EFFECT OF THREE TRAINING SYSTEMS AND HAND FRUITLET THINNING ON YIELD AND FRUIT QUALITY IN TWO CULTIVARS OF JAPANESE PLUM (*Prunus salicina* Lindl.)

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A B S T R A C T

The aim of this study was to determine how different training systems and different levels of hand thinning affect yield and fruit quality in Japanese plums. In autumn 2003, Japanese plum trees of the cultivars 'Kometa' and 'Najdiena' grafted on Myrobalan seedling rootstock (*Prunus divaricata* Led.) were planted in the Experimental Orchard in Dąbrowice in central Poland. The distance between trees in each row depended on the training system used. Trees trained using the cordon system were spaced 0.75 meters apart. Trees trained using the trellis system were spaced 2.0 meters apart. Trees trained using the slender-spindle system were spaced 1.5 meters apart. With all systems, the distance between rows was 3.5 meters. Trees trained as cordons were not headed back after planting, even though they were very tall (1.8 to 2.0 m). They were tied to bamboo canes. All of the all side shoots were left on. Side shoots over 0.3 m long were shortened. Trees trained using the trellis system were headed back to 1.2 m above ground level, but this turned out to be too high. There were too many side shoots at the top of the trees, and not enough at the bottom of the trees. The side shoots were bent and tied to wires suspended from concrete posts so that they would form a solid fruiting hedge. Trees trained as slender spindles were headed back to 1.2 m above ground level so that they would have an upright leader, long branches at the base, and short branches at the top. In 2005, the second growing season after planting, the trees were thinned either lightly, moderately or heavily. With light thinning, fruitlets were left 5 cm apart. With moderate thinning, fruitlets were left 10 cm apart. With heavy thinning, fruitlets were left 15 cm apart. Tree vigor and growth habit varied depending on the training system used. The trees started bearing in the second growing season after planting (2005), and yields were high for such a young orchard. In the second year of cropping (2006), yield per tree was significantly lower with the cordon system than with the trellis or slender spindle

systems. However, yield per hectare was over 30 tons in the trees trained using the cordon system, which were spaced 0.75 meters apart in the rows. This was twice as high as in the trees trained using the trellis system, which were spaced 2.0 meters apart. Dense planting may be an economically wise strategy if trees are not expensive.

Key words: Japanese plum cultivars, tree spacing, training, hand fruit thinning

INTRODUCTION

Japanese plums (*Prunus salicina* Lindl.) have been cultivated in Japan and China for over 2000 years. Currently, twelve Japanese plum cultivars and hybrids of Japanese plums and other plum species are grown in Japan. These varieties bear yellow, pink, red, blue or black fruits. Japanese plums start bearing very early, are extremely productive, require hand fruit thinning, and have attractive fruits with a long shelf life (Childers, 1983; Yoshida, 1994).

Most Japanese plum cultivars and hybrids require hand thinning to ensure optimal fruit size, which ranges from 30 to 150 grams, depending on cultivar. NAA, ethephon, DNOC and several other chemicals have been used to thin flowers or fruitlets in 'Santa Rosa'. Ethephon can be used to thin Japanese plums cultivated for processing. However, hand thinning is necessary to produce high quality dessert plums (Bajwa and Kirpal, 1970).

In Japan, the most popular cultivar is 'Santa Rosa'. Trees in older orchards are trained to have an open center. Trees in newer orchards are trellised to spindle system (Yoshida, 1994).

In the United States, Japanese plum cultivars and hybrids of Japanese and American plums are grown mainly in California, where about 50,000 hectares are under cultivation. The main cultivars are 'Larosa' and 'Santa Rosa'. Most trees are spaced 4.0 x 3.0 meters apart, and are trained to have an open center. Trellising has also been tried in newer orchards. Most cultivars are hand-thinned before the pits completely harden in June. The fruitlets left on the shoot are spaced 7 to 10 cm apart (Childers, 1983).

There have been recent attempts at growing Japanese plum cultivars and hybrids in the warmer parts of Europe. In a study conducted in Hungary, for example, Japanese plums proved frost hardy down to –25°C. The Japanese plums tested began to blossom about one week earlier than European plums, and were therefore more susceptible to spring frost damage. All of Japanese plum cultivars blossomed abundantly and set too many fruits (Szabo and Nyeki, 2002). Japanese plums set 150 to 250 flower buds per meter of branch, and one cultivar, 'Shiro', even sets 350 flower buds per meter of branch. European plums, on the other hand, set only 60 to 80 flower buds per meter of branch. Profitable production is not possible without hand thinning (Harangozo et al., 1996). Recommended cultivars in Hungary are: 'Burbank', 'Friar', 'Shiro', 'Santa Rosa', and 'Black Amber'.

In Poland, ethephon has proved very effective in thinning European plums, but no trials have been conducted on Japanese plum cultivars or their hybrids (Basak et al., 1993). Japanese plum cultivars have a higher value than European varieties because they are very precocious, productive and capable of acclimating to local conditions. Furthermore, crossbreeding with other plum species yields highly valuable hybrids (Sękowski, 1993). In one trial in Poland with Japanese plums, the problem was that the fruits were too small (Rozpara et al., 1996). In another study on Japanese plums in Poland, promising results were obtained with new training systems and hand thinning (Buler et al., 2002).

The aim of this study was to determine how different training systems and different levels of hand thinning affect yield and fruit quality in Japanese plums.

MATERIAL AND METHODS

In autumn 2003, Japanese plum trees of the cultivars 'Kometa' and 'Najdiena' grafted on Myrobalan seedling rootstock (*Prunus divaricata* Led.) were planted in the Experimental Orchard in Dąbrowice in central Poland. The distance between trees in each row depended on the training system tested. Trees trained using the cordon system were spaced 0.75 meters apart. Trees trained using the trellis system were spaced 2.0 meters apart. Trees trained using the slender-spindle system were spaced 1.5 meters apart. With all systems, the distance between rows was 3.5 meters.

Trees trained as cordons were not headed back after planting, even though they were very tall (1.8 to 2.0 m). They were tied to bamboo canes. All of the side shoots were left on. Side shoots over 0.3 m long were shortened. The following year, the trees produced some more side shoots, mainly at the top. Cordons training was finished in the first growing season after planting.

Trees trained using the trellis system were headed back to 1.2 m above ground level, but this turned out to be too high. There were too many side shoots at the top of the trees, and not enough at the bottom. The side shoots were bent and tied to wires suspended from concrete posts so that they would form a solid fruiting hedge. It was difficult to fill in the lowest part of the tree canopy with good branches. Trellis training was finished in the summer of the second growing season after planting.

Trees trained as slender spindles were headed back to 1.2 m above ground level so that they would have an upright leader, long branches at the base, and short branched at the top. Heading back produced many strong shoots that had to be selected and bent horizontally to ensure proper tree shape. With shoot bending and pruning, the trees had the desired shape at the end of second growing season after planting.

Starting in the second growing season after planting, the trees were pruned by the renewal method

(Buler et al., 2000). The trees were drip irrigated. The soil between the rows was mowed, and the strips in the row were kept fallow with the help of broad-spectrum herbicides applied in accordance with standard commercial orchardry procedures.

The experiment was conducted in a random block design with three blocks for each cultivar. Each block consisted of five adjacent trees in the same row. All five trees in each block were trained using the same training system. The trees trained using the slender spindle system served as the standard.

In 2005, the second growing season after planting, three trees from each block were chosen for hand thinning. Fruitlets were thinned in June. The trees were thinned either lightly, moderately or heavily. With light thinning, the fruitlets were left 5 cm apart. With moderate thinning, the fruitlets were left 10 cm apart. With heavy thinning, the fruits were left 15 cm apart. The thinned trees were compared to the non-thinned trees in the same block.

All results were statistically elaborated using Fisher's analysis of variance, followed by means separation using Duncan's multiple-range t-test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Tree vigor and growth habit varied depending on the training system used.

In the first growing season (2004), the trees trained using the cordon system, which had not been headed back after planting, formed numerous fruiting spurs along the leader, and only three or four medium-sized shoots. The trees trained using the trellis and slender spindle systems formed only a few spurs, and about ten long shoots per tree.

In subsequent growing seasons, annual shoot growth was lower in the trees trained using the cordon system than in the trees trained using the trellis and slender spindle systems. The difference was statistically significant starting in the first or second growing season after planting, especially with 'Najdiena' (Tab. 1). With 'Najdiena', trunk growth expressed as TCSA was also significantly weaker with the cordon training system. With 'Kometa', trunk growth was visibly weaker with the cordon training system than with the trellis and slender spindle systems, but the difference was not statistically significant. This agrees well with previous reports that heading back stimulates tree growth (Mika, 1986).

In this trial, both 'Kometa' and 'Najdiena' proved to be ideally suited to cordon training because they naturally form a long, upright leader with numerous, weak side shoots. When trained using the cordon system, these cultivars should not be headed back neither immediately after planting nor within the first five years of training. When they reach the desired shape, they should be headed back so that they are between 2.0 and 2.5 meters tall.

Neither 'Kometa' nor 'Najdiena' was suited to trellis training because they tend to produce spreading crowns

T a b l e 1 . Effect of training system on tree growth in two cultivars of Japanese plum

	Kometa			Najdiena		
	2004	2005	2006	2004	2005	2006
Trunk cross-sectional area [cm^2]						
Cordon	4.2 a*	9.1 a	13.2 a	4.2 a	8.5 a	11.3 a
Trellis	4.2 a	10.7 a	16.6 a	4.5 a	11.3 c	18.8 c
Spindle	4.9 a	11.9 a	17.3 a	3.8 a	9.6 b	14.5 b
Total annual shoot growth [m/tree]						
Cordon	5.9 a	26.0 a	11.8 a	5.8 a	26.8 a	11.9 a
Trellis	6.3 a	28.1 a	16.4 b	9.0 b	32.5 b	25.1 c
Spindle	8.6 a	26.3 a	15.2 ab	6.8 ab	26.9 a	19.0 b

*Means in the same column followed by the same letter do not differ according to Duncan's multiple-range t-test at $P \leq 0.05$

with numerous short shoots. However, with some effort, they could be trained to form a hedgerow. When trained using the trellis system, these cultivars should be headed back only once after planting to a height of 0.8 meters above ground level. In the following two years, they should be headed back once or twice more so that they produce long shoots to fill the space within the tree row.

Both 'Kometa' and 'Najdiena' appeared to be suitable for spindle training. When trained using the slender spindle system, these cultivars should be headed back only once after planting to a height of 0.8 meters above ground level. In the following two years, the leader should not be headed back. Trees treated this way form take on by themselves an ideal slender spindle shape. The slender spindle has proved to give excellent results with European plums (Mika et al., 2001).

Any intensive system of plum growing requires judicious pruning when the trees are dormant and supplemental pruning in summer to ensure that the tree canopy is well lit (Hugard, 1980; Webster, 1989). In an earlier study, 'Kometa' and 'Najdiena' proved less suited to trellis training than most European plum cultivars (Mika et al., 2001).

The trees started bearing in the second growing season after planting (2005). The first crop averaged 2.5 kg/tree, which was high for trees that age, and higher than in European plum cultivars (Mika et al., 2001). In the first year of cropping, there were no significant differences in yield per tree among the training systems (Tab. 2). On the other hand, yield per tree was significantly lower with moderate and heavy hand thinning (Tab. 3).

In the second year of cropping (2006), yield per tree varied widely depending on the training system used.

Table 2. Effect of training system on yield per tree, fruit weight and total soluble solids content in two cultivars of Japanese plum

	Kometa			Najdiena		
	2004	2005	2006	2004	2005	2006
Yield per tree [kg]						
Cordon	-	2.3 a*	6.2 a	-	2.3 a	6.0 a
Trellis	-	2.3 a	8.8 b	-	2.8 a	10.4 c
Spindle	-	2.9 a	7.9 ab	-	2.0 a	8.2 b
Mean fruit weight [g]						
Cordon	-	29.9 a	19.9 a	-	24.0 a	13.0 a
Trellis	-	34.6 b	19.4 a	-	28.4 b	16.4 b
Spindle	-	32.0 ab	19.0 a	-	29.9 b	17.2 b
Total soluble solids content [%]						
Cordon	-	14.5 b	12.7 a	-	16.2 a	17.2 a
Trellis	-	14.0 ab	12.9 a	-	16.3 a	16.2 a
Spindle	-	13.7 a	12.7 a	-	16.6 a	16.3 a

*Explanations see Table 1

Table 3. Effect of hand fruitlet thinning on yield per tree, fruit weight and total soluble solids content in two cultivars of Japanese plum

Level of hand thinning	Kometa		Najdiena	
	2005	2006	2005	2006
Yield per tree [kg]				
Light	3.0 ab*	9.0 b	2.4 ab	8.7 bc
Moderate	2.0 a	5.2 a	1.9 a	7.1 b
Heavy	1.7 a	4.5 a	1.7 a	5.3 a
Control	3.4 b	10.0 b	3.3 b	9.9 c
Mean fruit weight [g]				
Light	32.1 a	19.3 ab	28.2 a	15.6 a
Moderate	32.0 a	20.9 ab	27.6 a	15.3 a
Heavy	33.7 a	23.2 b	27.8 a	17.8 b
Control	30.7 a	16.7 a	26.1 a	14.4 a
Total soluble solids content [%]				
Light	13.8 a	12.3 a	16.6 b	16.6 a
Moderate	14.4 a	13.1 a	16.7 b	16.7 a
Heavy	14.4 a	13.3 a	16.8 b	16.9 a
Control	13.7 a	12.3 a	15.4 a	16.1 a

*Explanations see Table 1

Yield per tree was significantly lower with the cordon system than with the trellis or slender spindle systems. In previous studies, yield per tree, trunk growth, and production index were low in trees planted very close together because they had to compete with each other for light, water and nutrients (Mika et al., 2001). In this study, yield per tree in the second year of cropping was highest in 'Najdiena' using the trellis training system. Light hand thinning had no effect on yield per tree, whereas moderate and heavy hand thinning substantially reduced yield per tree. In 'Najdiena', yield per tree was reduced by more than 50% with heavy hand thinning.

In both 'Kometa' and 'Najdiena', mean fruit weight varied depending on which training system was used. In 'Najdiena', mean fruit weight was significantly lower with the cordon system than with the trellis or slender spindle systems in both 2005 and 2006.

In 2005, neither mean fruit weight nor total soluble solids content were affected by which level of hand thinning was carried out. All fruits weighed about 30 grams, which is optimal for both 'Kometa' and 'Najdiena'.

In 2006, fruit weight was significantly lower in all cases than in 2005. Heavy thinning improved fruit weight to some degree, but even with heavy thinning, fruit weight was still below 30 grams. This may have been because hand thinning in 2006 was carried out too late. Thinning that year was carried out in June, after the end of the fruit drop, but before the pits had completely hardened. Hand thinning should be carried out before the pits completely harden (Childers, 1983). In Poland, in our experience, hand thinning should be done in the first few days of June, regardless of whether the natural fruit drop has ended or not. Hand thinning of Japanese plum trees is very labor intensive. In 2006, hand thinning required about twenty minutes per tree.

In both 2005 and 2006, yield per hectare was very high for such a young orchard (Tab. 4). The high yield was mostly due to the fact that the trees were planted densely together. In both 'Kometa' and 'Najdiena', yield per hectare was over 30 tons in the trees trained using the cordon system, which were spaced 0.75 meters apart in the rows. This was twice as high as in the trees trained using the trellis system, which were spaced 2.0 meters apart in the rows. Yield per hectare was about 20 tons in the trees trained using the slender spindle system, which were spaced 1.5 meters apart in the rows. Dense planting may be an economically wise strategy if trees are not expensive.

CONCLUSIONS

The Japanese plum cultivars 'Kometa' and 'Najdiena' are best trained using either the cordon or slender spindle systems. With high density planting, growth and yield per tree were lower, but the yield per hectare was much higher. Hand

Table 4. Effect of training system and planting density on cumulative yield per tree and cumulative yield per hectare in two cultivars of Japanese plum

	Spacing [m]	Trees per hectare	Total yield per tree 2005-2006 [kg]	Total yield per hectare 2005-2006 [t]	Total yield per tree 2005-2006 [kg]	Total yield per hectare 2005-2006 [t]
			Kometa		Najdiena	
Cordon	3.5 x 0.75	3809	8.5 a*	32.4	8.3 a	31.6
Trellis	3.5 x 2.0	1428	11.1 b	15.8	13.2 c	18.8
Spindle	3.5 x 1.5	1904	10.8 b	20.6	10.2 b	19.4

*Explanations see Table 1

thinning of fruitlets seems to be necessary, but further study is needed to confirm this.

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WYNIKI ZRÓŻNICOWANYCH SPOSOBÓW PROWADZENIA DWÓCH ODMIAN ŚLIWY JAPOŃSKIIEJ I RĘCZNEGO PRZERZEDZANIA ZAWIĄZKÓW OWOCOWYCH

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S T R E S Z C Z E N I E

Odmiany ‘Kometa’ i ‘Najdiena’ Śliwy japońskiej (*Prunus salicina* Lindl.), szczepione na siewkach ałyczy, posadzono w Sadzie Doświadczalnym w Dąbrowicach jesienią 2003 roku. Zastosowano rozstawę 3,5 x 0,75 m dla formy sznurowej (kordony); 3,5 x 1,0 m dla formy wrzecionowej; 3,5 x 2,0 m dla formy szpalerowej. Drzew przeznaczonych na sznury nie cięto po posadzeniu, pomimo że miały 1,8 m wysokości. Przywiązano je do tyczek bambusowych. Przewodniki drzew formowanych w szpalerze przycięto w pierwszym i drugim roku, a wyrosłe pędy przyginano i przywiązywano do drutów po posadzeniu. Przewodniki drzew prowadzonych w formie wrzeciona przycięto po posadzeniu w celu uzyskania jednego okółka dłuższych pędów. W drugim i trzecim roku unikano cięcia przewodnika, aby uzyskać jedynie pędy krótkie. Od drugiego roku po posadzeniu wprowadzono 4 stopnie ręcznego przerzedzania zawiązków owocowych: przerzedzanie słabe (zawiązki pozostawiono w odległości około 5 cm od siebie); średnie (10 cm); silne (15 cm). Kontrolę stanowiły drzewa z naturalnym opadaniem zawiązków.

Rozstawa i systemy formowania koron miały wpływ na wzrost drzew, szczególnie odmiany ‘Najdiena’. W trzecim roku po posadzeniu wzrost drzew wyrażony powierzchnią przekroju pnia i sumą przyrostów jednorocznych był najsłabszy w kombinacji z koroną w formie sznura, silniejszy w formie wrzecionowej i najsilniejszy w formie szpalerowej, w której drzewa miały największe odstępy w rzędzie. Drzewa weszły w owocowanie w drugim roku wegetacji. Drzewa silniej

rosnące, mające większą objętość korony, prowadzone w formie szpalerowej i wrzecionowej plonowały w trzecim roku po posadzeniu istotnie lepiej niż drzewa prowadzone w formie sznurów. Z drzew prowadzonych w formie szpalerowej i wrzecionowej zebrano również lepiej wyrośnięte owoce. Przerzedzanie zawiązków w stopniu średnim i silnym istotnie spowodowało zmniejszenie plonu. W 2006 roku silne przerzedzanie zawiązków spowodowało zwiększenie ich średnicy i ciężaru. Suma plonu odmiany 'Kometa' w przeliczeniu na hektar za 2 lata owocowania wyniosła 32,4 t z drzew prowadzonych w formie sznurów i była dwa razy większa niż zebrana z drzew prowadzonych w formie szpalerowej (15,8 t). Suma plonu tej samej odmiany z koroną wrzecionową wyniosła 20,6 t/ha. Relacje między kombinacjami w sumie plonu były podobne u odmiany 'Najdiena'.

Słowa kluczowe: odmiany Śliwy japońskiej, rozstawa, formowanie koron, ręczne przerzedzanie zawiązków