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Red bayberry – a new and exciting crop for Australia?

An investigation of the potential for commercialisation of *Myrica rubra* Sieb. and Zucc. (Yang mei) in Australia.

A report for the Rural Industries Research and Development Corporation

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Foreword

Red bayberry is an important commercial horticultural crop grown in a small area of China, centred on Zhejiang province. Climatic conditions in Zhejiang are similar to certain horticultural production areas in Australia, suggesting that red bayberry could be developed as a commercial crop in Australia.

The purpose of this project was to investigate both the literature of red bayberry, and to visit production areas, producers, processors and researchers in Zhejiang. The final activity included a reciprocal visit by Chinese collaborators, for assessment of likely Australian production areas.

This publication summarises the results of this investigation and concludes that (1) red bayberry is likely to succeed horticulturally in production areas such as Nambour, Alstonville, Innisfail and Darwin.

This project was funded from RIRDC Core Funds, which are provided by the Australian Government.

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This report incorporates much information previously presented to RIRDC in the form of a literature review. That review forms the basis of this document.

Red bayberry - the name

The subject of this report is named *Yang Mei* in its native China. There is no direct English translation of this name in common usage, and *M. rubra* is referred to variously as waxberry, and red bayberry. It is sometimes erroneously cited as Irish Strawberry tree (*Arbutus Unedo* L.*)*, to which it bears a superficial resemblance. It is also occasionally referred to as Chinese strawberry tree. Bayberry is generically applied to both North American as well as Asian species of the genus *Myrica*.

Contents

Executive Summary

Red bayberry plants are evergreen trees cultivated in hilly areas of south-eastern China. The plant bears edible fruit. There are also local uses for its seeds, leaves and roots. The red bayberry plant has a height of 2-10 m and a uniform round-shaped canopy. Red bayberry trees grow well on poor soils due to a nitrogen-fixing bacterium association with the root system. Thus, strong growth and high productivity can be achieved on infertile hill slopes. Male and female catkins are on separate plants and pollination is by wind. Red bayberry fruit from cultivation can be about 3-cm diameter. The edible portion is comprised of many soft and succulent segments in a radial arrangement, around a single cherry stone-like seed. The fruit surface is characterised by many small swellings, which are distal tips of the segments. Fruit vary in size, colour and ripening time depending upon the variety. Fruit of most cultivars are 10-20 g-weight and 2-3 cm-diameter and bright red to almost black in colour.

The fruit ripen in China from mid-June to early July, in mid-Summer. The harvest period is short, being just 2-3 weeks duration. Red bayberry fruit are harvested when appearance and taste are optimal. The fruit have a palatable sugar-acid balance. They contain a broad spectrum of vitamins (eg vitamin C, thiamine, riboflavin, carotene) and minerals. Harvested red bayberry fruit rapidly break down under ambient conditions, and present similar post-harvest handling challenges to temperate berry fruits. Their delicate nature makes it difficult to store and transport the fresh fruit. Appropriate packaging, careful handling and maintenance of the cool chain are fundamental to efficient handling and distribution of red bayberry fruit. These difficulties present a challenge to long –distance transport, however this shortcoming is not insurmountable. Red bayberry fruit are also processed into juice and wine and canned, frozen or dried as alternatives to fresh consumption. Red bayberry fruit are in strong demand and production in China has increased dramatically over the last decade.

In the context of introducing this crop into Australian horticulture, this report presents general information on the cultivation of red bayberry plants and features information on post-harvest characteristics of the fruit. An investigation of climatic similarities between production areas in Zhejiang and potential areas in Australia reveals that red bayberry has specific requirements not only for a warm – temperate range of temperatures, but also requires high humidity as fruits swell and ripen. This latter requirement is likely to limit the potential range within Australia of this exciting new crop, however close climatic matches do exist between production areas in Zhejiang, and some northern and eastern coast horticultural regions. The authors are confident that the crop will succeed horticulturally in Australia. The next challenge is to establish plantings, and commercial structures to optimise market development.

1. Introduction

The red bayberry (*Myrica rubra* Sieb. and Zucc.) plant is native to China and is indigenous to warm and humid environments (Li, 2001). Red bayberry is widely known as Yang mei in China. It is also known, incorrectly, as arbutus; this being the genus name of the ornamental Irish strawberry tree *Arbutus Unedo,* L. Red bayberry is grown mainly in hills or uplands near rivers, lakes or the sea in south-east China (Fig. 1A).

Outside China, red bayberry is cultivated in amenity horticulture in Japan, where it is the 10th most important street tree in Tokyo (Araki 2003). However, it is seldom grown commercially in other countries. Nonetheless, reports of red bayberry plants growing in non-Asian countries include the UK (Anon 2002). There are prospects for introduction of this crop into Australian horticulture, particularly given the broad range of environments; including the climatic gradation down the eastern seaboard. Red bayberry could be produced for local markets (including the Chinese sector) and also for export. Cropping would be counter-season to China and in this sense would offer opportunities for collaboration. The fruit is extremely popular in China. As an indicator of its value, a typhoon that hit east China's Zhejiang Province in July 2001 ruined around 100,000 tons of red bayberries (Anon 2003a). The cost of the damage was estimated to be US$120 million.

In China, cultivation for fruit production is changing from managed trees on hillsides to more intensive cultivation. Elite varieties are being selected. 'Donkui' has large fruit ranging between 20-25 g each. Grafting, fertilisation, pruning and pest control are increasingly practiced by growers. Consequently, improved growth and production are being achieved on infertile hill slopes (Table 1). Production has increased dramatically in the last decade. The total red bayberry production area in China is 136,500 ha and the managed area is 103,100 ha. In Zhejiang province, the prime production area of 40,000 ha yields about 29.3% of national production (Li, 2001). Growth in red bayberry fruit production may be attributed to greater recognition of the crops economic potential and to improvements in pre- and post-harvest management practices (eg. Joyce and Li, 2002a, b). Nonetheless, over most of the production area, red bayberry is still grown in a semi-cultivated manner. Substantial potential exists for genetic improvement and optimisation of cultural practices.

Table 1. Reported *Myrica* yields (Zou, 2001).

Species	Yield (kg/tree)	No. female plants/ha	Tree no. / ha	Yield[a] (kg/ha)
rubra	7.2	540	500	3400
esculenta	5.1	450	410	2000

[a] NOTE: From other sources (pers. comm.), yang mei fruit yields range from 7,500 to 15,000 kg/ha at commercial orchards in Zhejiang Province. The highest record in CiXi is 18,000 kg/ha. The orchard visited in LanXi district by the authors reported 15 t/ha but it is the yield of high-grade quality fruit. The lesser yields reported in this table may be for managed 'wild' orchards.

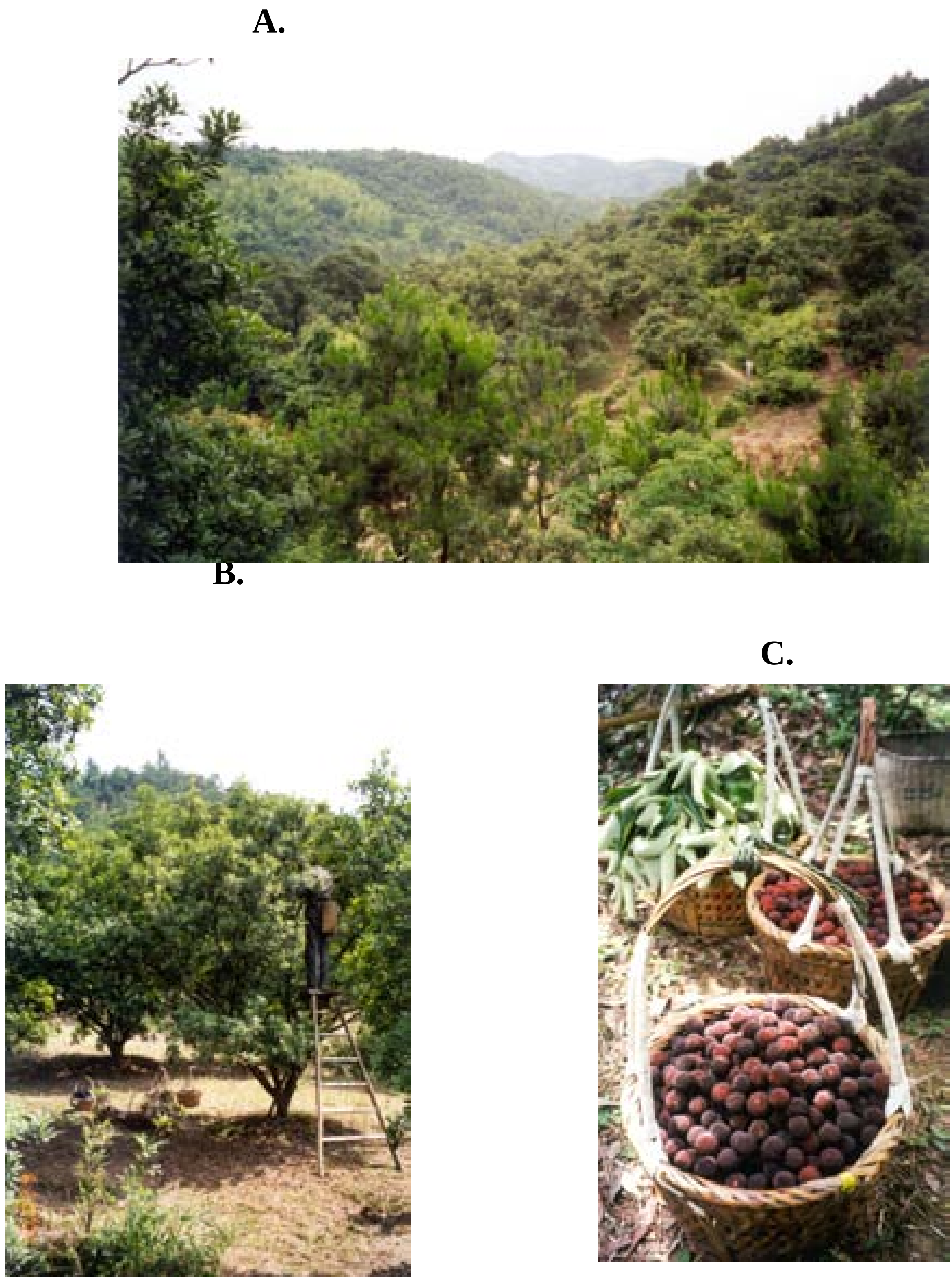
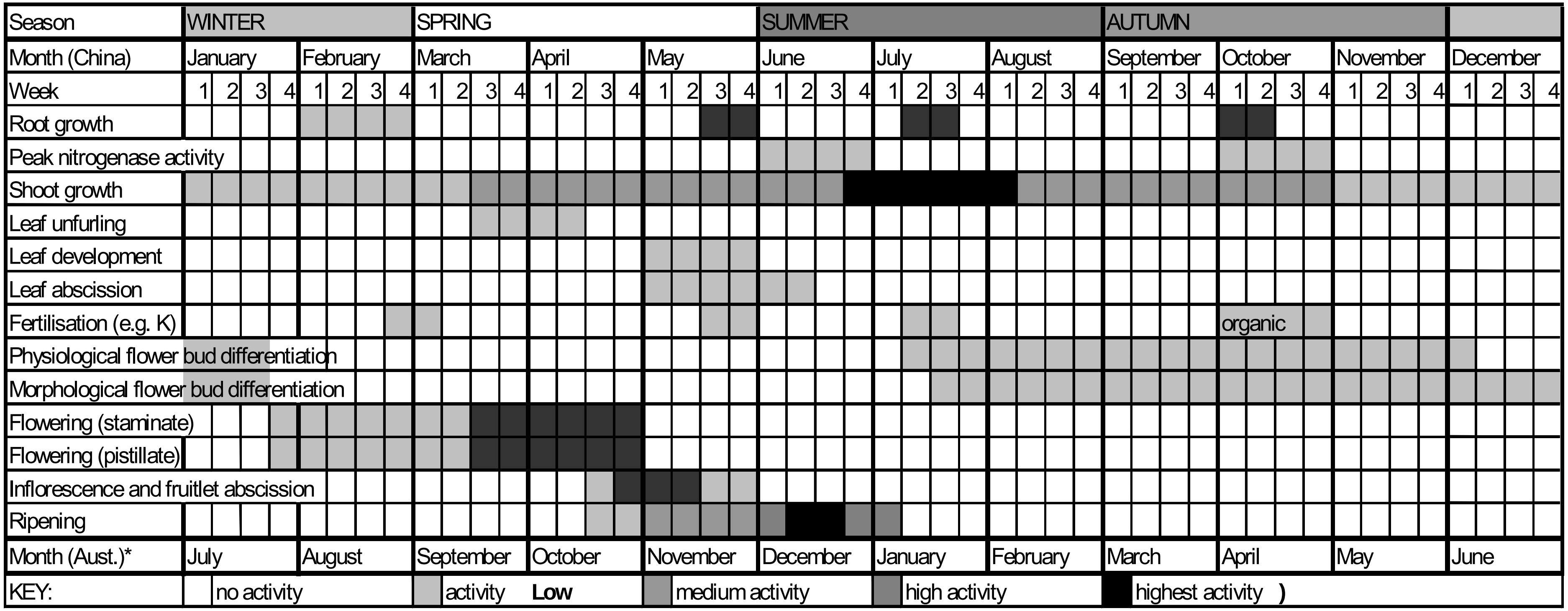


Fig. 1. A hilly Zhejiang Province landscape where red bayberry fruit trees grow (A.), harvesting red bayberry trees (B.), and harvested red bayberry fruit in a basket (C; Joyce and Li 2003).

The red bayberry tree flowers at the end of winter (Fig. 2). Fruit, borne on panicles are harvested over 2-3 weeks in mid summer (Li and Dai, 1980; Li et al., 2003). The fruit is a pleasant combination of sweet (sugar) and tart (acid) tastes. It is rich in vitamin C, thiamine, riboflavin and carotene. It also contains the minerals calcium, phosphorous, iron and potassium (Wang et al., 2002b). The fruit are said to have beneficial health effects, including settling the stomach and bowels and being thirst quenching (Li, 2001). The fresh fruit are popular, but the short harvest period and restricted post-harvest life limit consumption in this form (Xi et al., 1994). Processing into juice and wine and canning, freezing and drying constitute alternatives to fresh consumption (Li, 2001).

Increased attention to post-harvest technology in recent years has grown in response to the general realisation that limited post-harvest infrastructure leads to large losses. Soft and juicy red bayberry fruit are extremely susceptible to mechanical injury (Chen et al., 1995). Significant inputs of labour, materials and capital are needed to optimise post-harvest handling systems for the fresh fruit (Li et al., 1999). Thus, short post-harvest longevity is problematical for development of red bayberry fruit in China (Hu et al., 2001).

This review presents general information of production and handling of red bayberry, with an emphasis on post-harvest management of the fresh fruit. Another useful English language review of red bayberry production was published by Li et al. (1992) and presents proportionally more pre-harvest information. Similarly, Chen et al. (2004) recently published a review on the botany and horticulture of *Myrica rubra*. More detail on the biology of and technology for harvested red bayberry fruit can be found in the proceedings of a post-harvest workshop published in English (Joyce and Li 2002a).



(after: Chen et al. 2004)

Fig. 2. Annual red bayberry growth and development characteristics. Note: the timelines shown are approximations (Chen et al. 2004).

2. Origin

Myrica rubra is native to Southern China. Its wild type can still be easily found today, but presently is usually used as a rootstock (Li et al., 1992). Evidence from a Neolithic site at Homutu in Yuyao (Zhejiang Province) suggests that red bayberry has been utilised for at least 7,000 years (Anon, 1976). Records in Chinese literature suggest that Zhejiang Province has a long history of managing red bayberry plants and the greatest variety of cultivated genotypes (Miao and Wang, 1987).

3. Distribution

Apart from being planted as an amenity tree in Japan, red bayberry it is seldom cultivated in other countries (Li et al., 1992). China is pre-eminent in the world for production of red bayberry fruit both in terms of cultivated area and quantity of fruit produced. Distribution in China is in the area 97-122^{o}E longitude and 20-31^{o}N latitude. Major production in China is mainly south of the Yangtze River and Qingling mountains (Zou, 2001). While Zhejiang Province is most important in terms of cultivars, production area, total yield and fruit quality, red bayberry is also produced commercially in Fujian and Guangdong Provinces. Growing locations for red bayberry are characterised by proximity to large water bodies, which may influence the local environment (viz. temperature, relative humidity).

4. Germplasm

More than 50 species of *Myricaceae* are distributed widely in tropical, subtropical and temperate areas (He et al., 2002). Four main *Myrica* fruit species are:
1. *Myrica rubra* (Lour.) Sieb. & Zucc. - Red bayberry varieties in cultivation (eg. ‘Donkui’ and ‘Hetian’) are derived from this species. It is an arborous plant with a height of 5-10 m. It is mainly found in Southern China, but also in Japan, South Korea and the Philippines.
2. *M. esculenta* Buch. Ham. - This species is found at elevations of 1,600-2,300 m in the mountains of southwest China (Provinces of Yunnan, Guizhou and Sichuan). It is also found in India, Nepal and Vietnam. The fruit are small, ovate and red when ripe. Several fruit are borne in clusters arising from one inflorescence.
3. *M. adenophora* Hance - This *Myrica* species is known as small-leaf arbutus. The shrub is typically 3-6 m high. It is found in Guangdong, Guangxi and Hainan Provinces of China. The fruit are usually elliptic and red in colour.
4. *M. nana* Cheval. - This species is also known as the dwarf or Yunnan arbutus. It is indigenous to Yunnan and Guizhou Provinces. The fruit is small and sour, but edible.

A key for the *Myrica* genus (species: *M. adenophora*, *esculenta*, *nana* and *rubra*) is available on-line via the internet (Anmin and Bornstein 2003). Allozyme analysis suggests that *M. rubra* and *M. adenophora* are genetically similar, the latter possibly being derived in evolutionary terms from the *M. rubra* genome (Cheng et al. 2000).

5. Botanical Characters

As noted above, the principle cultivated red bayberry varieties are derived from *Myrica rubra* (Yu, 1979). The evergreen trees about 2-10 m high have a round-shaped canopy with dense foliage. The dark green leaves are glossy and glabrous. The oblanceolate-shaped leaf has midrib protruding on the lower side and lateral veins extending in a parallel pattern from the midrib (Ruan and Wu, 1991). The root system is fibrous, usually with tap roots. An English language botanical description has been published by Flora Online (Anon 2003b).

Myricaceae can be divided into four flowering types according to male and female flower presentation (Miao and Wang, 1987); viz. 1 = only male flowers; 2 = only female flowers; 3 = female flowers > male flowers, and, 4 = male flowers>female flowers. *Myrica rubra* generally has male and female catkins borne on separate plants (ie. dioecious; Fig. 3). It is difficult to distinguish female from male flowers prior to blossom (Zou, 2001). The pollen grains are small (*ca*. 20 um diameter) and pollination is mainly by wind. The hierarchical relationship among male (staminate) floral structures is: individual flowers, on individual catkins, on compound catkins, on staminate flowering shoots. The hierarchical relationship among female (pistillate) floral structures is similar, but on pistillate flowering shoots. The catkins arise axially from shoots as a racemose inflorescence. Numbers of catkins per shoot vary greatly; eg. 10-20 catkins per shoot for male plants and 6-9 catkins per shoot for female plants. Male catkins are 1-3 cm long and comprised of 15-36 sub-inflorescences. Each sub-inflorescence is composed of 4-6 florets, with each floret having two stamens from which yellow pollen is released. The female catkin is about 1 cm long and bears 7-26 florets. Female florets have one involucre, but no stalk and receptacle. The stigma presents in pinnatipartite form and scarlet colour. Usually one floret at the distal end of the female catkin develops into a fruit (Miao and Wang, 1987). Thus, the axis of the catkin becomes a peduncle.

The red bayberry is a stone fruit (drupe; Fig 4A). Soft and succulent edible flesh (epicarp) surrounds the single stone (endocarp) within which is the single seed. The flesh (pericarp and mesocarp) develops from the exocarp and consists of many papillae. These papillae are arranged in a radial fashion around the endocarp that develops into a stony pit either clinging to or free from the flesh.

6. Environmental Requirements

Red bayberry is adapted to acidic soils (pH 4-5). Plants usually grow in groves at the foot to part-way up hills. They share a niche with fern, rhododendron, pine and China fir. Green tea, stone fruit (eg. peaches) and citrus are cropped in the same areas. A nitrogen-fixing bacterial (*Actinomyces frankia*) association produces nodules on the root system and facilitates growth in infertile hill soils versus on fertile flat lands (Wang et al., 1990). With adequate soil moisture and humid conditions, the trees tend to produce thick growth and large fruit, and have a long bearing life (>30 years; Mao et al., 1995). They prefer warm temperatures, with an annual average temperature range of 15-21^{o}C. High temperatures of >35^{o}C may damage the red bayberry trees (Mao and Wang, 1987). Red bayberry trees can tolerate sub-zero temperatures down to *ca*. -10^{o}C. Red bayberry does not have special light requirements for normal growth and development (Mao et al., 1996). Sun exposure during the end of summer to early autumn favours fruit colouration and flower bud formation. High light intensity during mid-late summer may facilitate heavy cropping in the following season. Ambient relative humidity during fruit development can influence fruit quality. At high humidity, fruit are soft and succulent with rounded tips on their papillae. Conversely, fruit from drier areas have more pointed papillae and are comparatively firmer. As a result, they have better transport and storage, but poorer organoleptic, characteristics. Excess heat and direct solar radiation stress can exacerbate low relative humidity effects. Earlier in the year, high relative humidity favours pollination.

7. Cultivation

Red bayberry is relatively easy to grow. Seed can be sown fresh, but stored seed benefit from cold stratification (Anon 2002). Vegetative propagation can be achieved from both cuttings and suckers arising from layering. A comparative investigation of propagation practices for *Myrica* spp. in relation to planting time, methods and survival rate is summarised in Table 2. The vegetative period from planting seeds to fruit bearing can be 8-10 years or more. The use of rootstocks grafted with elite scion selections increases the survival rate for plantation trees, enhances new root system development and decreases the time to initial fruit bearing (Li et al., 1999; Zou, 2001). Under management that involves application of plant grow regulators such as paclobutrazole (PP333) the vegetative period of red bayberry from planting to bearing may be reduced from 8-10 years to 3-4 years. Stem girdling also promotes flowering. Tree form is controlled by tipping and pruning. The vase-shape is useful for tree vigour control and ease of harvest. In high labour cost countries, such as Australia, the Tatura trellis in combination with mechanical harvesting might be trialed. However, the fruit are delicate and, in China, fallen fruit are only used for processing.

Table 2. Comparative investigation of propagation practices for *Myrica* spp. in relation to planting time, methods and survival rate.

Species	Planting time	Methods	Survival rate (%)
nana	November	leaves completely removed, stems in moist medium	70
	April	cuttings in bamboo basket	90
esculenta	November	leaves completely removed, stems in moist medium	50
	April	leaves completely removed, stems in moist medium	80
rubra	November	leaves completely removed, stems in moist medium	50
	April	leaves completely removed, stems in moist medium	90

A large planting hole favours growth and expansion of the root system. Holes are typically 1 m-diameter and 0.8 m-deep. When nursery stock is planted-out, ≤50 kg of livestock manure is applied in the hole. Planting density depends on soil depth, fertility and its physicochemical properties. Planting density per hectare in China varies from around 250 plants with inter-row spacings of 5-7 m up to *ca*. 600. Greatest survival is achieved when seedlings are transplanted prior to bud break in spring. At this time, nursery stock is in the state of relative dormancy with stored nutrients and low transpiration. Flowers are borne on 1-year-old wood. Biennial bearing can be a problem. Summer sprays with gibberellic acid (eg. 250 g GA_3 / L) may help suppress flower differentiation for the following year.

A number of pests and disease affect red bayberry. The bayberry whitefly (*Bemisia myricae*) is an insect pest of red bayberry plants and also citrus (Hamon et al., 2001). Fruit fly and scale insects are problems (Table 3). Fungi, bacteria and nematodes all cause diseases of red bayberry plants (Table 3).

8. Production Area

The total growing area of red bayberry trees in China was estimated to be 136,500 ha in 2002, including a cultivated area of 103,100 ha (Li et al., 2001). *Myrica rubra* is primarily grown in Zhejiang province where the growing area is 40,000 ha (about 29% of the national area) and the cultivated area is 39,300 hectares (about 38% of the national area). Due to increasing recognition of the economic importance of red bayberry and improvement in cultural practices, production has increased rapidly in recent years. Nonetheless, for the majority of areas, red bayberry still grows in semi-cultivated state. Thus, potential exists for improvement by either cultural practices and/or germplasm selection, both of which should result in better yields.

Table 3. Diseases and pests of red bayberry (after Chen et al. 2004).

Common name	Latin name	Tissue affected
Disease		
Brown leaf spot	*Mycosphaerella myricae*	leaves
Red mould	*Corticum saimonicolor*	branches
Root knot nematode	*Meloidogyne* spp.	roots
Root rot	*Botryosphaeria dothidea*	roots
Rust	*Caeoma makinoi* Kusano	leaves
Shoot rot	*Valsa coronata*	shoot cortex
Stem blight	*Myxosporium corticola*	trunk
Tumours	*Pseudomonas syringae* pv. Myricae	shoots, trunk
Pest		
Fruit fly	*Drosophila melanogaster*	fruit
Leaf rolling moth	*Homona* spp.	leaves (young)
Leaf wilt moth	*Lebeda nobilis*	leaves
Scale (1)	*Lepidosphes cupressi*	leaves (Spring)
Scale (2)	*Fiorinia myricae*	fruit
White ants	*Odontoermes formosanus*, *Macrotermes barneyi*	trunk, root

9. Fruit Growth and Development

Initial seed development is followed by a rapid growth of red bayberry fruit flesh (Li et al. 1999; Joyce and Li 2003). Fruit diameter and weight continued to increase until harvest (Fig. 4B, 5A and 5B), while fruit firmness reduced most at the beginning of colouration (Fig. 5C). Early harvest of red bayberry may give firmer fruit that are less susceptible to mechanical injury. For the most important varieties in Zhejiang, it takes about 2 months from anthesis to ripening. The bright red to nearly black colours of red bayberry are due to anthocyanins (Ye et al., 1994). Fruit continue to synthesise anthocyanins during fruit colouration up to harvest time (Fig. 5D; Li et al., 2002a). Flesh colour varies among cultivars (*ca*. 270 in China) from white through various shades of pink and then red to dark red and almost black.

9.1 Harvest maturity

Red bayberry is typically non-climacteric and thus will not continue to ripen once removed from the tree (Joyce and Li, 2002a; Joyce and Li 2003). Consequently, fruit must be harvested (Fig. 1B) when they reach optimal eating quality and visual appearance. General guidelines for harvesting are difficult to find because of the wide range of varieties grown. Maturity may be determined on the basis of fruit weight, colour, sugar content, acid level, sugar:acid ratio, flavour and/or days from anthesis. Red bayberry taste is largely determined by its sugar and titratable acidity contents and the TSS:acidity ratio is a good indicator of taste (Miao and Wang, 1987). However, in practice, maturity is assessed on the bases of fruit colour and flavour.

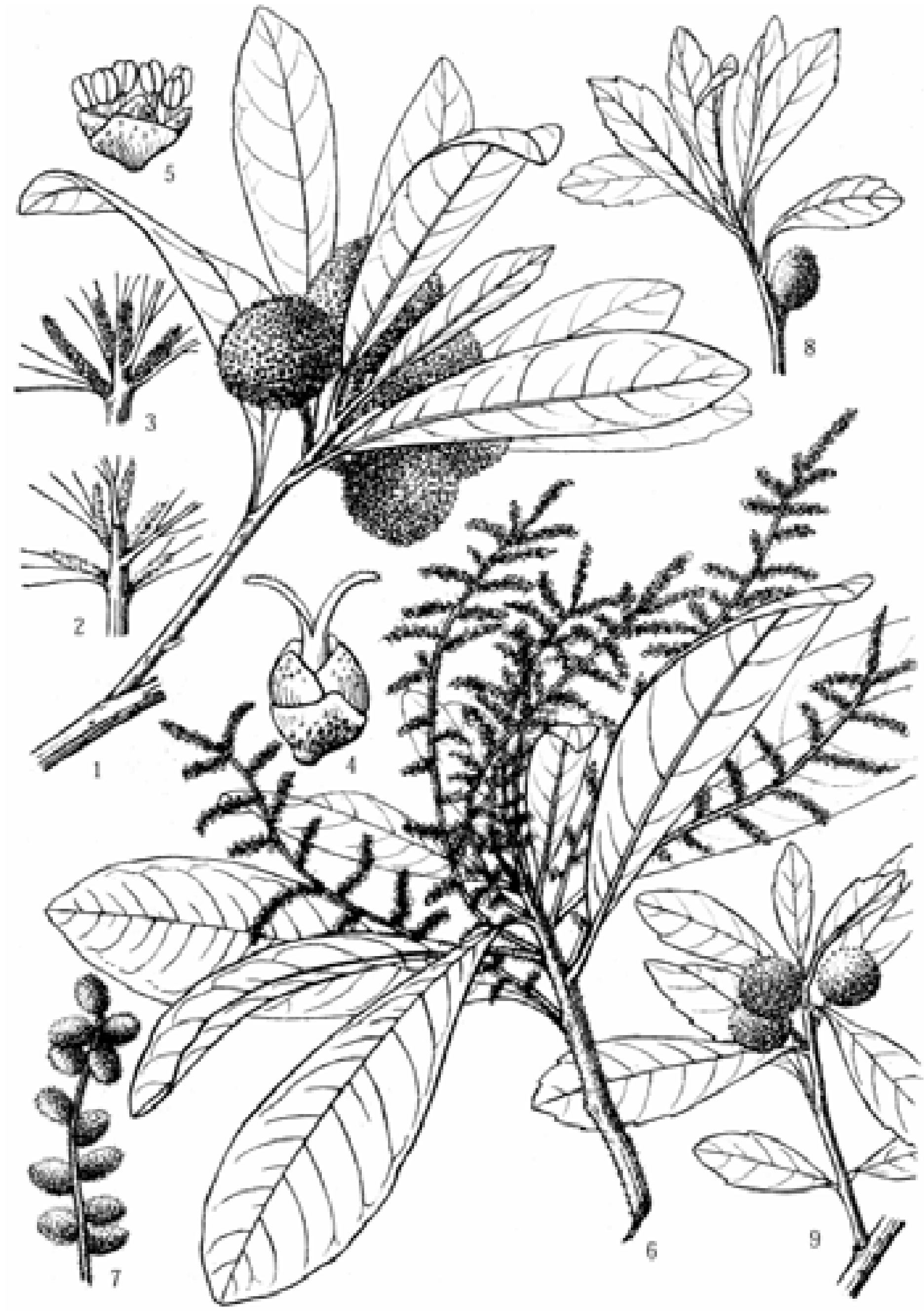
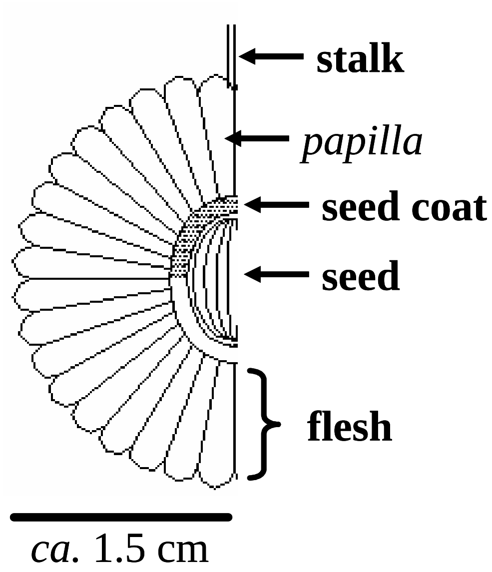


Fig. 3. Diagrammatic representation of red bayberry (*Myrica rubra* Siebold and Zuccarini; yang mei) 1. fruiting branchlet, 2. branchlet with female spikes, 3. branchlet with male spikes, 4. female flower, and, 5. male flower; *M. esculentum* Buchanan-Hamilton (mao yang mei) 6. branchlet with male spikes, and, 7. fruiting spike; *M. adenophora* Hance (qing yang mei) 8. fruiting branchlet, and; *M. nana* A. Chevalier (yunnan yang mei) 9. fruiting branchlet. (reproduced with permission from FOC 276, 276; FRPS 21: 5, pl. 1. 1979 – Wu Zhanghua, redrawn by Zhang Taili.; from http://mobot.mobot.org/cgi-bin/search_vast?w3till=21700085_001.gif and http://digitalis.mobot.org/mrsid/217/21700085_001.gif)

A.



B.

Fig. 4. Diagrammatic representation of bay berry fruit structure (A) and red bayberry fruit development series (dates in May-June, China; B; Joyce and Li 2003).

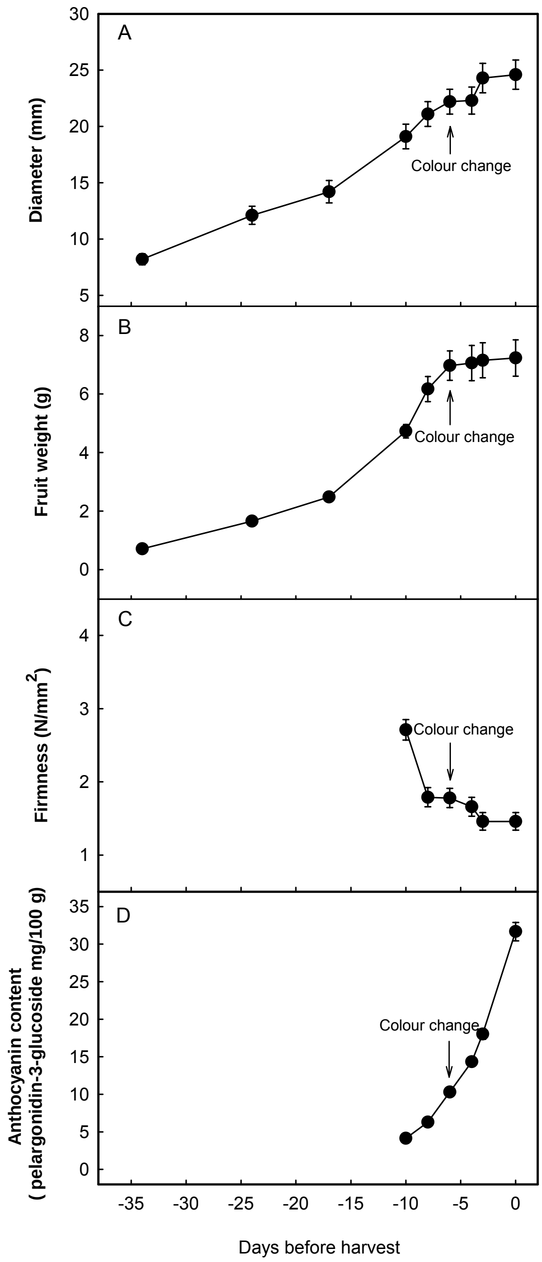


Fig. 5. Changes in weight (A), size (B), firmness (C) and anthocyanin content (D) during growth and at harvest of red bayberry fruit (after Li et al. 2002b). The colour change point marks the time when the fruit change colour from green to red. Each value is the mean and standard error.

Total soluble solids (TSS) increase steadily during fruit colour change up to harvest (Fig. 6A; Li et al., 2002b). Titratable acidity (TA) decreases continuously during maturation and then tends to stabilise (Fig. 6B). TSS and TA decrease slightly with storage. Where post-harvest changes in TA and TSS occur, they are slight in comparison to climacteric fruit (Sawamura et al., 1989; Xi et al., 2001a). Ascorbic acid content increased *ca*. 6 d before harvest. After this time, ascorbic acid tends to reduce and then rise again (Fig. 6C).

Red bayberry fruit contain vitamin C, thiamine, riboflavin and carotene, and minerals such as calcium, phosphorous, iron, potassium (Table 4; Wang et al., 2002b). The fruit are reputed to have health benefits (ethno-botanical) effects, including anti-diarrhoea, anti-vomit, improved digestion and thirst-quenching properties (Li, 2001).

Table 4. Composition of red bayberry fruit (amount/100g) (Wang et al., 2002b)

Composition	Amount	Composition	Amount	Composition	Amount
Edible part	82 g	Potassium	149 mg	Phenylalanine	4 mg
Calories	117 kJ	Sodium	0.7 mg	Tyrosine	44 mg
Moisture	92.0 %	Calcium	14 mg	Threonine	34 mg
Protein	0.8 g	Magnesium	10 mg	Tryptophan	4 mg
Lipid	0.2 g	Iron	1.0 mg	Valine	46 mg
Dietary fibre	1.0 g	Manganese	0.72 mg	Arginine	39 mg
Carbohydrate	5.7 g	Zinc	0.14 mg	Histidine	36 mg
Ash	0.3 g	Copper	0.02 mg	Alanine	46 mg
Carotene	40 μg	Phosphorous	8 mg	Aspartic acid	96 mg
Retinal	7 μg	Selenium	0.31 μg	Glutamic acid	109 mg
Thiamine	0.01 mg	Isoleucine	41 mg	Glycine	50 mg
Riboflavin	0.05 mg	Leucine	66 mg	Proline	64 mg
Nicotinic acid	0.3 mg	Lysine	65 mg	Serine	69 mg
Ascorbic acid	9 mg	Methionine	16 mg	Total VE	0.81 mg
		Cystine	10 mg		

9.2 Respiration and ethylene evolution

Red bayberry fruit respiration rate reduces initially during colouration and then increases before harvest (Fig. 7A). The fruit do not have the upsurge in respiration typical of climacteric fruit. Li (2001) found that respiration decreases on the first day of storage at 1 or 5°C, then maintained a relatively low level and finally increases. The increase in respiration was associated with disease development. Hu et al. (2001) reported that the red bayberry showed evidence of a respiratory climacteric during storage at 21^{o}C. However, the increase in respiration rates observed may alternatively be due to mechanical injury, fungal infection or/and a varietal character.

Red bayberry ethylene production increases slowly with fruit ripening with an increase evident at late colour change near harvest time (Fig. 7B; Li et al., 2002b). This late increase suggests that the fruit entered senescence. Red bayberry fruit produce about 3.8 μl ethylene l $kg^{-1}.h^{-1}$ at the peak rate after harvest. Rapid deterioration of red bayberry fruit may be associated with ethylene effects. However, it is uncertain whether this ethylene is either senescence-associated or attributable to non-physiological factors such as mechanical injury or fungal development.

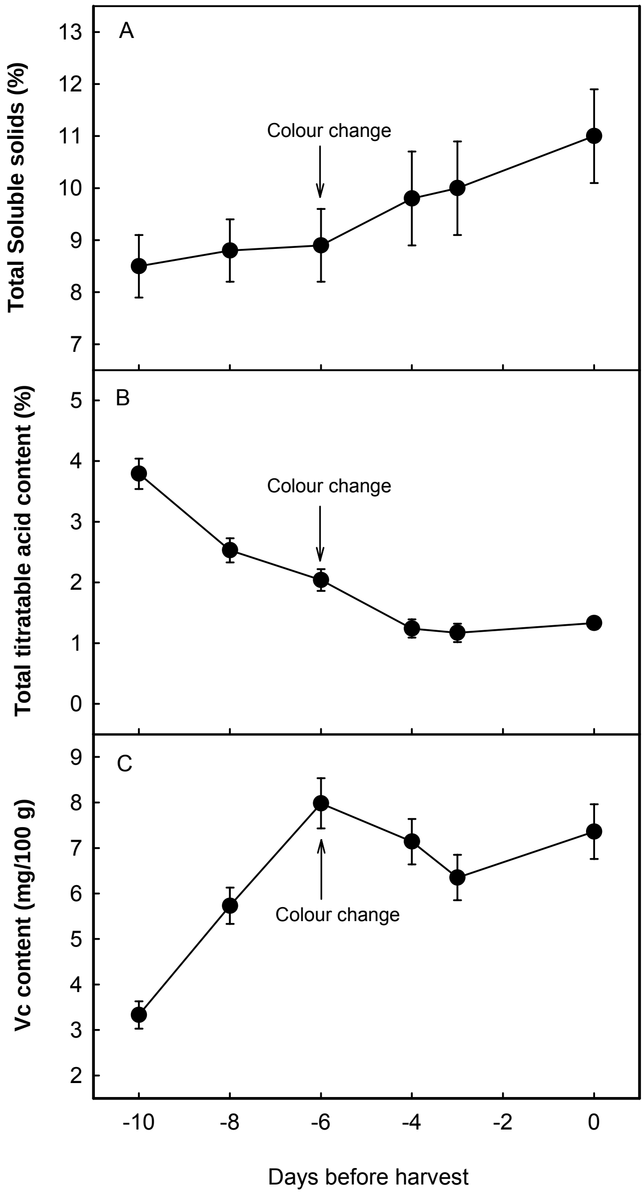


Fig. 6. Changes in total soluble solids (A), titratable acidity (B) and ascorbic acid (Vitamin C [Vc]; C) during growth and at harvest of red bayberry fruit (after Li et al. 2002b). The colour change point marks the time when the fruit change colour from green to red. Each value is the mean and standard error.

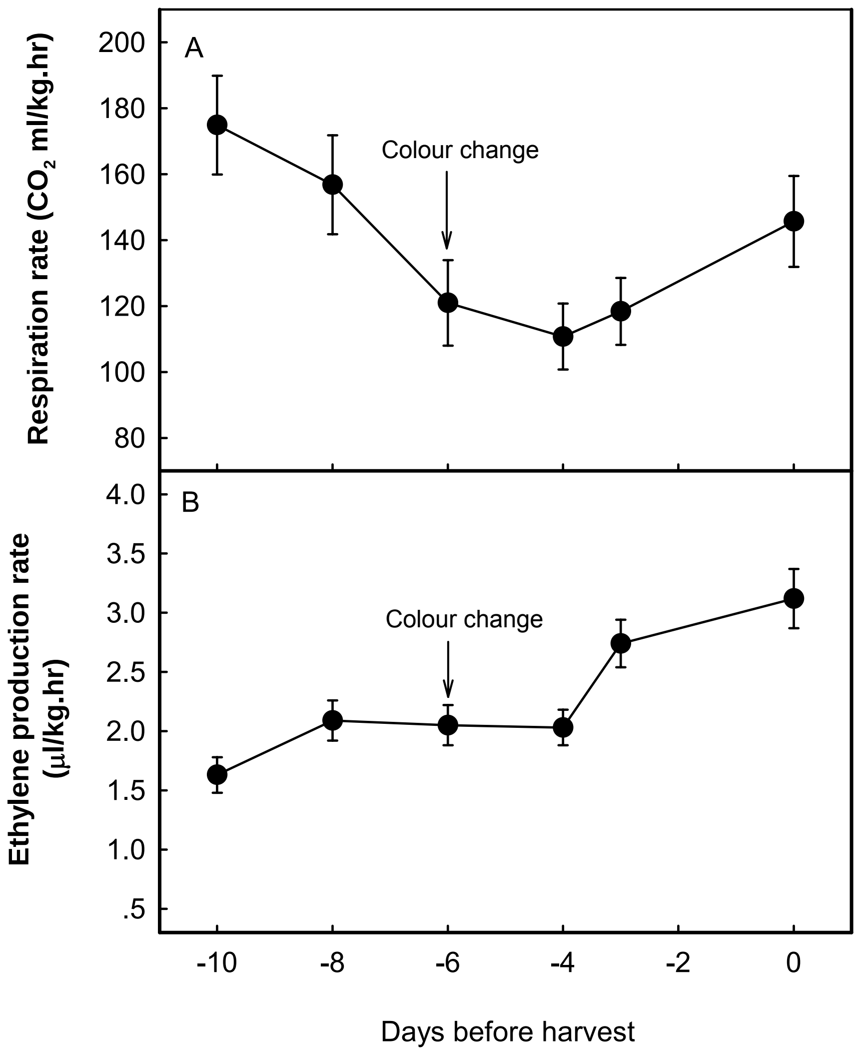


Fig. 7. Changes in respiration rate (A) and ethylene production rate (B) during growth and at harvest of red bayberry fruit (after Li et al. 2002b). The colour change point marks the time when the fruit change colour from green to red. Each value is the mean and standard error.

10. Post-harvest

10.1 Pest and disease problems

Red bayberry fruit can host fruit flies of the *Bactrocera dorsalis* complex, which can have plant quarantine implications with respect to trade with Japan (Anon 2003c, d) and other destinations. Red bayberry fruit are highly susceptible to post-harvest decay (Wang et al., 1998). Twenty types of fungi have been isolated from red bayberry fruit from CA (controlled atmosphere) storage (Qi et al., 2003). Common fungi and yeasts include *Alternaria* sp., *Aspergillus* sp., *Candida* sp., *Penicillium* sp. and *Saccharomyces* sp. (Li et al., 2002c; Qi et al., 2003).

10.2 Grading and handling

No official grade standards are available for red bayberry fruit. In practice, red bayberry fruit are graded on the basis of their size or weight. 'Dongkui' fruit ranging between 40-50 fruit per kg are usually considered to be top grade (Li, 2001).

In China, bamboo baskets are commonly used to package red bayberry fruit for local markets (Fig. 1C). Cardboard boxes and plastic crates are preferentially used for transport and distribution to central cities (Li, 2001). Greater storage life of red bayberry fruit was obtained at 1-3^{o}C, with fruit remaining marketable for 20-30 d inside sealed bags. In contrast, non-bagged red bayberry fruit at this temperature became unmarketable within 15 d. Under conditions for minimising moisture loss, the shelf life of red bayberry fruit stored at low temperatures is limited by disease development.

For optimum eating quality, delicate red bayberry fruit need to be harvested fully ripe. In this state, they are extremely susceptible to mechanical injury (Chen et al. 1994). Vibration, impact and compression during storage and transport of red bayberry readily injure the fruit (Zheng et al., 1996; Wang et al., 2002b). Sub-packaging in small boxes and padding with moisture absorbent materials can reduce the degree of injury sustained during transport and storage (Yin and Xi, 1997).

Techniques to maintain the bright colour of and extend storage life of red bayberry fruit have included cold storage, modified atmosphere packaging (MAP), CA storage and edible coatings (Du, 2000). Of these, only cold storage and MAP have been used commercially.

10.3 Precooling and cold storage

Loss in red bayberry fruit shelf life is characterised by a decline in visual appearance, a reduction in organoleptic quality and the development of diseases (Li, 2001). Under low temperature conditions, the shelf life of red bayberry is limited more by visual appearance than a decline in organoleptic quality. Rapid moisture loss occurs after harvest if improper packaging is employed (Wang and Shen, 1999).

Immediate and rapid precooling is important in cold chain maintenance for red bayberry fruit. Removal of field heat provides for effective temperature management during subsequent storage or shipment (Li and Chen, 2002). Hydrocooling using iced-water for 2-3 h at 0-2^{o}C may be satisfactory for red bayberry fruit. For forced-air cooling, a high-capacity cold room is required and it can take ≥12 h. Furthermore, unless the cold room operates at ≥85% relative humidity (RH), forced-air cooling may lead to fruit desiccation. Thus, hydrocooling may be preferable (Joyce and Li, 2002b). The effect of hydrocooling (ie. free water) on disease development has not been fully investigated. Nonetheless, hydrocooling has been progressively adopted commercially in China.

Red bayberry fruit are more tolerant of low temperatures than many other tropical and subtropical fruits (Li, 2001). Maximum postharvest life is attained in the lower temperature range of 1-5^{o}C. Decline in visual appearance and disease development eventually limit longevity (Wang et al., 2002a). Whilst low storage temperature inhibits senescence and fungal growth, fruit may deteriorate rapidly when removed from cold storage.

10.4 MAP and CA storage

Gas atmosphere modification has been reported to slow the rate of skin colour change in red bayberry fruit. However, MAP and CA studies to date have tended to lack adequate control treatments. Thus, it is unsure as to precisely how beneficial effects of atmosphere modification are derived. Xiao et al. (1999) and Wang et al. (2002a) reported MAP storage to be effective in delaying senescence and disease development. Modified atmosphere conditions with low CO_2 were more effective than those with high CO_2. CA of 15 % O_2 delayed accumulation of active oxygen radicals, prolonged storage life and maintained quality of red bayberry 'Buji' fruit (Xi et al., 2001a, 2001b). However, CA storage is not used commercially at present.

10.5 Processing

Red bayberry is often dried outside under ambient conditions unless controlled drying facilities are available. The fruit can be frozen without any apparent adverse effects on flesh qualities other than upon texture. In addition, red bayberry can be canned in syrup or processed to produce wine or juice (Miao and Wang, 1987; Li, 2001, Li et al., 2002a).

11. Likely Climatic Adaptation

This exercise focuses on matching a few sites in Australia to two main Red bayberry growing regions in China in terms of climatic similarity. Two sites in Zhejiang province were selected for this purpose, namely Wengzhou and Ningbo. Both sites are in the south-eastern part of Zheijiang province, with an annual rainfall of 1640-1720 mm and an average total of 2700-3000 heat units per year. In this exercise, six Australian sites: Nambour (southern Queensland), Mareeba (southern Queensland), Innisfail (northern QLD), Alstonville (New South Wales), Bright (Victoria) and Darwin (NT) were compared with Wengzhou and Ningbo cities of Zhejiang province.

11.1 Methodology:

The Heat Unit mapping program developed at the Agricultural Research and Advisory Station, NSW Department of Primary Industries, Dareton was used to match different areas from three Australian states (Queensland, New South Wales and Victoria) and the Northern Territory.
Data on average minimum and maximum monthly temperatures were obtained for two Chinese sites, namely Wengzhou and Ningbo. Using these monthly averages, synthetic daily mean maximum and minimum temperatures were derived by using Heat Unit mapping software. After deriving the daily maximum and minimum temperature for the entire year (growing season), heat units were calculated using the following thresholds:

Maximum temperature Threshold = 35 ^{0}C
Minimum temperature Threshold = 2 ^{0}C
Base temperature = 10 ^{0}C

Heat Units = [(Maximum + Minimum)/2] – Base temperature

These thresholds are used with the belief that above 35 ^{0}C, additional heat does not contribute to physiological processes, and below 10 ^{0}C, the plant does not function. These are assumptions based on the behaviour of a range of temperate and sub-tropical crops, and firm evidence is lacking in the case of Red bayberry.

Table 1. The latitudes, longitude and elevation of Wengzhou, Ningbo, Bright, Alstonville, Mareeba and Nambour, Innisfail and Darwin.

Sites	**Latitude ^{0}**	**Longitude ^{0}**	**Elevation (m)**
Wengzhou	28.01 N	120.40 E	7
Ningbo	29.55 N	121.28 E	6
Bright	36.43 S	146.57 E	320
Alstonville	28.51 S	153.27 E	140
Mareeba	17.00 S	145.25 E	405
Nambour	26.37 S	152.55 E	25
Innisfail	17.31 S	146.01 E	4
Darwin	12.26 S	130.53 E	31

Table 1 presents a summary of the geographical locations of the existing and suggested sites used for climatic comparisons and suitability for growing Red bayberry crop. The weather data used is based on averages of 18 years for Wengzhou, 20 years for Ningbo and 14 years for Bright, Alstonville, Mareeba and Nambour, Innisfail and Darwin. It is believed that average data of the last 14 to 20 years will provide appropriate information on the climatic suitability to compare and distinguish among existing and suggested sites for growing Red bayberry.

11.2 Temperature

Red bayberry tree performs well in tropical, subtropical and temperate zones with optimum temperature of 15-20 ^{0}C. It can tolerate winter freezing temperature with average temperatures of more than 2^{0}C and an absolute minimum above -9^{0}C. Heat units were calculated at the at the appropriate threshold levels for maximum, minimum and base temperature as mentioned above.

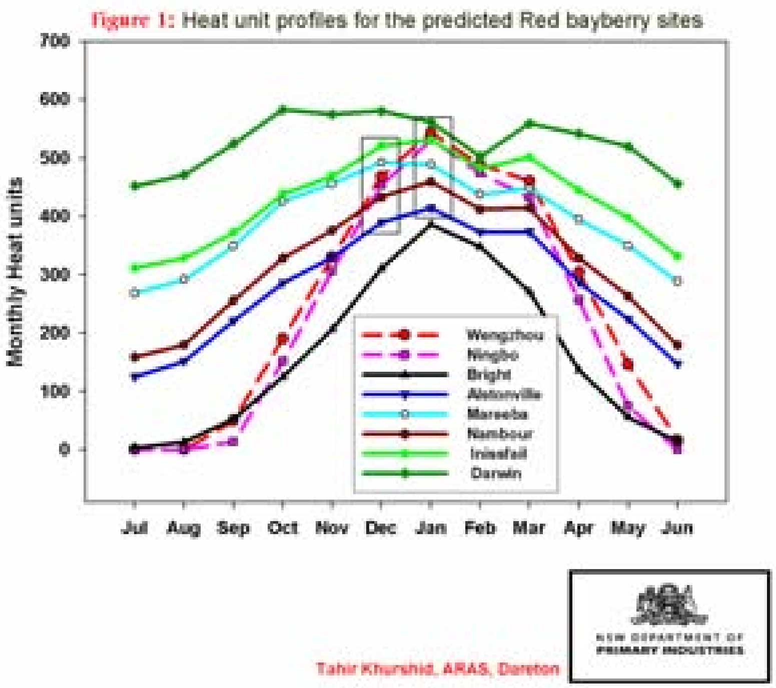
11.2.1 Heat Units

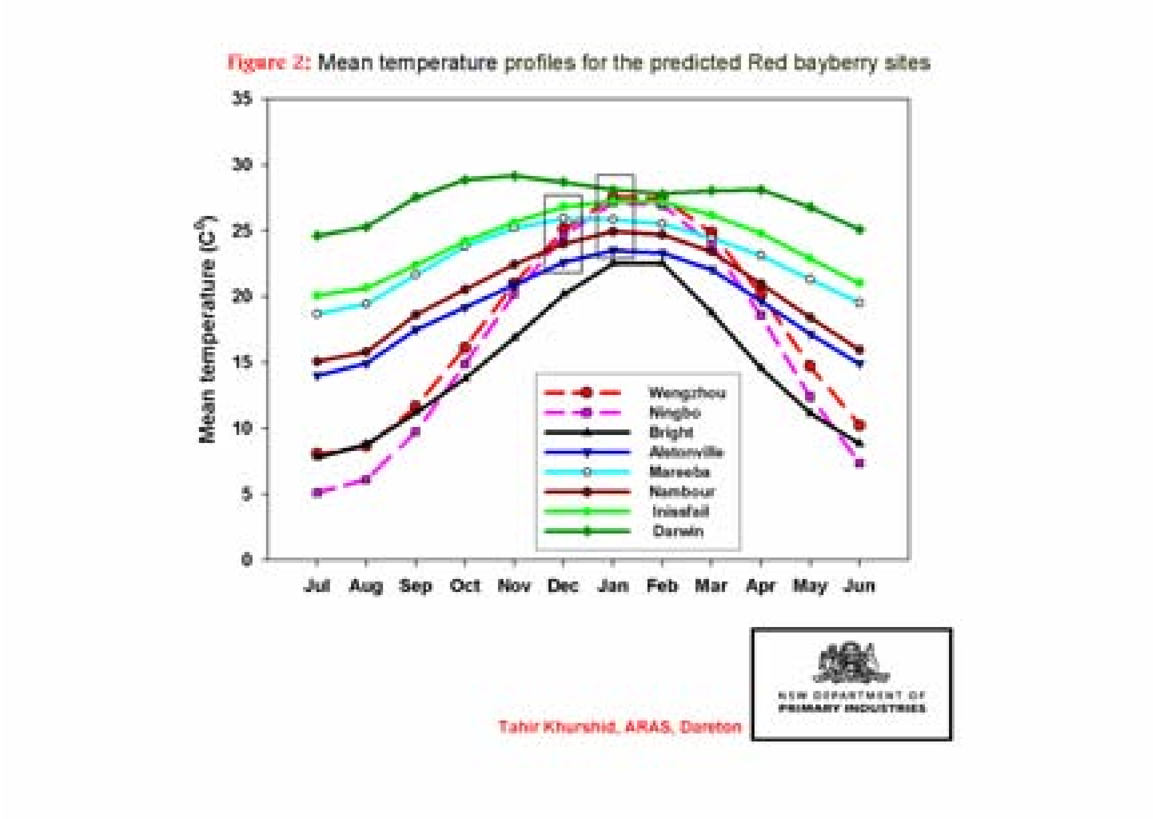
Heat units for Red Bayberry crop were calculated with a base temperature of 10 ^{0}C. Figure 1 indicates that the total heat units for Wengzhou and Ningbo ranged between 2700-3000 per annum. This differs from Miao et al. (1995) who suggest a total number of 6174 heat units above 10^{0}C. The discrepancy could be that the heat units have been calculated without adjusting the upper and lower temperature thresholds or some other method of calculation may have been used, eg., total number of days with average temperature above 10^{0}C .

The current heat unit data also suggest that Alstonville and Nambour are very much like the Chinese sites in the month of November (the time of fruit maturity); however, Mareeba and Innisfail have higher (> 100) heat units than the other sites for the same month. Darwin is very hot and has +500 heat units in Nov-Dec respectively (Figure 1). In December (Harvest time), Innisfail, Mareeba, Alstonville and Nambour match well with Wengzhou and Ningbo. In January, Innisfail and Darwin have similar heat units to Wengzhou and Ningbo. Bright had a total number of 1927 heat units per year. Generally, Bright had lower heat units in October and November compared to other sites.

11.2.2 Mean temperature

To achieve higher yield and better fruit quality, the growing conditions should meet appropriate optimum temperatures. Figure 2 shows that all sites followed the same pattern as Figure 1. Figure 1 also indicates that the spread in temperature range is less broad across sites in November-December months than other months before November or after December, suggesting that the early to mid – season cultivars which mature in December/January will be more suitable under Australian conditions.





11.3 Rainfall

Rainfall is one of the important factors in assuring high yields and high-quality fruit. In China most trees are planted on hills and slopes without any artificial irrigation. Annual rainfall and its distribution are the most important factors influencing tree growth and fruit production. In Zheijiang province, rainfall of more than 1000 mm is usually required for crop production; however, the optimum ranges lies between 1300-1700 mm.

Data in Figure 3 indicate that rainfall in Nambour and Alstonville closely match Wengzhou and Ningbo in November and December. Innisfail and Darwin have higher rainfall in December and January, suggesting that late cultivars may be suitable for these two sites. Normally, rainfall of more than 160 mm in December is required for successful fruit production. Rainfall of less than 100 mm will result in small, poor quality fruit and a reduction in yield. Figure 3 also indicates that rainfall in Mareeba is lower in November as compared to other sites and rainfall of 100 mm in December may not be enough for growing Red bayberry without supplementary irrigation. Bright also has lower rainfall of 80 mm and 70 mm in November and December respectively.

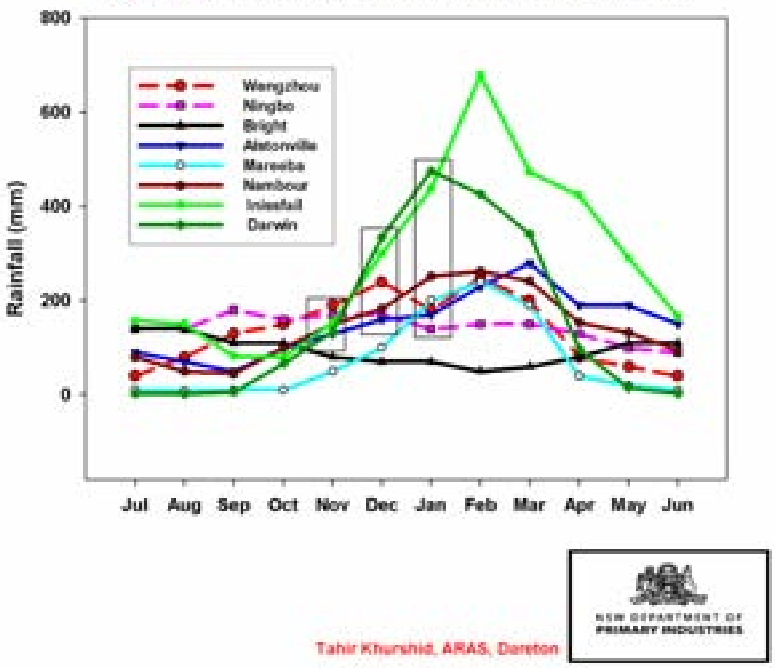


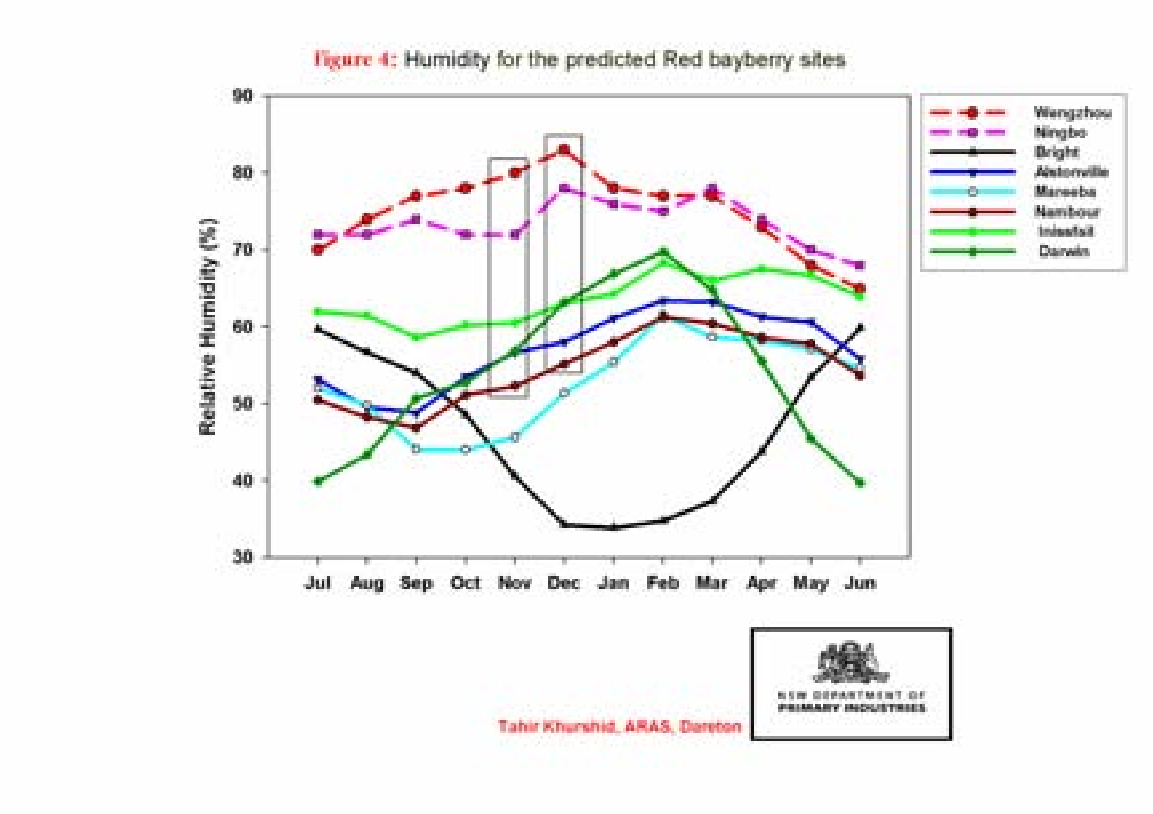
Figure 3: Rainfall (mm) for the predicted Red bayberry sites

11.4 Relative Humidity (RH)

Relative humidity is very important in the months of November-December for early maturing cultivars and probably in months of December-January for some late maturing cultivars. Low humidity can result in poor pollination and reduced yields.

Relative humidity data used for Wengzhou and Ningbo has been recorded at evening times, and may not be directly comparable to Australian data. Relative humidity data used in this report for the Australian sites have been recorded at higher temperatures (BOM). Data are available for RH at lower temperature for Australian sites, but they did not show any significant differences across sites, so it was decided not to use them for the comparisons presented herein.

Data in Figure 4 indicates that Wengzhou and Ningbo are certainly very humid sites, ranging from 70-85% RH. Figure 4 also indicates that Innisfail has more than 60% RH in the months of November and December, bringing it closer to the Chinese sites. Innisfail was followed by Darwin, Alstonville and Nambour with average RH ranging from 46-58% in November-December, with the only exception of Darwin where RH was higher in December and in January, suggesting that Darwin may be more suitable for late cultivars. Bright had an average RH of 29% (Mean value of months of November-December). These lower humidity figures for Bright and Mareeba suggest that these regions may not be suitable for growing Red bayberry fruit without microclimatic modification, such as poly-tunnel production.



12. Summary

The available climatic data obtained from different sources suggest that Nambour is probably closest to Wengzhou and Ningbo in terms of climatic suitability for growing early cultivars of Red bayberry fruit, followed by Alstonville. Innisfail and Darwin are the most suitable sites to grow late cultivars of Red bayberry, due to higher rainfall and humidity in December-January.

13. Recommendations

REGIONS WITH CLIMATES LIKELY TO SUIT RED BAYBERRY FRUIT PRODUCTION

1. Innisfail and Darwin are examples of the most suitable sites to grow Red bayberry for late cultivars.
2. Nambour and Alstonville are likely suitable sites to grow Red bayberry for early cultivars.
3. Bright and Mareeba may not be suitable production areas for Red bayberry due to lack of humidity and rainfall in the important months of the growing season. Supplementary irrigation is a normal practice in north-east Victoria, however there may be no competitive advantage to investment in climate modification if this crop succeeds well in warmer regions without climate modification.

14. Conclusion

Myrica rubra is a horticultural crop that has relatively limited production worldwide. However, it receives more attention nowadays than ever before. In China, cultivation is moving from semi-cultivated management to a cultivated basis. Production of the fruit has increased dramatically in the last decade. New varieties, such as 'Donkui' with large fruit, are being selected. Management practices such as nursery-grafting, fertilisation, soil tillage, pruning, plant growth regulator treatments and pest and disease control are increasingly adopted by Chinese growers. Strong growth and high productivity are achieved on infertile hill slopes. A rapidly expanding sector of the red bayberry industry is based on organic production with independent third-party accreditation. Agri-tourism focused on pick-your-own sales and regional celebrations (eg. concerts) is encouraged is several centres in Zhejiang Province.

Red bayberry is a non-climacteric fruit, and must be harvested at their visual and organoleptic optimum. Thus, unlike climacteric fruit that are harvested green-mature (eg. banana, mango), their organoleptic (eating) quality can only be lost once fruit are removed from the tree. Ripe red bayberry fruit typically have a very short post-harvest life and are difficult to store and transport. Post-harvest treatments and storage regimes that maintain quality closest to that at harvest are being sought. Loss of quality can be greatly alleviated by keeping the fruit under refrigerated conditions and by minimising mechanical injury. Depending on the cultivar, temperatures between 1-5^{o}C effectively extend storage life. Sub-packaging in small boxes and padding with moisture absorbent materials can reduce injury. Technologies such as storage in sealed polyethylene bags or plastic containers and coatings with calcium pectate have potential to help maintain quality. Although reliable data are limited, enhanced CO_2 atmospheres may increase storage life by 2-3 d. The maximum extension in postharvest longevity will no doubt be realised through a combination of effective methods. The system could involve pre-cooling and possibly the use of ethylene adsorbents and/or mould inhibitors within packaging. Research into postharvest disease management is a priority.

Our investigations have not allowed for identification of any peculiarities in the soils which support Chinese red bayberry production, beyond their lack of fertility and sloping topography. The success of seedlings in several potting mixes suggests that soil type is not of itself a limiting factor to production, however this assumption needs to be tested.
The most specific demands imposed by this crop appear to be those of climate. Fruit quality appears to be determined by very high humidity, which in China is associated with high rainfall. The need for high humidity is the most likely explanation for the lack of development of this crop beyond its native region of south-eastern China.

Red bayberry presents a unique opportunity to develop a marketing structure, possibly including marketers of the Chinese crop, at the same time as the horticulture of the crop is being developed in Australia. The next step in horticultural development of red bayberry will involve importation of elite Chinese germplasm including leading cultivars, which will require multiplication in a nursery or nurseries. This "bottleneck" presents a natural focus for management of the crop in a similar fashion to managed varieties of stone and pome fruit, and would offer investors some control over fruit quality, production, a means of managing the volume of fruit sent to local markets, and a mechanism for managing and co-ordinating export markets. The project team has set the establishment of such a group as a high priority for phase 2 of this project.

15 References

Anon, Reconnaissance of the Neolithic site at Ho-Mu-Tu in Yuyao County, Chekiang (Zhejiang) Province. *Wen Wu (Cultural Relic.)* **8**, 6-12,1976. (In Chinese)

Anon, *Myrica rubra* cultivation notes. Plants for a Future. http://www.scs.leeds.ac.uk/cgi-bin/pfaf/arr_html?Myrica+rubra (18/02/02), 2002.

Anon, Typhoons, rains damage bayberries in east China province. People's Daily Online. http://english.peopledaily.com.cn/200107/16eng20010716_75084.html (27.08.03), 2003a.

Anon, *Myrica rubra*. Flora of China. Flora Online. http://flora.huh.harvard.edu:8080/flora/browse.do?flora_id=2&taxon_id=121458 (http://flora.huh.harvard.edu/china/PDF/PDF04/myrica.pdf) (27.08.03), 2003b.

Anon, List of the plants which are prohibited to be imported. (updated April, 2003). http://pps.go.jp/english/law/list2.html (27/08/03), 2003c.

Anon, Information for visitors from the Republic of Indonesia. http://pps.go.jp/english/trip/overseas/list/122.html (27/08/03), 2003d.

Anmin, L. and Bornstein, A.J., Myricaceae. http://hua.huh.harvard.edu/china/mss/volume04/MYRICACEAE.published.pdf (27.08.03), 2003.

Araki, S., Street trees of Tokyo. (updated 2002) http://home.interlink.or.jp/~s-araki/HP-E.html (27.08.03), (2003).

Chen, C.R., Ying, T.J., and Qiang, D.M., Research on mechanical properties of red bayberry fruit and their change regularity in storage. *Food Science* **15**(10), 56-60, 1994. (In Chinese with English abstract)

Chen C.R., Ying T.J., Qiang D.M., and Li S.P., Research on mechanical properties of red bayberry fruit and their change regularity in storage. *Bulletin of Science and Technology* **11**, 54-58, 1995. (In Chinese with English abstract)

Chen, D., Wang, Y.G., Luo, ZS, Xi ,Y.F., and Xu, C., Effects of chitosan coating on quality of Chinese bayberry fruit. *Plant Physiology Communications* **37**, 506-507, 2001. (In Chinese with English abstract)

Chen, K., Xu, C., Zhang, B., and Ferguson, I.B. Red bayberry: Botany and horticulture. Horticultural Reviews 30, 83-114, 2004.

Cheng, Y-P., Chien, C-T., and Lin, T-P., Population genetics of geographically restricted and widespread species of *Myrica* (Myricaceae). *Journal of Heredity* **91**, 61-66, 2000.

Du, Y.K., CA and postharvest technology of fruit, vegetables and ornamentals. Chinese Agricultural University Press, Beijing, China, 2000. (In Chinese)

Hamon, A.B., Nguyen, R., and Browning, H., Bayberry whitefly. Featured Creatures. http://creatures.ifas.ufl.edu/citrus/bayberry_whitefly.htm (27.06.01), 2001.

He, X,H,, Chen, L.G., Hu, X.Q., and Zhang, J.Y., Study on genetic diversity of *Frankia* strains from symbiotic of *Myrica rubra*. *Journal of Zhejiang University (Agriculture & Life Science)* **28**, 659-663, 2002. (In Chinese with English abstract)

Hu, X.Q., Yu, X., and Chen, L.G., Studies of Chinese bayberry fruits on some physiological characters during the storage. *Journal of Zhejiang University (Agriculture & Life Science)* **27**, 179-182, 2001. (In Chinese with English abstract)

Joyce, D.C., and Li, J.R., Introduction to the proceedings of the yang mei (red bayberry) postharvest workshop. *Postharvest News and Information* **13**(4), 23, 2002a.

Joyce, D,C,, and Li, J.R., Current trends in postharvest technology. *Postharvest News and Information* **13**(4), 24-27, 2002b.

Joyce, D.C., and Li, J.R., Postharvest characteristics of red bayberry. pp. 125-226. Proceedings of the Australasian Postharvest Horticulture Conference, 2003. 1st-3rd October, 2003, Carlton Crest Hotel, Brisbane, Australia. (IBSN 0-646-43074-2), 2003.

Li, J.R., Study on the key technologies of postharvest and deep processing of red bayberry. PhD Thesis, Zhejiang University, P. R. of China, 2001. (In Chinese with English abstract)

Li, J.R., Processing technologies for red bayberry and the main vegetables in CiXi city. *Postharvest News and Information* **13**(4), 39, 2002.

Li, J.R., and Chen, Y.P., Production and trade of red bayberry in CiXi city. *Postharvest News and Information* **13**(4), 40, 2002.
Li, S.Y., and Dai S.Z., Preliminary observations on flower bud differentiation of *Myrica rubra* S et Z. *Acta Horticulturae Sinica* **7**, 9-16, 1980. (In Chinese with English abstract)
Li, J.R., Chen, P.L., and Joyce, D.C., Study on thermal degradation kinetics of anthocyanin in *Myrica rubra* juice. *Bulletin of Science and Technology* **18**, 1-5, 2002a. (In Chinese with English abstract)
Li, X., Li, S., Lin, J., Effect of GA_3 spraying on lignin and auxin contents and the correlated enzyme activities in bayberry (*Myrica rubra* Bieb.). *Plant Science* **164**, 549-556, 2003.
Li, J.R., Wang, X.Y., and Joyce, D.C., Red bayberry physiology during fruit development and harvest. *Postharvest News and Information* **13**(4), 41-44, 2002b.
Li, J.R., Liang, X.L., Deng, G., and Joyce, D.C., Isolation and identification of spoilage fungi from red bayberry. *Postharvest News and Information* **13**(4), 49-52, 2002c.
Li XJ, Lu JL, Li SY., (1999) Advances in bayberry of China. *Journal of Sichuan Agricultural University* **17**, 224-229. (In Chinese with English abstract)
Li, Z.L., Zhang, S.L., and Chen, D.M., Red bayberry (*Myrica rubra* Sieb & Zucc.): A valuable evergreen tree fruit for tropical and subtropical areas. *Acta Horticulturae* **321**, 112-121, 1992.
Miao, S.L., and Wang, D.X., Red bayberry. Zhejiang Science and Technology Press, Hangzhou, China, 1987. (In Chinese)
Miao, S.L., Zhang, Y.J., and Liang, S.M., Overcoming the alternate bearing of the *Arbutus* by changing the timing of fertiliser application. *Journal of Fruit Science* **13**, 15-18, 1996. (In Chinese with English abstract)
Miao, S.L., Huang, S.B., Liang, S.M., and Zhang, Y.J., Study on the ecological distribution of Chinese red bayberry. *Journal of Zhejiang Agriculture University* **21**, 366-372, 1995. (In Chinese with English abstract)
Qi, X.J., Wang, L.P., Liang, S.M., Zhu, L.Q., and Chai, X.Q., Study on the mycoflora in bayberry (*Myrica rubra*) fruits treated by controlled atmosphere storage. *Acta Agriculturae Zhejiangensis* **15**, 28-30, 2003. (In Chinese with English abstract)
Ruan, Y.L., and Wu, L.M., A study of photosynthetic characteristics of wintering loquat and bayberry. *Acta Horticulturae Sinica* **18**, 309-312, 1991. (In Chinese with English abstract)
Sawamura, M., Yu, X.L., Miyazaki, T., and Osajima Y., Changes in the quality and components of *Myrica rubra* fruits stored in plastic bags. *Journal of the Japanese Society for Horticultural Science* **58**, 705-711, 1989. (In Japanese with English abstract)
Wang, H.Y., and Huang, W.N., Observation on the structure and ultrastructure of root nodule and nitrogenase activity in *Myrica rubra*. *Acta Phytophylogica Sinica* **16**, 153-157, 1990. (In Chinese with English abstract)
Wang, X.Y., and Shen, L.Q., Study of MAP of fruit. *Food Science* **20**, 62-65, 1999. (In Chinese with English abstract)
Wang, X.Y., Li, J.R., Yang, X.H., and Joyce, D.C. Fresh preservation of red bayberry. *Postharvest News and Information* **13**(4), 53-56, 2002a.
Wang, G.Y., Sheng, Q., Xi, J.R., Zhang, S.H., and Jiang, G.Q., Occurrence and control of major pests in the primary producing area of bayberry in Zhejiang province. *South China Fruits* 1998 (2), 29-31, 1998. (In Chinese)
Wang, X.Y., Li, J.R., Yang, X.H., and Joyce, D.C., Injury of red bayberry during storage and transport. *Postharvest News and Information* **13**(4), 45-48, 2002b.
Xi, Y.F., Luo, Z.S., Xu, C., Chen, D., and Wang, Y.G., Effects of CA storage on quality in fruit of Chinese bayberry (*Myrica rubra*). *Zhejiang Agricultural Sciences* 2001 (6), 291-293, 2001a. (In Chinese with English abstract).
Xi, Y.F., Luo, Z.S., Xu, C., Chen, D., and Wang, Y.G., Effects of CA storage on active oxygen metabolism in Chinese bayberry fruit (*Myrica rubra*). *Journal of Zhejiang University (Agriculture & Life Science)* **27**, 311-313, 2001b. (In Chinese with English abstract)
Xi, Y.F., Zhang, Y.H., Ying, T.J., Ying, J.F., and Chen, Z.L., Senescence physiology of Chinese bayberry fruits during storage. *Acta Horticulturae Sinica* **21**, 213-216, 1994. (In Chinese with English abstract)

Xiao, Y., Huang, J.C., and Li, H.B., The study of calcium and NAA treatment on the storage of red bayberry. *Journal of Southwest Agricultural University* **21**, 305-310, 1999. (In Chinese with English abstract)

Ye, X.Q., Chen, J.C., and Shu, P., Identification of the constituent of anthocyanin in Yang-Mei (*Myrica rubra* cv. Boqi). *Journal of Zhejiang Agricultural University* **20**, 188-190, 1994. (In Chinese with English abstract)

Yin, T.J., and Xi, Y.F., Study on the far transportation of red bayberry in highway. *Food Science* **18**(8), 52-55, 1997. (In Chinese with English abstract)

Yu, D.J., Taxonomy of fruits in China. pp. 305-309. Agricultural Publication House, Beijing, P. R. of China, 1979. (In Chinese)

Zheng, Y.H., Ying, T.J., Xi, Y.F., Mao, L.C., and Chen, Z.L., Effects of vibrational stress on postharvest senescence physiology of Chinese bayberry fruit. *Acta Horticulturae Sinica* **23**, 231-234, 1996. (In Chinese with English abstract)

Zou, T.C., Geographical distribution and evaluation of resource utilisation of Myricaceae in Guizhou. *Journal of Guizhou University (Natural Science)* **18**(2), 103-113, 2001. (In Chinese with English abstract)