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'Shiaying' Mulberry: A Promising Cultivar for Fresh Consumption and Processing

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Abstract

'Shiaying' mulberry (*Morus atropurpurea* Roxb.) is a promising cultivar for berry production in Taiwan. 'Shiaying' produces plentiful and attractive dark purple, glossy berries. Compared with the three most commercially available mulberry cultivars in Shiaying, Tainan (southern Taiwan), i.e. 'Taisang No. 19' (*Morus atropurpurea* Roxb.), 'Miaoli No. 1' (*Morus atropurpurea* Roxb.), and 'Elongated Fruit No. 1' (*Morus laevigata* Wall), the average berry weight (5.8 g) of 'Shiaying' was similar to that of 'Miaoli No.1' and 'Elongated Fruit No. 1', but significantly heavier than that of 'Taisang No. 19'. The yield of 'Shiaying' (19.5 kg/tree) was as abundant as the yields of 'Taisang No. 19' and 'Miaoli No. 1' but was much higher than that of 'Elongated Fruit No. 1'. Additionally, the fruit of 'Shiaying' ripened 5-20 days later than the fruits of the three comparable cultivars. 'Shiaying' fruit also has a much higher soluble solids concentration, SSC (14.0%), and the quality of the berry, in terms of taste, is superior to that of both 'Taisang No. 19' and 'Miaoli No. 1'. This particular cultivar is recommended for multiple uses in the horticultural and food industries and is very suitable for both fresh consumption and the processing market in Taiwan.

Origin

'Shiaying' mulberry (*Morus atropurpurea* Roxb. or *Morus alba* var. *atropurpurea*) (Vijayan et al., 2004), formerly tested as accession number '93C203', belongs to the Guangdong mulberry group (Chang,2008; Minamizawa, 1976; Zhao et al., 2007) and is a local genotype that was first discovered within a commercial orchard of six-year-old 'Taisang No. 19' (*Morus atropurpurea* Roxb.) trees located in Shiaying, Tainan (southern Taiwan) in 2004 by Chang (2006a; b). The air-layered liners for this orchard were originally purchased from Tianwei, Chunghwa (central Taiwan) in 1998 (personal communication from the farmer). 'Shiaying' could be a chance seedling, and it is difficult to identify its true origin with certainty because mulberry is wind pollinated, and its seeds are easily dispersed by birds (Reich, 2004; 2008; Minamizawa, 1976; Vijayan et al., 2011a; b). 'Shiaying' has been rapidly adopted throughout Taiwan due to its vigorous growth, abundant yield, and large, sweet berries (Chang and Liou, 2006).

In 2004, 'Shiaying' was introduced into the fruit tree breeding program trials conducted at the Miaoli District Agricultural Research and Extension Station (MDARES) in Kuan-Kung, Miaoli (central Taiwan) (Chang, 2006a). Since February 2011, 'Shiaying' has been incorporated into the mulberry germplasm collection at the National Chung Hsing University (NCHU) in Taichung (central Taiwan), where it has served as a potential parent in a breeding project aimed at developing new berry varieties for production.

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Evaluation Procedures

'Shiaying' and three other commercially comparable mulberry cultivars in Taiwan, 'Taisang No. 19' (*Morus atropurpurea* Roxb), 'Miaoli No. 1' (*Morus atropurpurea* Roxb), and 'Elongated Fruit No. 1' (*Morus laevigata* Wall), were obtained from an orchard established in 2007 in Shiaying (lat. 23.2 °N; 120.3 °E; alt. 5 m), Tainan (southern Taiwan). All of the cultivars were grown as self-rooting liners.

'Taisang No. 19', which was found in northern Taiwan in 1957, was chosen because it is still the most widely planted cultivar for the processing market in Taiwan, with a high yield of medium sized (3.6 g) berries that have a low SSC (4.8%) (Chang, 2006a). 'Miaoli No. 1' is a recently released cultivar that was mainly developed to meet processing demand and has a high yield of large (5.5 g), moderately sweet berries (7.0% SSC) (Chang, 2008). 'Elongated Fruit No. 1', specifically named for its unique berry shape, is a triploid cultivar (Chang et al., 2008) that is suitable for fresh consumption owing to its remarkable sweetness (20.1% SSC) and superior eating quality (Chang and Chang, 2010).

All of the mulberry trees were spaced at 4×4 m and were fertilized, irrigated, and subjected to periodic pest and disease control following standard local practices. In addition, 'Taisang No.1' (*Morus acidosa* Griff.) and 'Taisang No. 3' (*Morus alba* L.), which produce only staminate flowers were used as pollenizers (Chang, 2006a) and were planted within the row, at a density of approx. one-tenth of the tested plants. The trees received a post-harvest pruning (in late April to early May of each year) according to the routine management practices proposed by Chang and Liou (2006). In mid-October 2010, when the trees had reached their full size and could produce a regular yield, six uniform, healthy trees of each cultivar were selected and arranged in a completely randomized design. Subsequently, a total population of 30 bearing shoots was evenly selected from these six trees (i.e. five bearing shoots per tree which were arranged in a completely randomized design within the subsample unit). Tree characteristics, phenology, flower sex, fruit characteristics, annual fruit yield (during one season), taste ranking, disease and pest incidence, and injurious bird attacks were evaluated over three production cycles from October 2010 to April 2013.

The annual yield and the fruit characteristics were examined between mid-March and mid-April each year. To determine the quality and physical characteristics of the fruit, 120 fruits were sampled from the 30 bearing shoots (four fruit per shoot) of the six trees for each cultivar. The SSC of the fruit was measured using a digital refractometer (Atago PR-101, Tokyo). Titratable acidity was determined using a titrator (VIT90 Video Titrator, Toyko) with 0.01 N NaOH equilibrated to pH 8.1; the results were expressed as citric acid % (Ozgen at al., 2009). Tree characteristics, phenology and biological parameters were determined according to the methods of Chang (2006a; 2008) and Chang and Chang (2010). Taste ranking was rated using a sensory analysis by a panel of 10 experts (three authors included) according to the method of Lawless and Heymann (2010).

Yield, fruit characteristics and taste ranking data were subjected to an analysis of variance (ANOVA) using the SAS software package (SAS, 1996). The statistical significance of differences among the means was assessed using the least significant difference (LSD) test at the 5% error level.

Performance and Description

'Shiaying' is a highly vigorous, upright spreading, deciduous, and monoecious mulberry cultivar. The annual growth of new shoots after a post-harvest pruning has been reported to reach 2.0 m by the winter dormancy period; subsequently, the approximate height and canopy spread of a mature tree can reach 2.8 m and 2.1 m, respectively (Chang et al., 2005). In this study, conducted in Shiaying, Tainan, dormancy occurred between early December and late January, with budbreak occurring in January (Table 1).

Table 1. Tree characteristics and phenology of 'Shiaying' and three comparable mulberry cultivars tested in Shiaying, Tainan, Taiwan (2010-2013).

Cultivar	Tree characteristics		Dormancy period[y]		Flower sex	Bloom date[x]			Ripening time[x]		
	Tree vigor[z]	Canopy shape	Start date	End date		First bloom	Full bloom	Last bloom	First harvest	Full harvest	End harvest
'Shiaying'	10	Upright spreading	6 Dec.	24 Jan.	Female	31 Jan.	13 Feb.	21 Feb.	25 Mar.	5 Apr.	11 Apr.
'Miaoli No.1'	8	Spreading	20 Nov.	7 Jan.	Female	18 Jan.	26 Jan.	6 Feb.	10Mar.	15Mar.	24Mar.
'Taisang No. 19'	6	Spreading	30 Nov.	16 Jan.	Female	26 Jan.	7 Feb.	15 Feb.	19 Mar.	28 Mar.	3 Apr.
'Elongated Fruit No. 1'	10	Semi-upright spreading	2 Dec.	18 Jan.	Female	28 Jan.	9 Feb.	17 Feb.	22 Mar.	31 Mar.	5 Apr.

[z] Rated on a scale of 1 to 10, where 10 is the most vigorous (more than 2.5 m of annual shoot growth in length), 5 is moderate (approx. 1.3 m of annual shoot growth in length) and 0 is the least vigorous (less than 0.5 m of annual shoot growth in length)

[y] Leaf fall completed was regarded as the onset date of dormancy (endodormancy), while the end date represents the completion of dormancy (endodormancy followed by ecodormancy), i.e. bud break (following Campoy et al., 2011).

[x] One-sixth of the given characteristics is regarded as the start or first date, while four-sixths is the full event. The last/end date represents the completion of flowering, or harvest.

Species and cultivars within mulberry have been reported to be cross-compatible by wind pollination (Reich, 2004; 2008; Minamizawa, 1976; Vijayan et al., 2011a; 2011b; Zhao et al., 2007). 'Shiaying' produces only pistillate flowers, which can be cross-fertilized by two common pollenizer cultivars 'Taisang No. 1' and 'Taisang No. 3' in Taiwan. These pollenizer cultivars were bred and released for foliage production in the 1980s to feed silkworms (*Bombyx mori* L.) (Chang, 2006a).

During the 2010-2013 seasons in Tainan, 'Shiaying' flowering occurred from late January until late February. Ripe fruits were harvested from late March to mid- April, which was approximately 5-20 days later (at full harvest) than the harvest time of the other cultivars examined in this study (Table 1).

The berries of 'Shiaying' are ovate in shape, with an average weight of 5.8 g, which is similar to that of 'Miaoli No.1' and 'Elongated Fruit No. 1' , but they are significantly heavier than those of 'Taisang No. 19'. Fully

Fig. 1. Fruits of 'Shiaying'.

Table 2. Fruit characteristics of 'Shiaying' and three comparable mulberry cultivars tested in Shiaying, Tainan, Taiwan (2010-2013).

	Berry shape	Berry skin color	Berry length (cm)[z]	Berry width (cm)[z]	Berry weight (g)[z]	Soluble solids concentration (SSC, %)[z]	Titratable acidity (TA, %)[z]	SSC/TA[z]
'Shiaying'	Ovate	Bright purple	3.4 b[y]	1.6 a	5.8 a	14.0 b	0.7 a	20.0 b
'Miaoli No.1'	Ovate	Bright purple	3.5 b	1.8 a	6.1 a	7.7 c	0.8 a	9.6 c
'Taisang No. 19'	Ovate	Bright purple	2.8 bc	1.5 ab	4.3 b	5.0 d	0.9 a	5.6 cd
'Elongated Fruit No. 1'	Elongated	Bright purple	9.8 a	0.9 c	6.2 a	20.3 a	0.7 a	29.0 a
LSD	–	–	1.1	0.3	1.2	2.4	NS	4.3

[z] Means followed by different letters within the same column are significantly different as determined by LSD test at P 0.05.
[y] Mean of 120 fruit from 30 bearing shoots of six trees for each cultivar (where five bearing shoots were selected per tree and four fruits per bearing shoot were sampled).

mature 'Shiaying' berries have an attractive, bright, dark purple, glossy appearance (Fig. 1) and a medium titratable acidity (0.7%). The SSC, SSC/TA and taste ranking of the fruit at the time of harvest were 14.0%, 20.0 and 7.2, which overall are significantly less than the values for 'Elongated Fruit No. 1' but significantly greater than those for 'Taisang No. 19' or 'Miaoli No. 1' (Tables 2 and 3). Consequently, 'Shiaying' is also ideal for fresh consumption.

'Shiaying' produced an abundant yield (19.5 kg/tree) that was similar to the yields of 'Taisang No. 19' and 'Miaoli No. 1' but much higher than that of 'Elongated Fruit No. 1' (Table 3). Preliminary reports indicate that, due to the significantly improved sweetness and the high taste ranking of its fruit, 'Shiaying' is more popular in the local market than the other two older cultivars, 'Taisang No. 19' and 'Miaoli No. 1' (Chang and Liou, 2006).

Currently, 'Shiaying' is a unique cultivar that is very suitable for both fresh consumption and the processing market. It represents an emerging candidate for mulberry growers searching for promising cultivars to replace 'Taisang No. 19' and 'Miaoli No. 1'. 'Shiaying' has good characteristics for boosting the economic potential of the mulberry industry and for expanding berry production in Taiwan.

Adaptation

Similar to most mulberry species and cultivars, 'Shiaying' is easily adaptable to different agroclimatic environments and is suitable for all mulberry-growing areas within Taiwan (Chang, 2006a; Reich, 2004; 2008; Vijayan et al., 2011a). However, for maximum vegetative growth and berry fruit quality, as observed for 'Taisang No. 19', 'Miaoli No. 1', and 'Elongated Fruit No. 1' (Chang, 2006a; 2006b; 2008; Chang and Chang, 2010), 'Shiaying' should be grown in full sunlight at a daily mean temperature between 23-27°C with an annual rainfall of 750-1300 mm (preferably evenly distributed between post-harvest pruning and autumn). It is therefore recommended that 'Shiaying' be cultivated in central, southern, and eastern Taiwan, where the spring fruiting season is sunny and dry, to promote high berry yields and premium berry quality. 'Shiaying' may suffer from somewhat lower fruit sweetness and markedly reduced production due to the incidence of popcorn disease in northern Taiwan, where the climate is characterized by continual rains during the fruit set and growing seasons (Chang, 2006a; Chang and Liou, 2006).

The onset and end date of dormancy of 'Shiaying' was approximately 4-16 and 6-17

Table 3. Fruit yield, taste ranking and main disease, pest and injurious bird damage of 'Shiaying' and three comparable mulberry cultivars tested in Shiaying, Tainan, Taiwan (2010-2013).

Cultivar	Annual yield (kg/tree)[z]	Taste ranking[y]	Susceptibility[x] Popcorn disease／Mulberry beetle／Bulbul bird attack[w]
'Shiaying'	19.5 a	7.2 b	Moderate／Moderate／Moderate
'Miaoli No.1'	21.4 a	5.1 c	Moderate／Moderate／Mild
'Taisang No. 19'	18.9 a	2.3 d	Severe／Moderate／Mild
'Elongated Fruit No. 1'	5.6 b	9.2 a	Mild／Moderate／Severe
LSD	4.8	1.7	—

[z] Means followed by different letters within the same column are significantly different as determined by LSD test at P 0.05, n = 6

[y] Rated on a scale of 1 to 10 by sensory analysis through a panel of 10 experts (three authors included) who are specialized in research and extension on fruit crop category, where 10 is the best, 5 is moderate and 0 is the least desirable (following Lawless and Heymann, 2010).

[x] Based on a 0-8 scale where less than two-eighths of the given characteristics is regarded as mild susceptibility, four-eights is moderate and more than six-eighths is regarded as being severe.

[w] Popcorn disease = *Ciboria shirana* (P. Henn.) Whetzel; mulberry beetle = *Apriona germari* Hope; Bulbul bird = *Pycnonotus sinensis* Gemlin

days later, respectively, than these times with the other comparable cultivars in this study (Table 1), implying that it may have somewhat more cold hardiness and thereby could be grown at higher elevations in southern Taiwan.

Disease and Pest Incidence, and Injurious Bird Damage

Similar to 'Taisang No. 19', 'Miaoli No. 1', and 'Elongated Fruit No. 1', 'Shiaying' has been reported to be resistant or tolerant to various diseases and insect pests (Chang, 2006a; Chang and Liou, 2006). However, it shows moderate susceptibility to fruit popcorn disease during the rainy season and to mulberry beetle between late spring and midsummer (Table 3). The fruit initially swells to resemble popped corn, gradually becoming white and rotten as the popcorn disease infection progresses (Reich, 2004; 2008). The larvae of mulberry beetles attack the xylem of the trunk, and the adults attack the bark on the branches, which results in broken shoots and eventually leads to tree decay. Sometimes, 'Shiaying' can be prone to Chinese bulbul bird damage when the fruits are close to full maturity, owing to the sweeter berries (Table 3). The use of protective nets prior to harvest is therefore recommended.

Propagation

'Shiaying' can be easily propagated by air-layering or by cuttings from 1-year-old woody shoots obtained between May and July, such as for 'Miaoli No.1' (Chang, 2008). In addition, for renewing adult cultivars, top-working by grafting can also be utilized. Air-layered liners are usually transplanted once in the following spring and are maintained in containers for one year or longer before field planting.

Uses

In addition to domestication for sericultural purpose and livestock usage, the promising 'Shiaying' cultivar has specific commercial importance because its fruits have multiple uses in both horticultural and food industries. For example, 'Shiaying' may be planted on

pick-your-own farms for fresh consumption because of its increased sweetness, and it is also desirable in processing markets as a raw material for juice, jam, liquors, or even for making a traditional Greek spirit beverage called "Mouro" (Soufleros et al., 2004). It can also be used in natural dyes or in cosmetics, and has health benefits because it is rich in anthocyanin and phenols (Butt et al, 2008; Chang, 2006a; Chen et al., 2004; Ercisli and Orham, 2007; Ozgen et al., 2009; Vijayan et al., 2011a). 'Shiayang' may also serve as an excellent potential parent for breeding new commercially valuable hybrids or mutant offspring.

Plant Availability

Similar to 'Taisang No. 19' (Chang, 2006a; Chang and Liou, 2006), 'Shiayang' is not patented because it has been widely planted and has spread throughout Taiwan over the past decade. Thus, this cultivar may be propagated and sold freely. Plants can be obtained from wholesale, mail order, and retail nurseries in Taiwan. Liners or unrooted cuttings for nurseries wishing to propagate this cultivar are available by sending a request to the corresponding author (jerchiachang@dragon.nchu.edu.tw).

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Comparison of mid-winter cold-hardiness and soluble sugars contents in the shoots of 21 highbush blueberry (*Vaccinium corymbosum*) cultivars.

Abstract:
Cold-hardiness and the soluble sugars contents of the shoots of 21 highbush blueberry (*Vaccinium corymbosum*) cultivars ('Berkeley', 'Bluecrop', 'Bluegold', 'Bluehaven', 'Bluejay', 'Burlington', 'Chippewa', 'Collins','Dixi', 'Duke', 'Herbert', 'Jersey', 'Nelson', 'Northblue', 'Northland', 'Polaris', 'Rancocas', 'Sharpblue', 'Sierra', 'Spartan', and 'Sunrise') were compared in mid-Winter. The level of cold-hardiness was determined by measuring electrolyte leakage at various freezing temperatures and was expressed as LT_{50}, the temperature at which the incidence of injury reached 50%, and as T_{max}, the temperature at which the rate of injury was maximal. The LT_{50} and T_{max} values for the shoots of all 21 highbush blueberry cultivars ranged from -31.8º ± 0.09°C to -41.1° ± 0.12°C, and from -29.7° ± 0.06°C to -36.9° ± 0.13°C, respectively. T_{max} values were significantly positively correlated with LT_{50} values ($r = 0.98^{**}$, $P \leq 0.01$). Based on their levels of cold-hardiness in terms of LT_{50} values, the 21 highbush blueberry cultivars were ranked in order as follows: 'Jersey' > 'Northland' > 'Northblue' > 'Dixi' > 'Berkeley' = 'Sierra' > 'Chippewa' > 'Bluegold' > 'Burlington' > 'Bluejay' > 'Spartan' > 'Bluecrop' = 'Polaris' > 'Sunrise' > 'Duke' > 'Rancocas' > 'Herbert' > 'Sharpblue' > 'Collins' > 'Bluehaven' > 'Nelson'. Cold-hardiness, as estimated by LT_{50} and T_{max}, was highly negatively correlated with total soluble sugars content ($r = -0.78^{**}$, $P \leq 0.01$ and $r = -0.69^{**}$, $P \leq 0.01$ for LT_{50} and T_{max}, respectively). Among the soluble sugars detected, fructose and glucose concentrations, in particular, were significantly positively correlated with the levels of cold-hardiness in the shoots of all 21 highbush blueberry cultivars, but sucrose and raffinose concentrations were not correlated with cold-hardiness. Knowledge of intra-species differences in mid-Winter cold-hardiness in relation to soluble sugars contents will be useful during the breeding and cultivation of highbush blueberries.

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