All scion/stock combinations interacted significantly to affect shoot growth, trunk cross-sectional area (TCSA), and canopy spread. There was no noticeable difference in the fruit yield per tree of three cultivars grafted on PB and SPRB1, but the estimated yields per ha increased more than 20% in all cultivars on SPRB1. 'La France' trees on SPRB15 and SPRC20 began to bear early with significantly higher yields. Fruit quality characteristics of 'La France' and 'Conference' did not differ because of the influence of stock clones, however, 'Kosui'/SPRB1 had lower average fruit weight that corresponded to the lighter fruit skin color.

Key Words: dwarfing rootstock clone, pear, *P. betulaefolia*, *P. calleryana*.

Introduction

Pear varieties worldwide are grafted on different clonal and seedling rootstocks of *Pyrus* and *Cydonia* species. Clonal stocks are more suitable than seedling stocks because the former provide a more homogenous orchard system than do the latter. In addition, dwarfing clonal stocks are equally important to preserve their special characteristics and the specific influences they have on scions, such as dwarfing growth, precocious yield, disease resistance and environmental adaptability. Several attempts have been made for many years worldwide to breed dwarfing rootstocks within *Pyrus*. In Sweden, Balsgard Station developed BP-10030, a dwarfing, frost hardy clonal *Pyrus* rootstock that is difficult to root (Zhu et al., 2003). Dwarfing pear rootstock breeding has been successful in the development of the 'Old Home' × 'Farmingdale' (OH × F) clonal series by Brooks (1984) and for the perry pear hybrid rootstocks by Brossier (1977). Beginning with 516 seedlings from an open-pollinated cross, Brooks has selected 13 OH × F clonal rootstocks. More recently, Campbell (2003) reported that German pear breeding program developed 'Pyrodwarf' from a cross between 'Old Home' and 'Bonne Louise d'Avranches', which is more precocious and dwarfing than OHF 97, suitable for high-density planting. Webster (2003) mentioned that PC and *P. heterophylla* Regal & Schmalh have been shown to provide slight and inconsistent scion vigor control. Pear rootstock research at Oregon State University has identified several clonal stocks from *Pyrus* species, including PB (OPR 260, 261, 264) and PC (OPR 157, 191, 205, 211, 249) that show considerable promise as dwarfing rootstock but with poor rooting capacity (Lombard et al., 1984).

Pear varieties grafted on PB and PC are popular in Japan, the United States, China, and Chile because they display good anchorage and offer the most useful genetic traits as a rootstock. PB is a vigorous rootstock with a deep-rooted system; it is tolerant of winter cold and both wet and dry soils. It has particular importance for Japanese pear cultivars because of its resistance to Yuzuhada (rough fruit skin) disorder of the fruit. PC is a less vigorous rootstock with a wide range of soil adaptation, except alkaline soil, and suitable for hot and wet climatic conditions. It tolerates wet soil better than do OH × F, quince, and 'Bartlett' seedlings (Stebbins, 1989). It is also very resistant to fire blight and pear decline; it produces high yields of good quality fruits.

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Both PB and PC possess most of the desirable rootstock characters; however, improvement of rooting ability and incorporation of dwarfing traits would make them ideal rootstocks for pear trees. To date, no efforts have been made to develop genetically dwarfing rootstocks for pears. Although dwarfing scion growth for pear trees has been achieved on quince rootstock (Kawase, 1995), some members of the species are graft-incompatible with some *P. communis* and *P. pyrifolia* cultivars.

In Japan, traditionally pears have been (and still are) cultivated mainly on *P. pyrifolia* rootstock by fixing branches onto horizontal wire trellis (pergola training system) to prevent typhoon damage and to facilitate intensive field management (Kajiura, 1994). But a recent trend is to grow pears in the flat area rather than to plant rice or under protected cultivation in plastic houses to hasten the harvest time. Consequently, a strong demand for uniform and dwarfing scion growth has increased among the pear growers. Therefore, this trial has been initiated to test the postulation that the dwarfing clones from open-pollinated progenies of PB and PC may induce dwarfing scion growth as well as other important pomological traits.

Materials and Methods

This rootstock trial was initiated in 1992 at the Research Farm of the Laboratory of Pomology, Faculty of Agriculture, Shinshu University, Japan. The soil of the research farm is a volcanic ash series with perfect drainage. Two experiments were conducted simultaneously to select the dwarfing rootstock clones and to evaluate their influences on scion cultivars.

1. Screening of dwarf seedlings from the progeny of PB and PC (Experiment 1)

Numerous seeds of PB and PC that originated from open-pollination were germinated for seedling production during 1992. Seedlings, possessing a wide range of vigor, were assessed. A total of 1530 PB seedlings and 531 PC seedlings were screened as dwarf seedlings. Low-vigor seedlings were primarily screened from the progenies for further investigations on their growth performance and proliferating ability. The selected seedlings from PB and PC were named SPRB and SPRC, respectively.

The selected progenies and their parental counterparts (PB and PC as controls) were multiplied clonally by softwood cuttings under mist. Sub-apical cuttings were taken from actively growing shoots. Cuttings, 12–15 cm with 2–3 leaves at the distal end, were inserted vertically to a depth of 5–7 cm in a moist mixture of Kanuma soil and peat moss (1:1, v/v). Rooting by softwood cuttings of the selected seedlings and their clones were estimated once per year. Trunk circumference or diameter of each tree was measured 5 cm above the base each November during the 8-year experiment. Simultaneously, the trunk cross-sectional area (TCSA) was computed and recorded. Final screening was made on the basis of dwarfing growth and proliferating ability of the clones as two primary criteria.

2. Influence of the selected dwarfing PB and PC clones on the growth, productivity and fruit quality of scion cultivars (Experiment 2)

'Kosui', 'La France', and 'Conference' were grafted onto the selected clones of PB and PC in the successive years of clonal selections. 'Kosui' and 'La France' were grafted onto the primarily selected PB clone SPRB1 in 1995. In our second screening, 'Conference' was grafted onto the SPRB1 and SPRB13 selections in 1997; thereafter 'La France' was grafted on three SPRB (SPRB13, 15, and 22) and six SPRC (SPRC3, 5, 8, 13, 15, and 20) in 1999. Only 'La France' was grafted on both PB and PC clones to evaluate the comparative scion performance on both types of dwarfing clones. At least three graft combinations were established for each rootstock clone and also for the clones developed from their parental counterparts PB and PC to serve as control. All grafted trees were planted in east-west oriented rows with a 1.5 m in-row and 2.0 m between row spacing. To evaluate the dwarfing effects, trees were allowed to grow free standing with a modified leader and maintained by winter pruning to some extent.

Data on tree growth, shoot growth, graft-compatibility, pruning weight, flowering and fruit yield and quality, were recorded annually. Data on growth were collected in November each year after defoliation. Trunk circumferences of the scion and rootstock were measured approximately 10–15 cm above and below the graft union, respectively. The extent of dwarfism in relation to yield efficiency of scions was assessed on the basis of the following parameters: tree height, canopy spread, fruit yield, yield efficiency, and plant density per ha.

All fruit of each scion/stock combination were harvested in a single harvest based on their specific maturity criteria. Fruit yield per tree was recorded immediately after harvest; fruit quality analysis was done on the same day of harvest for 'Kosui' and after ripening for 'La France' and 'Conference'. For the analyses of fruit quality characteristics, total fruit were graded according to size. Five fruit from the bulk group were taken as a representative sample for further analyses. The important fruit traits such as individual fruit weight, length: diameter ratio, TSS, acidity, flesh firmness, skin color, etc. were measured. Fruit flesh firmness was measured on opposite sides of the fruit with skin removed by using fruit pressure tester (Tenryu, Fruit Tester, TFH-11). Fruit juice was squeezed from the flesh and TSS was measured with a digital refractometer (Atago PR-101). Titratable acidity of fruit juice was measured by titrating fruit juice against 0.1 N NaOH at pH 8.2 and was expressed as percent malic acid. Fruit skin color of 'Kosui' was measured by using a standard color chart (JA Zenno, Tottori).

Results and Discussion

1. Screening of dwarf seedlings from the progeny of PB and PC (Experiment 1)

In this experiment, research emphasis was focused on selecting dwarfing *Pyrus* rootstock clones having good rooting ability. Hence, numerous seedlings, derived from open-pollination of PB and PC showing a very wide range of vigor, were grown.

In 1992, after preliminary screening of 1530 PB seedlings, 14 seedlings that showed genetic dwarfism were selected for clonal propagation to observe their growth and rooting performance. Again in 1994, eight dwarfed PB seedlings were selected in the same manner. Growth and rooting ability of the clones of these selected seedlings varied greatly. However, some of them exhibited normal growth after the clonal propagation. Clones, showing normal growth but derived from the dwarfed seedlings, were discontinued for further investigations. Of 22 (14 + 8) SPRB seedlings, four (SPRB1, 13, 15, and 22) were selected as displaying more dwarfing tendency with good rooting ability. Accordingly, starting with 531 PC seedlings, 16 were primarily selected. However, six SPRC seedlings (SPRC3, 5, 8, 13, 15, and 20) were found to be more dwarfing with good rooting capacities. The selected SPRB and SPRC also displayed a similar growth tendency in TCSA (Fig. 1), but a distinct reduction compared with their parent clones PB and PC.

In our screening, the dwarfing variances in the seedling population of PB and PC were 1.4% and 6.0%, respectively. In general, the seedlings of PC showed a wide range of variations including morphological traits compared with those of PB. The selected clones are genetically dwarfed, based on their size characteristic that is determined by the genetic makeup of their parents. With these SPRB and SPRC, which have a high level of dwarfism (less than 15% compared with the control, Fig. 1), it was thought that enough dwarfing growth for scion cultivars would be found after being grafted onto these clones.

In general, all the selected SPRB and SPRC had higher rooting capacity by softwood cuttings compared with the controls (Fig. 2). Ease of rooting in *Pyrus* is less common, but it is an important character because it permits clonal propagation of rootstocks and the preservation of characters, such as dwarfing. In this trial the selected SPRB and SPRC rooted well by softwood cuttings under mist. In pear, softwood cuttings root easily under mist (Hartmann et al., 1990), but the cuttings have to stay in the same place for at least two years, otherwise the regrowth is very bad. To make the cuttings ready for grafting in the following year and to ensure a good regrowth, hardwood cuttings were placed under protected conditions where all the selected clones rooted better (45–55% for SPRB and 70–80% for SPRC, whereas 20 and 33% of the control PB and PC cuttings, respectively, rooted). PB and PC cuttings root poorly from hardwood cuttings (Ali and Westwood, 1966); rooting by hardwood cuttings of PB did not exceed 16% (Loreti and Morini, 1977). In this work, the higher rooting by hardwood cuttings is probably the result of protecting them from unfavorable environmental conditions, e.g. low humidity to prevent their dehydration. The annual rooting percentage was higher in all the clones, including the control during the initial growing seasons, but only the selected clones had higher rooting until the 12th-year trial. Although for most pear rootstocks the most easy to root shoots are taken from stock plants in a juvenile state (Ali and Westwood, 1968), the selected clones seem to have a more consistent rooting potential.

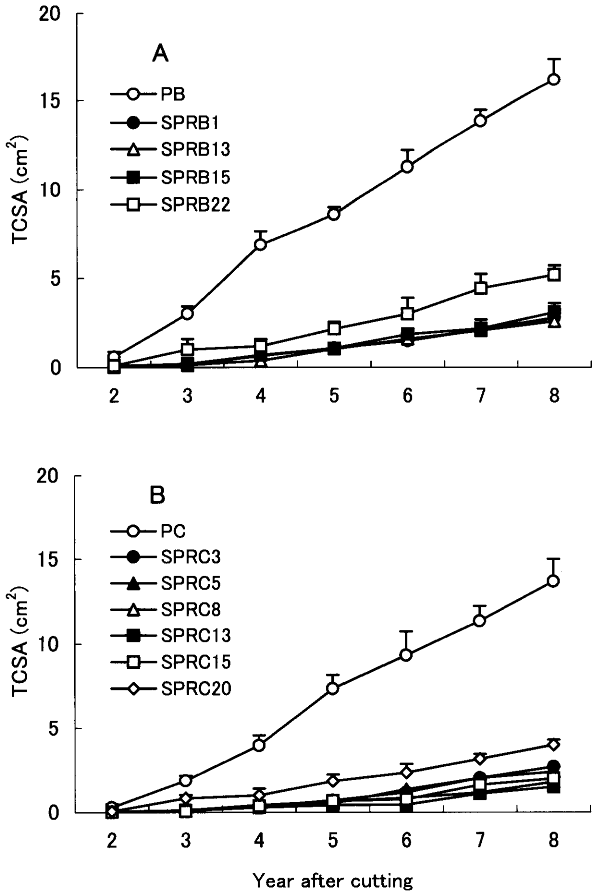

Fig. 1. Annual growth in trunk cross-sectional area (TCSA) of PB (A) and PC (B) clones. Vertical bars indicate SE (n = 3).

PB that originated in northeast China with severe cold winters; PC originated in central China where the climate is milder. This research was conducted in the cool-zone (minimum temp. below −15°C in winter) of Nagano in Japan; however, in this climate, even the selected PC clones, survived and grew well during the 12-year trial. In the United States, PC clones are also used in areas with relatively cold winters, such as northern Oregon. Accordingly, the selected PC clones seem to be cold-hardy enough for Nagano, Japan; both of these PB and

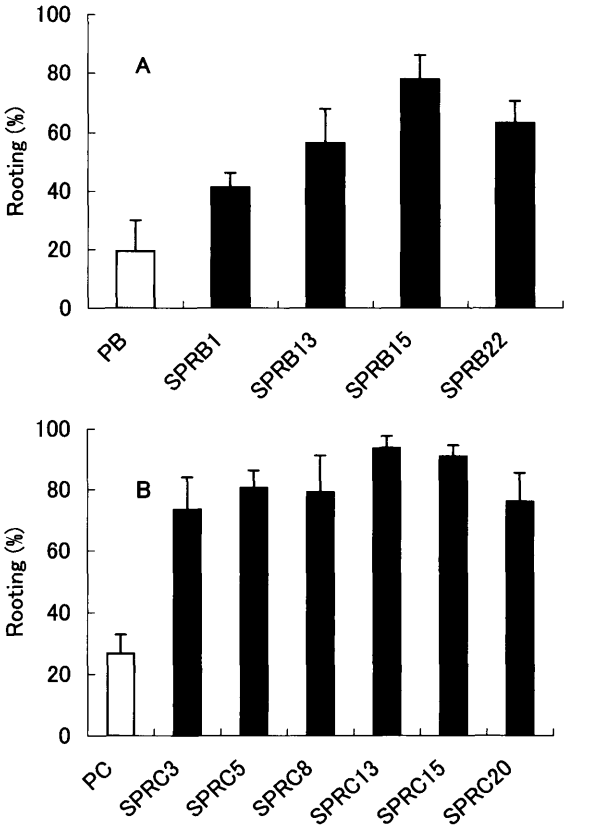

Fig. 2. Rooting by softwood cuttings of PB (A) and PC (B) clones. Mean values for 8-year. Vertical bars indicate SE (n = 8).

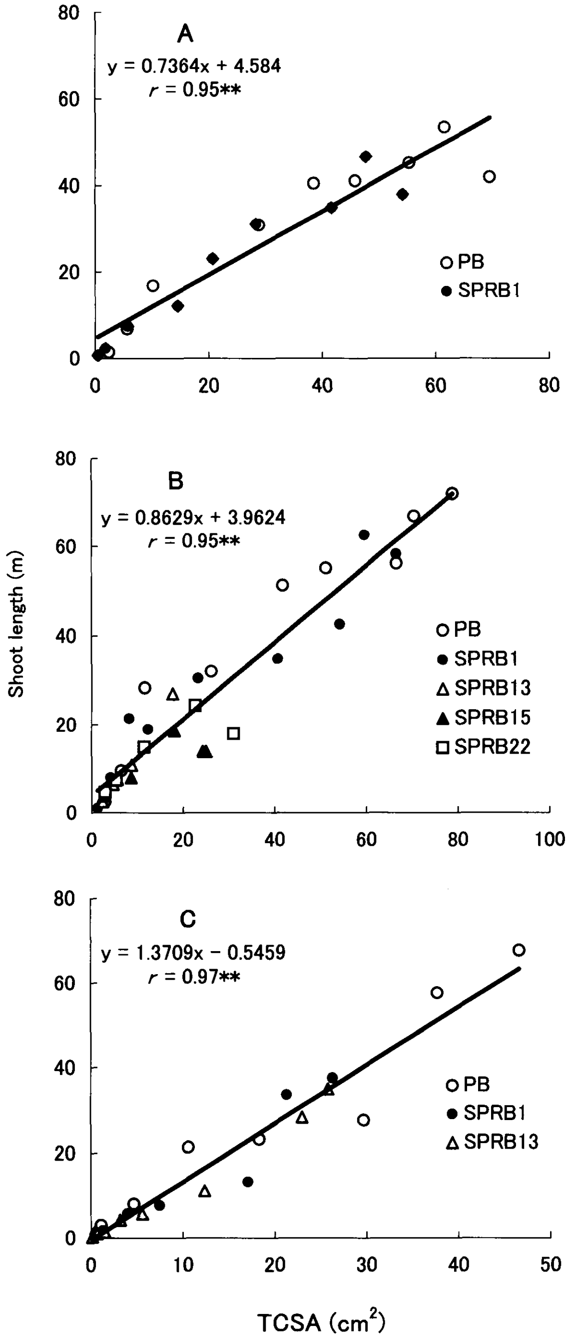

Fig. 3. Relationship between shoot growth and trunk cross-sectional area (TCSA) of 'Kosui' (A), 'La France' (B), and 'Conference' (C) on PB clones.

PC clones seem to be suitable for this climate. Adaptability to environmental stress factors of the selected clones is currently being investigated. In a preliminary trial on the flooding tolerance of these clones, we found variable flooding responses among them. Specifically, SPRB15, SPRB22, SPRC15, and SPRC20, were found to be more tolerant to anaerobic environments. Tamura et al. (1995) in *Pyrus* rootstocks reported that two strains of PC were more tolerant to flooding than were PB and *P. pyrifolia* Nakai.

2. Influence of the selected dwarfing PB and PC clones on the growth, productivity and fruit quality of scion cultivars (Experiment 2)

In Expt. 1, a range of dwarfing growth among the PB and PC clones was observed. To verify the effects of the growth variability on scions, Expt. 2 was conducted utilizing 'Kosui', 'La France', and 'Conference' as scions. Trees on PB and PC clones are now at different growing stages; hence, data reporting are subject to their availability.

1) Tree growth

Regression analysis that was done to quantify the relationship between shoot growth and TCSA of the scions revealed that when TCSA was plotted against the shoot growth, a linear relationship was observed (Fig. 3). Regression lines were calculated for the entire data set, but also for each stock-scion combination, in which the intercepts and slopes varied slightly (data not shown). The coefficients of determination were significant at the 1% level. These estimated relationships strongly support the conclusion made by Westwood and Roberts (1970) that TCSA is an excellent indicator of scion growth.

In this Expt., although scions had dwarfing growth habit after being grafted onto the selected SPRB (Fig. 4) and SPRC (Fig. 5), the results were not consistent for all the clones; the range of scion vigor varied from 50–

100%, when compared with the controls. Generally, the growth percentage of scions ranged from 60–80% on PB clones and 50–90% on PC clones. This result is partially consistent with the result of Lombard and Westwood (1987) who stated that in pear that originated from East Asia, tree sizes were 110% of standard on PB Oregon clones and 15–70% of standard on PC Oregon clones. The normal standard vigor on 'Bartlett' seedling rootstock was considered as 100%. In a pear rootstock trial throughout the USA and Canada, Azarenko et al. (2002) reported that trees were smaller on PC; PB produced vigorous trees with intermediate yields and performed consistently across the locations.

Dwarfing scion growth for pear trees has been reported on quince (*Cydonia*) stock, but it shows apparent incompatibilities because of a distant botanical relationship (Tukey, 1964). In this work, we selected genetic dwarfing clones from the same *Pyrus* genus that show reduced scion growth but with a good graft-compatibility with the scions involved. The mechanism of this dwarfing scion growth is a question because the clones are genetically dwarf and not all clones performed equally with the scions. To understand the mechanism of dwarfing scion growth better, we investigated graft-compatibility on the basis of rootstock to scion (R/S) ratio, because dwarfing scion growth for pear and apple trees have been based mainly on symptoms of graft-incompatibility, such as over-growth at the graft union (Tukey, 1964).

'Kosui' on PB and SPRB1 at year 10 had R/S ratios 1.35 and 1.21, respectively. 'La France' on PB and PC at year 5 had R/S ratios 0.75 and 0.70, respectively, but on PB and PC clones, the ratios ranged from 0.85–0.95 and 0.77–0.85, respectively. 'Conference' on PB, SPRB1 and SPRB13 at year 8 had R/S ratios 0.83, 0.92, and 0.90, respectively. The above results indicate that

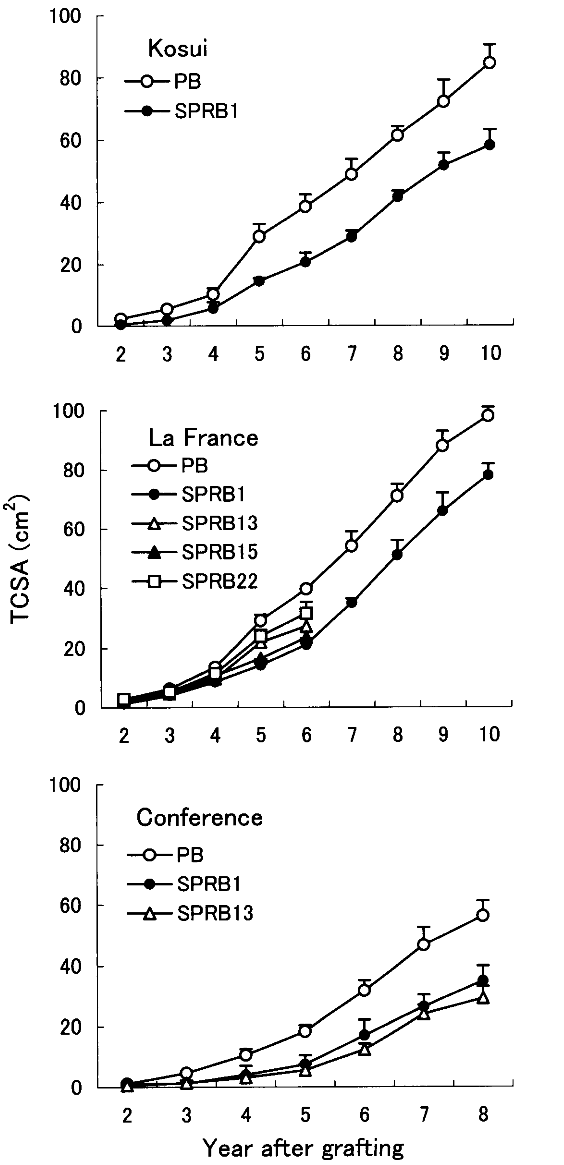

Fig. 4. Annual growth in trunk cross-sectional area (TCSA) of 'Kosui', 'La France', and 'Conference' on PB clones. Vertical bars indicate SE (n = 3).

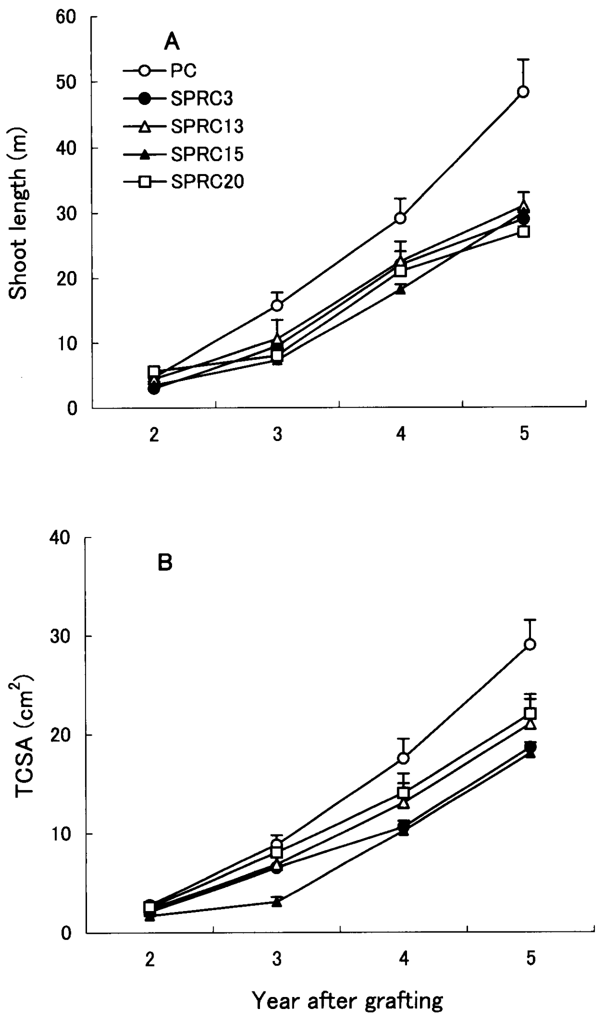

Fig. 5. Annual shoot growth (A), and annual trunk growth (B) in trunk cross-sectional area (TCSA) of 'La France' on PC clones. Vertical bars indicate SE (n = 3).

dwarfing scion growth had R/S ratios of approximately 1.0 that show an equal growth above and below the graft union compared with the control trees. Here, it can be deduced that the reduction in scion growth did not occur because of any extreme graft-incompatibility; rather it might be a result of the effects of genetic dwarfing attributes of the stocks to the growth of scions. Generally, dwarfing scion growth results from a multitude of inherent relationships between the stock and scion, where the various degrees of congeniality in scion/stock relations determine the degrees of dwarfness. According to Simons (1987) the dwarfing influence possessed by apple rootstocks was correlated with the amount of living tissue in the roots. Proebsting (1926) studied structural weaknesses in interspecific grafts of *Pyrus*, and reported that the structure of the wood of the rootstock roots (the amount of fiber elements and ray cells) was related to the vigor of the scion.

Another probable cause of dwarfing scion growth may be the utilization of enough food reserves of scion for the recovery of the growth of stock partner. For example, with SPRB1, the TCSA of rootstock itself was 2.8 cm^2 at year 8 (Fig. 1), whereas the TCSAs of the same rootstock at the same age grafted with 'Kosui', 'La France', and 'Conference' were 48.2 cm^2, 43.4 cm^2, and 31.3 cm^2, respectively. When scion was grafted, the TCSA of the dwarfing rootstock increased more rapidly while scion growth decreased to some extent, based on the stock/scion combination. Tukey (1964) stated that weak growing stocks require small reserves of carbohydrates and extract less minerals from the soil. The vigorous scions, on the contrary, tend to accumulate more carbohydrates and assimilate ease in nitrogen that result in high carbohydrate-nitrogen relation in the scion, which leads to dwarfing and precocity. However, since the selected SPRB and SPRC were derived from a large group of open-pollinated progeny, they could have a range of vigor potential for controlling the scion growth and may combine some other important rootstock traits.

2) Tree size

Trees were trained to a free standing system to estimate the actual dwarfing potential. Tree canopy spread of the scions was significantly lower, which ultimately resulted in higher tree accommodation per unit area (Table 1). Dwarfing culture that uses quince EM-A in Nagano prefecture recommends a 4 × 2 m plant spacing. Accordingly, taking the vigor of the scions into consideration, we used a comparable spacing to estimate an optimum density of trees/ha, where all the scions had considerably higher tree accommodation. This scheme anticipates the possibility of intensive planting with high return onto the selected clones because dwarfed trees could be planted at high densities to achieve maximum yield. The tree-to-tree growth variability was reduced onto the same stock clones, which correspond to the protected pear cultivation under plastic house with these selected clones.

3) Precocity and bloom dates

Bloom dates did not appear to be affected much by the influence of the selected rootstock clones. Only one to two days difference in anthesis between the control and treatments was observed. In general, Japanese pear cultivars are more precocious than European pears because of the ease of which many axillary flower buds differentiate on extension shoots. 'Kosui' is noted for developing many axillary flower buds among the Japanese pears. In addition, more vigorous shoots or trees develop more flower buds at the younger stage. Contrarily, European pears tend to bear terminal flowers on extension shoots; 'La France' is one of the comparatively precocious cultivars among them. In this trial, 'Kosui' on PB and SPRB1 began flowering at year

Table 1. Tree growth and productivity of 'Kosui', 'La France' and 'Conference' as influenced by the selected SPRB1.

Cultivar	Rootstock	Tree height (m)	Canopy spread (m)	TCSA[z] (cm^2)	Fruit yield (kg/tree)	Cumulative		Estimated plant density and yield per ha		
						Yield (kg/tree)	Yield efficiency (kg/cm^2TCSA)	Plant density[y] (No. of trees)	Yield (kg)	%Yield compared to control
Kosui	SPRB1	4.5	2.3	51.7	6.84	19.73	0.38	800	5474	121
	PB	4.9	3.2	72.3	8.01	23.01	0.32	570	4564	100
	Significance	NS[x]	*	*	*	*	*			
La France	SPRB1	4.4	2.5	66.6	5.22	22.69	0.34	800	4177	153
	PB	4.7	3.3	88.4	4.81	22.40	0.25	570	2743	100
	Significance	NS	*	*	NS	NS	**			
Conference	SPRB1	2.9	1.6	26.3	1.88	3.14	0.12	1000	1883	122
	PB	3.8	2.4	46.6	2.30	3.71	0.08	660	1520	100
	Significance	*	*	**	NS	NS	*			

Data for 'Kosui' and 'La France' at year 9 (2003) and 'Conference' at year 7 (2003).
[z] Trunk cross-sectional area.
[y] Cal. spacing: Kosui/SPRB1 and La France/SPRB1, 5 m × 2.5 m; Kosui/PB and La France/PB, 5 m × 3.5 m; Conference/SPRB1, 5 m × 2 m; Conference/PB, 5 m × 3 m.
[x] NS, *, ** indicate non-significant, significant at $P < 0.05$ and 0.01 by *t*-test, respectively.

4. There was no significant difference of number of flower buds per tree between both rootstocks until year 9 except year 6 (Fig. 6). Although 'Kosui' trees on PB had many axillary flower buds at year 6, there was no significant yield difference with the trees on SPRB1 because of the fruit thinning for adjustment of leaf-fruit ratio to a desirable level. Moreover, flower buds were counted before winter pruning where some of the lateral flower buds were pruned.

'La France' on PB and some SPRB began flowering at year 3 (Fig. 7) and the number of buds per tree on each rootstock increased rapidly until year 6. Particularly, 'La France' on SPRB15 began flowering at year 3 and continued to produce high, early yields to the current season (year 6). 'La France' on SPRC20 started fruiting at year 4 and yielded significantly more fruits than the control trees for two consecutive years. The above results may reflect the precocity of SPRB15 and SPRC20; moreover, trees on these two clones had many spur flower buds with few extension shoots from year 5, demonstrating the relative dwarfing potentials of these rootstocks. However, 'La France' trees on SPRB13, produced few flowers and low yield until year 6, indicating that the trees on SPRB13 are less efficient than other PB clones. Although 'Conference' trees on SPRB1 and SPRB13 first flowered at year 4, a substantial increase in fruiting occurred from year 6 followed by a gradual increase in the subsequent years (Fig. 8). Griggs (1969) found that several different rootstocks had little influence on bloom dates of three pear cultivars in California. In this trial, flowering and fruit productivity are still under investigation.

4) Fruit yield and quality

An annual alternating bearing was observed in 'Kosui' and 'La France' but not in 'Conference' (Figs. 6–8). This alternating bearing habit might be in part due to the young ages of plants. Fruit yields were drastically diminishing in 2001 (year 7 for 'Kosui' and 'La France', and year 5 for 'Conference'). The reason for lower yields to that fruiting season was the occurrence of early frost injury in April, 2001 during bloom. In that season the temperature dropped to −4°C, when most flowers were at anthesis. Fruit yield was also affected by inclement weather (severe typhoon) in July, 2004. Consequently, data on fruit yield and yield efficiency in relation to dwarfism are summarized in Table 1 for a substantial fruiting season (2003) with uninterrupted weather extremes. Although trees on PB and SPRB1 had no large yield differences, the estimated yields per ha were more than 20% for all the scions on SPRB1. Fruit yield efficiency of the scions was also significantly higher on SPRB1.

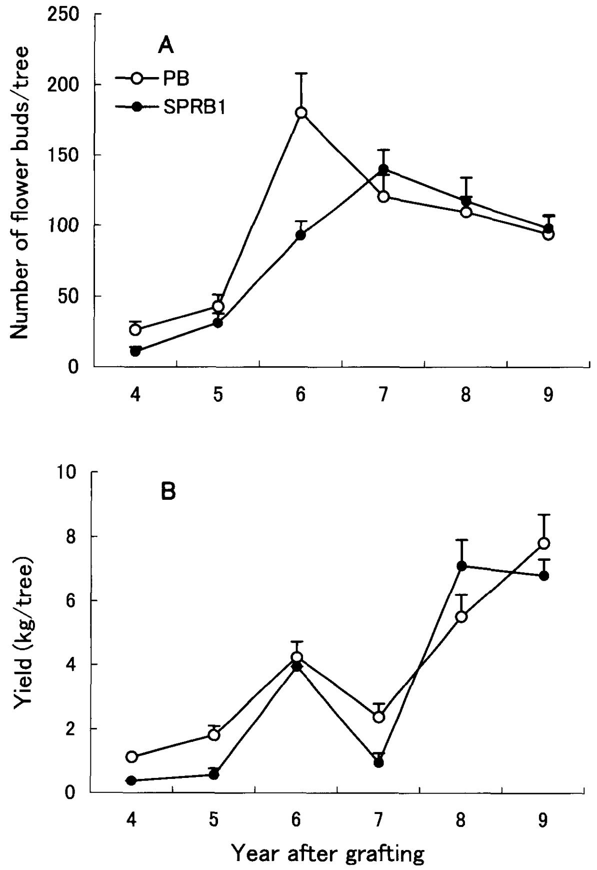

Fig. 6. Yearly change in the number of flower buds (A) and fruit yield (B) of 'Kosui' on SPRB1. Vertical bars indicate SE (n = 3).

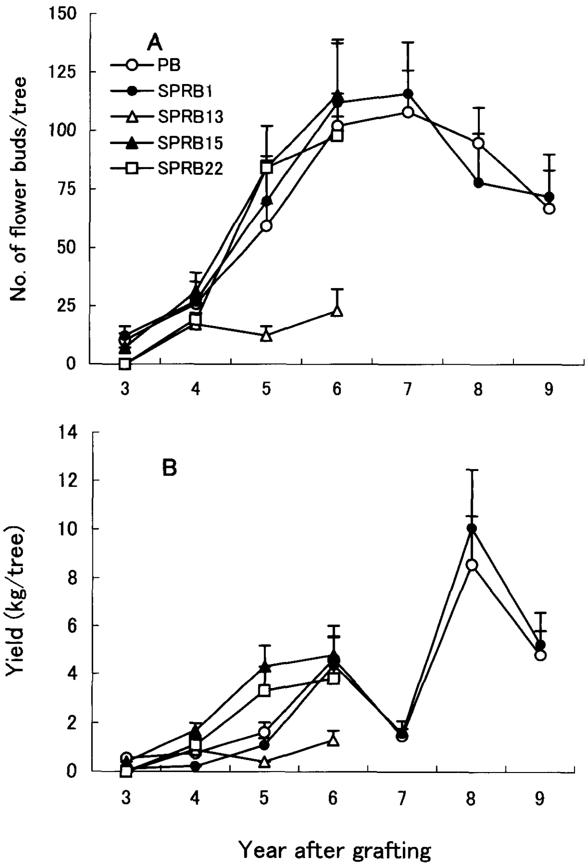

Fig. 7. Yearly change in the number of flower buds (A) and fruit yield (B) of 'La France' on PB clones. Vertical bars indicate SE (n = 3).

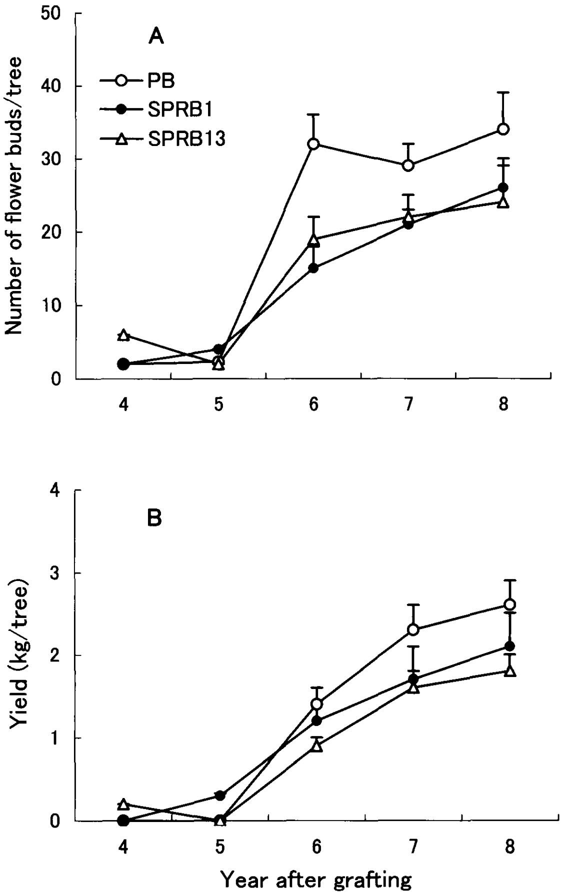

Fig. 8. Yearly change in the number of flower buds (A) and fruit yield (B) of 'Conference' on PB clones. Vertical bars indicate SE (n = 3).

The average fruit weight of 'La France' and 'Conference' did not significantly differ from the controls (Table 2). 'Kosui' on SPRB1 had significantly lower average fruit weight and also lighter fruit skin color. Thus, it is apparent that SPRB1 influenced fruit maturity of 'Kosui', because, fruit maturity corresponds to the skin color and also to the TSS and flesh firmness. Since the lighter fruit skin color range indicates an immature fruit, the average fruit weight may be gained by harvesting fruit at an appropriate fruit skin color. 'La France' trees on SPRC20 had significantly higher yield among the PC clones, including the control (Table 3). Fruit quality of the scions did not vary noticeably and no remarkable physiological disorder of the fruit was found to be the influence of the selected rootstock clones. Lombard and Westwood (1987) reported no incidence of black end on PB and PC rootstocks and that the rating of cork spot decay was also lower on PB and PC.

Clonal selection of rootstocks is by its nature a long-term project. To our knowledge, this is the first report on clonal dwarfing *Pyrus* rootstock selection in Japan. Our aim was to develop genetically dwarf rootstocks that have other important pomological traits, such as precocity, yield, and fruit quality. Our study presents a preliminary assessment of the opportunities for the introgression of certain dwarfing clones while combining several desirable rootstock traits. Our selected clones initiate roots with considerable ease by softwood cuttings, while certain clones, such as SPRB1, SPRB13,

Table 2. Fruit quality and other attributes of 'Kosui', 'La France' and 'Conference' as influenced by the selected SPRB1.

Cultivar	Rootstock	Average fruit weight (g)	Fruit shape (L/D ratio)	TSS (%)	Acid (%)	Flesh firmness (Lbs)	Skin color[z]
Kosui	SPRB1	277	0.80	11.94	0.09	5.8	2.7
	PB	319	0.81	12.81	0.08	5.5	3.2
	Significance	**[y]	NS	NS	NS	NS	*
La France	SPRB1	209	0.98	13.11	0.20	—	—
	PB	205	1.02	13.50	0.19	—	—
	Significance	NS	NS	NS	NS		
Conference	SPRB1	192	1.59	13.94	0.08	—	—
	PB	196	1.56	14.20	0.09	—	—
	Significance	NS	NS	NS	NS		

Data for 'Kosui' and 'La France' at year 9 and 'Conference' at year 7.
[z] Measured only for 'Kosui' by using a color chart (JA Zenno, Tottori).
[y] NS, *, ** indicate non-significant, significant at $P < 0.05$ and 0.01 by *t*-test, respectively.

Table 3. Fruit yield and quality attributes of 'La France' as influenced by the selected PC clones.

Rootstock	Fruit yield (kg/tree)	Average fruit weight (g)	Fruit shape (L/D ratio)	TSS (%)	Acid (%)
SPRC5	2.7b[z]	198a	1.05a	13.0a	0.19a
SPRC13	1.2c	198a	1.04a	13.1a	0.19a
SPRC15	1.1c	203a	1.05a	13.8a	0.18a
SPRC20	4.4a	205a	1.01a	13.4a	0.16a
PC	2.1bc	204a	1.03a	13.8a	0.21a

Data at year 5.
[z] Different letters represent significant difference by Tukey's multiple range test at $P < 0.05$.

SPRB15, SPRC3, SPRC13, SPRC15, and SPRC20 have the potential to reduce scion vegetative growth. In addition, SPRB15 and SPRC20 have induced precocious bearing. However, tree productivity, fruit quality traits and adaptability of all the clones are yet to be determined extensively. Subsequently, we intend to select the most suitable ones. We suggest that these clones be tested at different pear growing regions in Japan to assess the interaction of scion/rootstock combination versus location.

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マンシュウマメナシおよびマメナシ実生群からのナシわい性台の選抜

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ナシのわい性台木を選抜するためにナシ属2種を用いて台木試験を行った．マンシュウマメナシおよびマメナシ（カレリアーナ）の自然交雑実生から遺伝的に著しいわい化を示し，かつ挿し木発根性に秀れた系統を選抜した．マンシュウマメナシの実生からSPRB1，SPRB13，SPRB15およびSPRB22の4系統が，カレリアーナからはSPRC3, SPRC5, SPRC8, SPRC13, SPRC15およびSPRC20の6系統がそれぞれ選抜された．これらの数系統にニホンナシ‘幸水’，セイヨウナシ‘ラ・フランス’および‘コンファレンス’を接ぎ木しても穂木品種はわい化し，穂木品種の新梢成長，幹横断面積および樹冠容積の拡大が抑制された．これらの穂木3品種において，対照区とSPRB1との間では一樹当たりの果実収量に顕著な差異は認められなかった．しかし，面積当たりの果実収量はいずれの品種においても20%以上多くなった．また，SPRB15およびSPRC20台の‘ラ・フランス’では，初期収量が多く，早期結実性が認められた．‘ラ・フランス’および‘コンファレンス’の果実品質には台木間で顕著な差異は認められなかったが，SPRB 1台の‘幸水’では果皮色が劣り，平均果実重が小さかった．