Lotus Root: Production in Asia and Potential for New Zealand©

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INTRODUCTION

Lotus (*Nelumbo nucifera* syn. *N. speciosa*), is a member of the Nelumbonaceae family and is grown as a vegetable, medicinal, or ornamental plant. It is an impressive flowering rhizomatous, perennial, aquatic herb, which has a long history in the diverse cultures of Egypt, China, and India. The plant is sacred in the Hindu and Buddhist religions. Originally a native of China, lotus is now found in Japan (introduced from China through Korea), Russia, India, Sri Lanka, Indonesia, and Australia. The swollen cylindrical spongy rhizome is the lotus root of commerce and high prices are paid for it in the Japanese off-season. Lotus is a versatile species with all parts of the plant being edible and it is an important part of Japanese, Chinese, and Indian cuisine. In Japan it is known as renkon, in China as, ngau, and in India it is called kamal-kakri. Throughout Asia lotus root is cooked in many ways (i.e., stir fried, steamed, in soups, or battered and fried) with the seeds eaten raw or roasted and the young leaves eaten as a green vegetable or used to wrap food for steaming.

Medicinally lotus is also important. The rhizome is used to reduce bleeding and aid blood circulation by lowering blood pressure. The lotus seed and parts of the flower are also used as a tonic for the spleen, a replenisher for the kidney, and as nourishment for the heart. Lotus is also important for its beauty and it is an important aquatic ornamental. It is one of the top ten flowers in China.

Our interest in lotus has arisen because of its possible market potential, as a vegetable and medicinal herb, and its ability to grow in situations not favoured by other crops. It is already grown to a limited extent as an ornamental in northern New Zealand. This paper outlines production techniques used for lotus in Asia and outlines some initial propagation work carried out to establish a research crop in New Zealand.

PRODUCTION IN ASIA

In Japan the main production area is in Ibaragi Prefecture next to Japan's second largest lake, Lake Kasumigaura. The Ibaragi Prefecture supplies 91% of the lotus root sold through the Tokyo wholesale market. It is situated 36 ºN and is the northern-most production area in Japan. In New Zealand 36 ºS runs just south of Whangarei, in Northland. The second largest producer of lotus root sold in the Tokyo Wholesale Market is Chiba Prefecture, which supplies 3% of the product sold.

Large quantities of lotus are produced throughout China from 19 ºN to 47 ºN, which is equivalent to a latitude range running from Stewart Island up to Tonga in the North. In China it also ranges from the east coast to the Tian Mountains in the west and is found growing as high as 2000 m above sea level.

ENVIRONMENTAL FACTORS

Climate. Lotus is considered to be a warm climate plant which requires at least 6 months with temperatures greater than 15 ºC. Maximum rhizome growth occurs at temperatures over 20 ºC with flower bud development initiated with air temperatures over 25 ºC. However, with appropriate cultural techniques such as production under glass lotus root can also be grown in temperate regions. Frost will kill the foliage but the plant successfully overwinters as a rhizome.

Water and Soil. Lotus is a true aquatic that is grown in shallow ponds. Optimum soil depth is considered to be about 50 cm although many growers use shallower depths as this makes digging in winter easier. The optimum soil depth is also dependent on cultivar. Clay soils which feel extremely smooth when wet and rubbed between the fingers or soils with a high organic content are preferred. Sandy soils or any soil that feels grainy to the touch are less suitable and can cause the swollen rhizomes to become marked and discoloured. Optimum pH is between 6 and 7.

Lotus grows in water with low levels of dissolved oxygen. In Japan the water depth is about 5 cm at planting with this increased to 10 to 15 cm as the plants grow. Further south water depth is sometimes increased up to 60 cm. In harsher climates the water depth is reduced because larger volumes of water take longer to warm in spring. Water temperatures should be at least 15 ºC for good growth. Once the maximum depth has been achieved, water is only added to the beds to replace evaporation loses.

In China lotus may be grown at water depths of 1.5 m or more but generally a depth of 30 to 60 cm or 30 to 100 cm depending on cultivar is used. Cultivars adapted for shallower water take 100 to 140 days to reach maturity and yield 6 to 12 t/ha. Cultivars adapted to deeper water take 120 to 150 days to reach maturity and yield 9 to 18 t/ha.

PRODUCTION METHODS

Propagation. Lotus is most commonly propagated using recently harvested or stored rhizomes (Yamaguchi, 1988). At harvest the best rhizomes are saved and used for replanting. These rhizomes are planted to a depth of 20 to 30 cm below the soil in beds resembling rice paddies. When planted at a shallower depth the plants tend to work free and float to the surface of the water before they have had time to develop roots. Firming of the soil after planting also helps prevent the roots from floating.

Plant density can vary depending on the size of the planted rhizome with 200 to 300 kg of rhizome planted per 1000 m^2. Planting is generally carried out in October and November.

Most lotus root production occurs outside, but it is also produced in tunnel houses and under glass in order to ensure year-round supply. Tunnels and glasshouses are simply erected over existing beds. Under structures the planting density is higher with approximately 500 kg/1000 m^2 of rhizome used to establish a crop under glass.

Seed propagation is sometimes used to obtain virus-free plant material. The seed stores well and is long lived (Yamaguchi, 1988). The seed has a hard seed coat that needs to be scarified before sowing into a rich loamy medium in early spring. In Japan it is recommended that the seed is covered with 5 cm of water maintained at a temperature of 25 to 30 ºC. Once the seed has germinated, the seedlings are replanted and hardened off by gradually increasing the water depth as they grow. Plants propagated from seed will require about 3 years to reach maturity and are highly variable.

Table 1. Fertiliser rates (kg·ha^{-1}) for lotus root production in Japan.

	Basal			Side dressing		
Production method	N	P	K	N	P	K
Glasshouse	100	200	200	0	0	0
Tunnel house	150	200	150	50	0	50
Open	80	200	80	88	0	88

Fertiliser. Fertilisers are applied both as basal applications and side dressings. Traditionally organic fertilisers have been used however disease is more likely to be a problem. Most growers now use modern inorganic fertiliser mixes. Prior to planting the basal fertiliser is broadcast over the beds and allowed to sink then cultivated in. Application rates are given in Table 1.

Selections. There are three main selections. The 'Oulian' cultivar has been specifically developed in China for producing high quality rhizomes with few flowers or seeds. The rhizomes are excellent for salads, soup, and cooked dishes with a long shelf life when stored at low temperatures. The rhizomes produce a high quality food starch that is commonly used in food preparations for the very young and the elderly and is reputed to have tonic effects. In Japan there are six registered cultivars for the commercial production of rhizomes along with a large number of grower-developed lines. Cultivar development has allowed the production of lotus root over a wider climatic range and water depths. These two factors being interrelated as shallower water depths allow the water to warm more quickly in spring.

'Zilian' is a Chinese cultivar grown for seed production. It has large flowers which have a high seed yield but produces only low quality rhizomes. The seeds are reputed to have a delicious nutty taste and are used in soups, cakes, and Chinese medicines.

Lotus flower, commonly called Hualian in China, is grown as an ornamental and medicinal plant. The flowers are large and attractive and it has large leaves. Hualian selections are commonly grown as ornamentals in park and garden ponds. The seedpod and stamen are used as medicinals while the leaves are used for wrapping food that gives a fresh lotus flavour. The leaves can be used fresh or dried.

Crop Management. After planting, water depth is increased as the crop grows and must be maintained during production with this being especially critical during the summer months when evaporation is high. Weed, pest, and disease management must also be maintained during the season. Aquatic weeds are considered a major problem especially early in the season when an extensive weed cover slows warming of the water by the sun. As the crop dies down in winter herbicides can be used in late winter and early spring. However, hand weeding is more common. Birds can be a major problem with sharp pointed beaks damaging rhizomes when foraging for food.

The major diseases are *Fusarium oxysporum, F. solani* and *Pythium afertile* which cause tuber rots. Disease is a major problem if the rhizomes are allowed to dry out. Lotus is generally regarded as a crop requiring low management inputs except during harvesting and planting. There is also a large degree of flexibility with respect to the timing of planting and harvest. For this reason lotus root production appeals to younger Japanese farmers who have more spare time than for example, their colleagues growing rice.

Harvesting can be carried out at any time during the year. Rhizomes are lifted either by hand or mechanically. The rhizomes can be broken at the node to produce a single rhizome for replanting or strings of two to four rhizomes for the market.

RESEARCH IN NEW ZEALAND

Research in New Zealand is at a preliminary stage. Propagation trials have been completed using seed imported from China. Seed only germinates after scarification, and of the imported seed lots, germination percentages varied widely, ranging from 20% to 100%. Seed had a mean weight/seed of 1.34 g (SD ± 0.253). A series of seed germination experiments in water baths showed that the seed germinated satisfactorily at temperatures ranging from 18 to 30 ºC. Seed germination was quickest at 30 ºC occurring within 3 days and was closely followed by seed, which germinated within 4 days at 25 ºC (Fig. 1). Shoot development was also the most rapid for seedlings grown at 30 ºC (Fig. 1). However, root development occurred first in seed left to germinate at 25 ºC. This occurred after 14 days and can be compared to 16 days for root development in seedlings grown at 30 ºC. Although lotus seed germinated well at 30 ºC it was also the most prone to stem and root rots. Seed did not germinate at temperatures of 15 ºC or less but seedling growth started within 1 day once the temperature was increased from 15 to 25 ºC.

For many species seed is immersed in water so that any nonviable seed can be

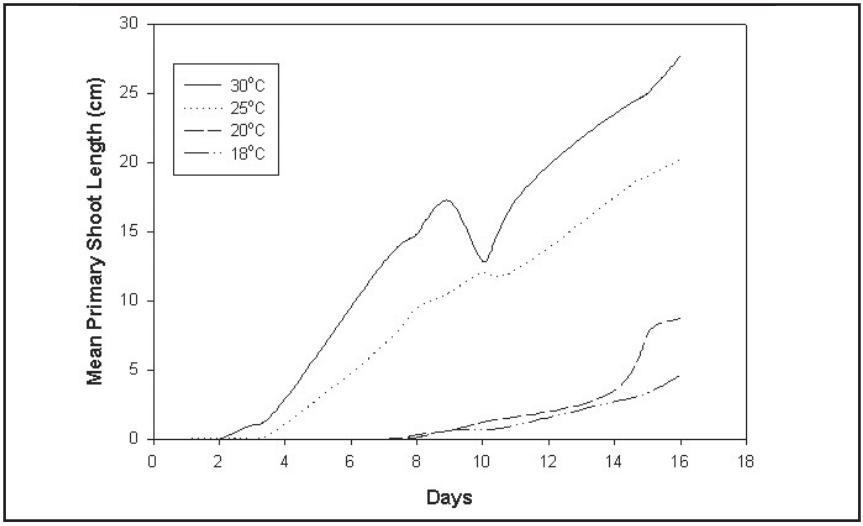

Figure 1. Effect of water temperature on the growth rate of the primary shoot of lotus seedings. Note: The reduction in leaf length at 30 ºC at Day 10 was caused by one primary leaf dying as a result of disease.

separated after it has floated to the surface. In these experiments viable seed was found to be negatively, positively, and neutrally buoyant and would easily germinate when completely submerged. Seedlings were successfully transplanted to permanent beds once the roots had started to develop. Further work to evaluate production technologies is now required.

RELEVANCE TO NEW ZEALAND

Initial investigations suggest lotus root may be successfully produced in Northland and other warmer areas of New Zealand. The wide diversity of lotus as a food, medicine, and ornamental along with the increasing Asian presence in New Zealand would suggest that there may be opportunities for supplying both the local market as well as providing export opportunities.

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Acceleration of Blueberry Selections from Tissue Culture©

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INTRODUCTION

When micropropagated plants are first removed from culture vessels they are vulnerable to abrupt changes in environmental conditions (Kyte and Klein, 1983). The plants are extremely tender, with soft leaves and poorly developed stomata for water regulation (Zobayed et al., 1999). Transpiration losses are high and the plants wilt readily if a sudden drop in relative humidity is imposed, as for example when the lid of the vessel is removed too quickly. The plants may also be more sensitive to pathogen attack. Unless in vitro plants are acclimatized and handled carefully, losses can be high.

Factors to consider when transplanting micropropagated plants to the greenhouse have been well documented (Preece, 2001), but individual crops have specific requirements and nurseries generally develop their own methods through trial and error. HortResearch uses shoot-tip micropropagation with blueberries (*Vaccinium* sp.) to bulk-up plants of elite selections for evaluation. Although we have developed a protocol for multiplication of the plants in the laboratory (Miller and Rawnsley, 2001), reliable exflasking techniques are still being developed. In this work we investigated factors that affect survival and growth of in vitro blueberry plants after exflasking, with particular emphasis on economics of the system.

MATERIALS AND METHODS

Four different blueberry cultivars were used in this trial: two commercial production types, *Vaccinium corymbosum* 'O'Neil' and Selection A; and two ornamental home-garden types: Selection B and Selection C.

Shoot tip micropropagation was carried out as previously described (Miller and Rawnsley, 2001) in the HortResearch tissue-culture laboratory at Ruakura, Hamilton. When ready, the tubs were removed from the lab and allowed to acclimatise to room temperature for 10 days.