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Daikon in Australia

by Wendy Morgan
and David Midmore

Publication No 03/091
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A report for the Rural Industries Research and Development Corporation

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and Professor David Midmore

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Foreword

While Australian rural industries and research institutions are typically based more on a competitive spirit than on active cooperation and coordination, there are a number of instances where a particular industry or section of an industry has adopted a successful collaborative approach to the development of new export or domestic industries

Collaborative research amongst groups of specialists located across the length and breadth of Australia has the potential to be an effective catalyst to the development of cooperative arrangements for continuous supply of perishable vegetables to satisfy domestic and export markets

This publication, one of a number arising from the RIRDC project UCQ-10a, presents data from cooperative trials on daikon run in Western Australia and New South Wales, and illustrates how various institutes can cooperate in such ventures.

This project was funded from RIRDC Core Funds which are provided by the Australian Government, with varying levels of co-funding from the cooperating institutes.

This report, a new addition to RIRDC's diverse range of over 1000 research publications, forms part of our Asian Foods R&D program, which aims to support industry in its drive to develop new products and markets and to gain competitive advantage through improving productivity in, and achieving price premiums for, Australian production.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/Index.htm
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Simon Hearn
Managing Director
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Western Australia

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Contents

Tables and Figures

Executive Summary

Daikon (*Raphanus sativus* L.), also known as Japanese radish, has until recently been grown in a few locations in Australia, in particular the Sydney Basin of New South Wales (NSW), by growers of Chinese background. Opportunity to export has promoted some large-scale growers in Victoria, Western Australia (WA) and NSW to produce according to the importers' requirements. Trials undertaken within the project, in part funded by RIRDC, Horticulture Australia Limited and State Departments of Agriculture, in WA and NSW were set up to focus mainly upon export to the Japanese market, but also to enhance production methods, and varietal suitability, for the domestic market. Given the distance to overseas markets, and the bulky nature of the commodity, post-harvest storage trials were also undertaken.

Yields were greater in WA than NSW, although yields in both states exceeded those reported for other countries. Where average monthly maximum temperatures are 20-25°C there is potential to successfully grow quality daikon. Based upon the trials reported here, recommended cultivars for southern Western Australia include Narumi, Tarumi Sobutori, Radish F1 NO's 14 and 16, Kurazukuri F1 depending on season and site. Recommended cultivars for the central coast of New South Wales also included Narumi and some other cultivars, which were trialed more than 10 years ago. The seed companies identified in this report can advise on suggestions for best cultivars for other locations.

Post-harvest trials, run at 1°C and 1.7°C, suggest that sealed low density polyethylene bags would maintain root quality, even up to the 28 or 36 days of storage in each trial. The high cost of modified atmosphere packaging may make export too costly, and cost benefit analyses are required to answer this.

1. Introduction

Daikon, (*Raphanus sativus* L.) long white radish, Oriental radish, lobak, Japanese radish, Chinese radish) is a brassica vegetable cultivated for its root and, in some countries, the leaves are also eaten as a vegetable. Roots are harvested when still crisp and with a pungent mustard taste and are considered best when the flesh is snow white. Roots are eaten raw or cooked.

Production in Australia has been limited to growers of Chinese background and most was grown in the Sydney Basin of New South Wales. More recently a limited number of specialist growers, often carrot growers on lighter soils have been growing daikon for export. Both groups of growers have their own production methods and markets. The newer growers often grow for export and usually buy seed to meet their customers' requirements.

Daikon has not been a major Asian vegetable in Australian diets but its export potential, fresh and value-added, resulted in its inclusion in the national Asian vegetable project's cultivar evaluation field trials. Scope exists to produce daikon for export to Asian markets at times when supplies of high quality fresh product are short and prices are higher. This usually corresponds to the middle of the SE Asian, summer, and during the NE Asian winter. Economic analysis shows that production of fresh or processed daikon for export may be worthy of further investigation.

The major issues in expanding production have been market access, cultivar evaluation to suit market requirement as well as identification of potential production locations and improving post-harvest shelf life whilst maintaining market characteristics.

One of the aims of the project was to identify suitable daikon varieties for Australian conditions. Hence cultivars sold as very slow bolting, slow bolting, suitable for summer or both summer and autumn cropping were evaluated. Two states were involved in the field trials, Western Australia (1999-2000) and New South Wales (1989 and 1991-92). The trials in Western Australia were funded by the Department of Agriculture, Horticulture Australia Limited and the vegetable growers R&D levy. The trials in NSW by NSW Agriculture.

The Western Australian trials were aimed at identifying cultivars for Japanese market requirements and the New South Wales trials at identifying cultivars for the Japanese market as well as improving yields and profitability and quality of produce for the domestic market. There were two field trial sites in Western Australia: Medina Research Station, 40 km south of Perth and Manjimup Horticultural Research Institute, 300 km south-east of Perth. The New South Wales field trials were carried out at Gosford on the New South Wales coast. Several potential varieties of daikon were identified for both sites for various times of the year.

Post-harvest issues are important when growing for export as daikon is too expensive to air freight to Japan. A number of modified atmosphere packages were evaluated for 36 days storage to simulate shipping from Western Australia to Japan. Cool storage studies were conducted in New South Wales to determine whether marketable quality could be maintained for 4 weeks (a simulated export period).

Twenty cultivars were assessed in Western Australia at monthly plantings in 1998/9 and 25 in New South Wales at one planting in 1989 and two trials in 1991/92. This report draws together research undertaken at regional and state level between 1989 and 1998/99 with the aim to identify national production capability and supply and productivity issues for domestic and export supply chain development.

1.2 Current Knowledge

Botanical name

Raphanus sativus L. Cv. group *Chinese Radish* (name proposed by PROSEA)

Family

Cruciferae

Botanical synonyms

Raphanus sativus L. var. *hortensis* Backer
Raphanus sativus L. var. *longipinnatus* Bailey
Raphanus sativus L. var. *niger* (Miller) Persoon

Common names

alibanos	Filipino
cari curi	Vietnamese
chhaay thaaw	Khmer
Chinese radish	English
cu cai trang	Vietnamese
cu cai	Vietnamese
daikon	English, French, Japanese
fejil	Arabic
hua piahs	Thai
Japanese radish	English
japanraeddike	Danish
kaad khaaw	Laotian
kinaraeddike	Danish
labanos	Filipino
lai fu	Chinese
lo baak	Chinese
lobak beureum	Indonesian
lobak isi	Malaysian
lobak merah	Indonesian
lobak putih	Indonesian, Malaysian
lobak	Indonesian, Malaysian
lobok	Chinese: Cantonese
loh baak	Chinese
loh bo	Chinese
loh bok	Chinese
loh buk	Chinese
loh paak	Chinese
loh pak choi	Chinese
long white radish	English
lopo	Chinese: Mandarin
lu fu	Chinese
luo bo	Chinese
luobo	Chinese
monla	Burmese
mu	Korean
muli	Indian
mullengi	Thai
oriental radish	English

oriental winter radish	English
peh chai tau	Chinese
phakkat-hua	Thai
phakkhithut	Thai
rábano	Portuguese, Spanish
rabanos	Filipino
rabão	Portuguese
rades	Indonesian
radis	Indonesian
raeddike	Danish
rafano	Italian
ramenas	Dutch
rave	French
red'ka	Russian
rettich	German

Daikon, or white radish, is milder than the European radishes. It was introduced to Japan from China about 1000 years ago, and since then a range of shape and taste variants have been bred (Larkcom 1991).

Daikon can be eaten raw in salads, cooked in stews, or grated as a garnish for dipping sauces. Generally, the hotter varieties are used in cooking and the milder for salads. Leaves, roots, seedpods and seedlings are eaten. The root is processed as a pickle, salted or dried (Vinning 1995). It is sold with the leaves attached or removed, depending on the market (Moody 1997).

Varieties

There are numerous Japanese and Korean varieties to select from (Douglas 1997), but cultivars should be selected for the target market. Variety trials have been conducted by various Australian seed companies, government agriculture departments (NSW, WA, Vic, Tas) and universities (UQ Gatton College and Central Queensland University). Japanese breeders are combating the problem of bitterness in spring harvested varieties (Vinning 1995).

Production

Daikon is grown throughout Australia, usually by Chinese or Vietnamese producers for the domestic market. There has been some interest by the larger companies, but margins are usually considered too low for export production.

Mixed cropping
The crop can be rotated with edible chrysanthemum to help reduce any pest and disease burdens (Tony Holder, Victoria, in Douglas 1997).

Season
Daikon can be grown year round in NSW (a), Victoria (Tony Holder in Douglas 1997) and Western Australia, but it is a cold season vegetable. The best production time is spring and early autumn for a high quality radish (Nguyen 1998a), and different varieties should be used for each (Larkcom 1991).

The growing season varies from 50-90 days, depending on cultivar, desired product (Piluek and Beltran 1994) and season (Tony Holder, Victoria, in Douglas 1997). It normally takes 50-60 days in summer and 70-80 days in winter to produce a root weight of 500 g (Nguyen 1998a). Processing cultivars generally reach market size 5-10 days later (Nguyen *et al.* 1997).

Temperature
The ideal temperature range is 20-25°C. Summer temperature and strong sunlight cause the roots to grow rapidly and become pithy soon after maturity (Nguyen 1998a), and can also cause internal browning in Japan (Kawai *et al.* 1992). Low temperatures at sowing (~12°C) increase the risk of bolting (Larkcom 1991) and shallow roots (Waters *et al.* 1992), as do low temperatures followed by a long day length (Piluek and Beltran 1994). Even storing the seed at 5°C before sowing increases bolting (Yoo and Uemoto 1976).

Day length
Long daylengths of 15 hours cause early flowering and roots to become misshapen (Piluek and Beltran 1994).

Soil type
Rich, light, well drained (Chew and Morgan 1998) and deep soil is preferred. Heavy soils will cause misshapen roots (Piluek and Beltran 1994) but some varieties have become suited to heavy clay by producing much of the edible root above ground (Larkcom 1991). Commercial production requires clean soil, as returns are too marginal to include cleaning costs.

pH
The optimum range is 6.0-6.5 (Piluek and Beltran 1994) but the crop tolerates slightly acid soils (Nguyen 1998a).

Soil preparation
A well prepared raised bed is best. Apply 15 t/ha manure or compost before sowing to improve water holding capacity and nutrient availability, then 1.5 t/ha of NPK (1:1:1) fertiliser soon before planting (Nguyen 1998a). Smaller clod size increases germination (Waters *et al.* 1992).

Germination
Daikon will germinate in temperatures as low as 5°C (Nguyen 1998a). Germination rate is increased by 30% in a magnetic field of 1 Hz (Namba *et al.* 1998).

Sowing
Sow at a rate of 10-15 kg/ha (Piluek and Beltran 1994), 5-10 cm deep (Nguyen 1998a). Preferably sow into sunken drills 4 cm deep to support seedlings (Chew and Morgan 1998). Daikon is usually sown directly, but transplanting is possible (Larkcom 1991). Time to emergence is about 4 days at 20-30°C (Piluek and Beltran 1994).

Plant density
Recommendations for plant density vary considerably, reflecting the enormous variation in cultivar requirements. With a row spacing of 35 cm, optimum plant spacing can vary from 7.5-40 cm (Chew and Morgan 1998) but is generally about 15-20 cm (Piluek and Beltran 1994, Nguyen 1998b). Higher densities reduce the frequency and degree of pithiness (Fukuoka and Kano 1997) but excessive densities will result in small, irregular and misshapen roots (Nguyen 1998a). Late thinning (about 40 days after sowing) can be used to control product quality (Latimer *et al.* 1991).

Nutrition
Daikon can be difficult to grow, requiring attention to nutrition (Tony Holder, Victoria, in Douglas 1997). Soil must be rich and fertile since the crop grows rapidly. Apply NPK before sowing and use regular side dressings of an N fertiliser until the roots mature. Excessive N can cause excessive leaf growth (Waters *et al.* 1992). It is preferable to apply manure to a previous crop, rather than directly onto daikon (Larkcom 1991).

Water
The plant must grow rapidly with plenty of moisture to produce a mild, tender and visually attractive product (Piluek and Beltran 1994). Water must be applied at the correct time and quantity (Tony Holder, Victoria, in Douglas 1997). The crop is sensitive to water logging. Infrequent or excessive watering may cause the root to split. Too little water can lead to an under sized product (Tony Holder,

Victoria, in Douglas 1997) and elongated roots (Piluek and Beltran 1994). Overhead sprinklers provide a moist environment but also encourage fungal diseases, particularly in summer (Nguyen 1998a).

Root hollowing / pithiness

The major limiting factor for export of fresh daikon from Australia is the development of pithiness during growth and storage. Pithiness is highly genotype dependent (Harris *et al.* 1993) and is more common when temperatures are high during the early growing phase (Kano 1989). It is caused by excessively rapid growth in the later part of root development. Slowing the peak root growth can reduce incidence (eg; by increasing plant density, pruning leaves in immature plants or using sub-optimal growth conditions). An experiment indicated that sodium salt of α -naphthalenacetic acid could also be used (Fukuoka and Kano 1997), but check for legality before using. The physiology of pithiness formation is discussed in Kano and Fukuoka (1995).

Bolting

Soaking seed in abscisic acid can reduce seedling bolting (Amagasa *et al.* 1993).

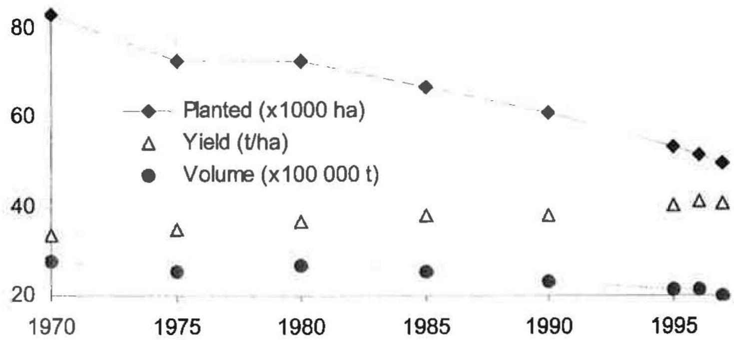

Figure 1: Japanese production of daikon (MAFF 1999).

Harvest

Roots for the fresh market are harvested when they are 5-10 cm diameter at the neck. In Japan they are left with foliage, either untrimmed or trimmed to 10 cm. Roots sold for processing are allowed to grow larger (Nguyen 1998b). Specialised farm machinery for harvesting daikon is available commercially in Japan (Pan 1995). Carrot harvesters tend to be too rough on the produce.

Not in refs

Yield

Australian gross yields are around 40-50 t/ha (Pan 1995). Similar yields have been achieved in Hawaii (Orzolek and Ferretti 1995), but 15-20 t/ha is more common (Piluek and Beltran 1994). Japanese yields have climbed steadily to 41.0 t/ha in 1996 (Figure 1).

Post-harvest

Temperature

Harvest during cool part of day and keep cool and moist until stored (Nguyen 1992). Storage is best at 0°C (Debney *et al.* 1980, Nguyen 1992, Waters *et al.*1992) They must not be allowed to freeze, since thawing causes extensive damage. Rapid cooling with forced draught air (Nguyen 1998) or water is recommended (Piluek and Beltran 1994).

Relative humidity

Optimum humidity is 95-100% (Welby and McGregor 1997).

Shelf life

A shelf life of up to four months is possible under optimal storage temperature and relative humidity (Welby and McGregor 1997), but is severely reduced under less than optimal conditions (Nguyen 1998b). Many growers pick to order and deliver the same day (Douglas 1997). Shelf life is reduced if pithiness has developed in the root (Nguyen 1992), or if leaves are still attached (Piluek and Beltran 1994).

Packaging
Use of controlled atmosphere bags made for other crops may be beneficial. The extra cost for modified atmosphere bags may not result in beneficial returns.
Cleaning
In Japan, roots are thoroughly washed mechanically or by hand (Nguyen 1998b). A brush cleaner may be required to achieve the quality required for fresh exports, but the extra cost may not be recoverable at the marginal prices offered.

Chemicals
Postharvest chemical treatments are generally unnecessary (Nguyen 1998b). Dipping in a growth regulator can reduce postharvest regrowth of radish leaves and roots, which detract from appearance and increase weight loss (Wang 1998, using 2×10^{-3} M methyl jasmonate). Check legality of chemicals before use.

Processing

The root should be crunchy, not pithy, and low in water content (Nguyen 1992). For takuan the roots should be dried to 50% fresh weight, by placing in a shaded and well ventilated area for 3-5 days. For dried sliced radish, the leaf is trimmed and the root sliced, and it is dried to approximately 10% of its original weight, either by the sun or by drier. Dried radish is best kept in sealed plastic to retain the strong odour (Nguyen 1998).

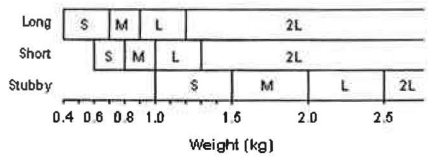

Figure 2: Japanese grade daikon according to type (long, short or stubby) and weight (Vinning 1995).

Quality assessment

Smooth, white, unblemished skin is preferred. Internal flesh should show no sign of pithiness or hollowness (Nguyen 1998) and should be free of fibrous tissue. If leaves are attached when sold, they should be turgid, green and free of pathogens (Waters *et al.* 1992). The Japanese grade daikon according to shape and weight (Figure 2), and an acceptable size for export is approximately 1 kg (Nguyen *et al.* 1997). Some prefectures also use a 2S or a 3L grade (Vinning 1995).

A rapid method for determining daikon pungency (4-methylthio-3-butenyl isothiocyanate) is described in Ohguchi and Asada (1990). Levels range from 2 (Chinese cultivars) to 17 μ mol/ml and are negatively correlated to water content (Okano *et al.* 1990).

Roots harvested earlier in the season tend to have higher levels of vitamin C and β-amylase, while roots harvested later tend to have higher total sugar content (Ishii and Saijo 1987).

Daikon was linked to the Japanese outbreak of food poisoning in 1996, and was suspected in another 1998 outbreak (Anonymous 1998).

Pests and diseases

The crop suffers from the same pathogens as affect any Brassica crops (Nguyen 1992), as it comes from the same family. Rotate to avoid root nematode and eelworm populations building up (Larkcom 1991). Potential viruses are listed at Plant Viruses Online (Brunt *et al.* 1996). See Hawaiian pests & diseases.

Domestic market

Trade in daikon at Flemington Markets, Sydney, is shown in Figure 3.

Export market

Two studies have indicated that fresh exports of daikon would not be viable from Australia (Vinning 1995, Lee 1999). Fresh exports must be transported by boat to minimise cost, thus incurring a four week transit time (Harris *et al.* 1993). However there may be opportunities for semi- or fully processe daikon, as dried or pickled (Vinning 1995). Production is declining in Japan, Korea and Taiwan, but being replaced by cheap Chinese imports. Prices are generally low but there is some dissatisfaction d with Chinese quality.

Japan

Japan does not appear to be a viable fresh export market for Australia, but opportunities may exist for processed product (Lee 1998, 1999) such as dry and salted daikon, and cut daikon within frozen vegetable mixes (Pan 1995). Domestic production is steadily declining, down to 2.1 million t in 1996 (Figure 1). Total consumption is approximately 20 kg/person/year and is the highest of any vegetable (Otsubo 1996), but is also declining (JETRO 1995). Much has been semi-processed by salting, and imports are expected to increase.

A demand for lightly pickled vegetables has resulted in a greater proportion of the crop being produced in the spring (JETRO 1995). Tariff rates vary from 12 to 22.4 %, depending on sugar and processing level. Quarantine requires a declaration that it is free of *Radopholus similis* (Vinning 1995). Blanched seedlings with green cotyledons are sold in Japan as a pungent garnish (Kimura *et al.* 1995).

Japan fresh

160 000 t of fresh daikon was traded through Tokyo markets in 1994 at an average wholesale price of ¥100/kg. Prices were rising but throughput was falling. Prices were highest from July to September (Figure 4) though there were considerable fluctuations (Vinning 1995). Daikon comprises 3.2% of all Japanese fresh cut vegetable products (Pan 1995).

Japan dried

2 900 t of dried daikon was traded through Tokyo markets in 1993 at an average wholesale price of ¥200/kg (Vinning 1995).

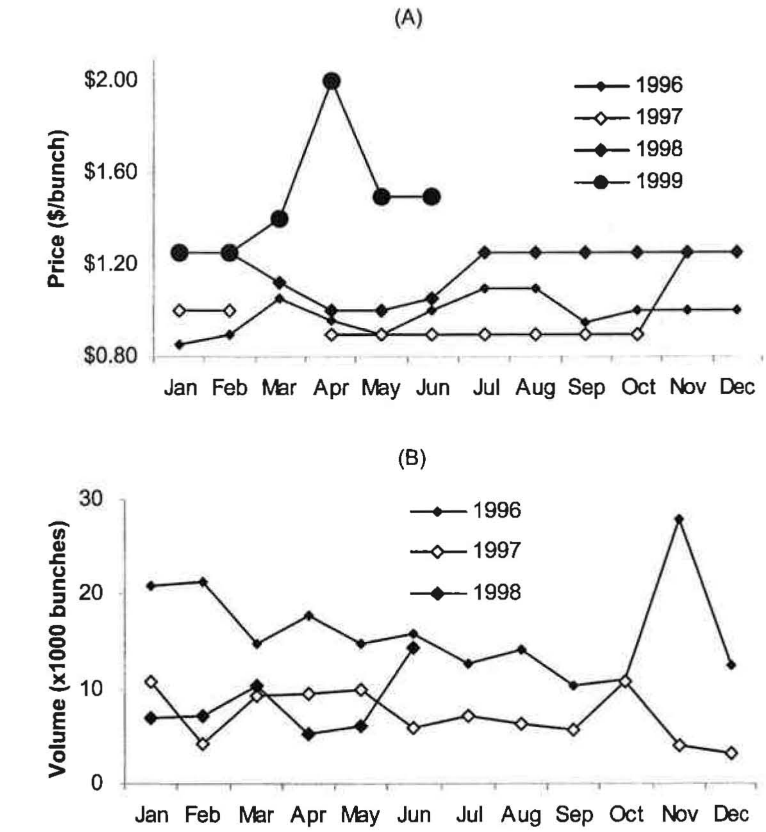

Figure 3: Prices (A) and throughput (B) of daikon at Flemington Markets, recorded o a monthly basis (Flemington Market Reporting Service, NSW Agriculture).
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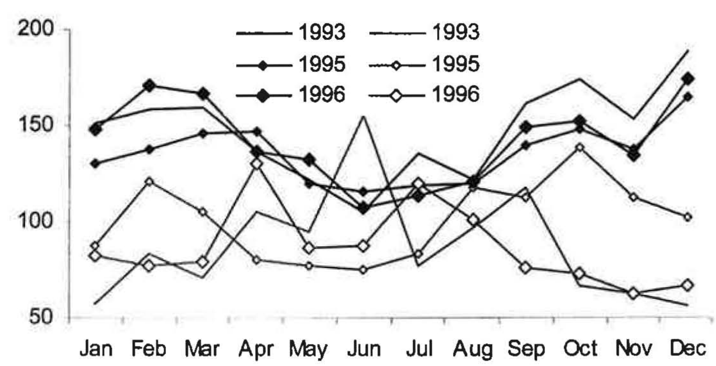

Figure 4: Prices (¥/kg), and throughput (x100 t/month) of fresh daikon at Tokyo Wholesale market (adapted from Anonymous 1996 via Nguyen 1998b).

Uncut dried daikon was valued at around ¥115/kg and sliced dried daikon at ¥308/kg (Nguyen 1998b). Imports of dried daikon to Japan reached 3 983 t in 1996 at a CIF
Japan reached 3 983 t in 1996 at a CIF price of ¥171/kg (Nguyen 1998b). Import records commenced in 1995 (2 926 t at ¥137/kg) since the Ministry of Finance previously grouped this product with others. Most were from China (2898 t), followed by South Korea (27 t) and Indonesia (1 t). Daikon that is sliced and dried in sunshine and natural air seems to occupy a large share (JETRO 1996).

Japan fresh preserved
500 t of fresh preserved daikon (lightly salted) was traded through Tokyo markets in 1993 at an average wholesale price of ¥850/kg. Seasonal price did not show a clear trend but probably peaked December / January (Vinning 1995).

Japan organic
Organically grown daikon represented 13.1% of the 2.32 million t of daikon produced in 1991 (JETRO 1994).

Japan pickled
Total pickled daikon consumed in Japan totals 250 000 t/year at an average price of ¥524/kg wholesale (Nguyen 1998b). 5 700 t of pickled daikon was traded through Tokyo markets in 1994 at an average wholesale price of ¥400/kg. Prices were rising but throughput was falling. Seasonal price varied with no clear trend (Vinning 1995). A range of pickling mediums is used (Table 1).

Table 1: Pickled daikon (takuan) type and preservation base (Inden *et al.* 1997 and Nguyen 1998a).

Name	Preservation base
nakazuke[1]	rice bran paste
misozuke	soybean paste
kasuzuke	sake lees
shozuzuke[2]	soy sauce
tsubozuke	salt
wariboshizuke	sliced, sun-dried and preserved

[1]:Preservation in rice bran greatly increases the level of vitamin B_1. B_2 is increased less and B_3 is reduced (Inden *et al.* 1997).
[2]:Domestic production of shozuzuke takuan is around 56 000 t/year (JETRO 1996).

South Korea
Daikon is the second largest vegetable crop in South Korea due to its inclusion in Kim Ch'i. Production is approximately 1.7 million t/year (Lee 1996), with wholesale prices of around 145 Won/kg in 1991. Prices were generally increasing, peaking in spring and autumn (Vinning 1995). There may be a need for South Korea to import more materials for Kim Ch'i in both fresh and semi-processed form (Nguyen 1998b). However, Australian exports do not appear to be viable (Lee 1996).

China
Chinese exports were increasing in both price and quantity, reaching 19 000 t of fresh and 5 500 t of dried product in 1992. Export prices were US$0.25 and US$0.44/kg respectively (Vinning 1995).

Taiwan
The Taiwan market has some potential for Australian exports (Lee 1996) but may be too small to be worth pursuing (Pan 1995). Production has steadily decreased to 120 000 t in 1993, but throughput at Taipei has remained steady at around 23 000 t in 1994, priced at NT$6.70/kg. Prices peak June to August. Exports must have a certificate declaring they are free of the white fringed beetle *Graphognathus leucoloma*, and fresh or chilled imports attract a 40% tariff (Vinning 1995).

Hong Kong
The Hong Kong market has some potential for Australian exports (Lee 1996) but may be too small to be worth pursuing (Pan 1995). Small volumes (20-30 t/year) have been sent from Western Australia, but returns are poor.

Singapore
The Singapore market has some potential for Australian exports (Lee 1996) but may be too small to be worth pursuing (Pan 1995).

Indonesia
Daikon is used in Indonesia, but is not a major vegetable (Lee 1996). Production was around 37 000 t in 1989 (Vinning 1995).

Philippines
The Philippines produced 6 500 t in 1992, but production is declining. Retail prices increased during the late 1980's (Vinning 1995).

Malaysia
Malaysia produced 5 500 t in 1990, but volumes are erratic (Vinning 1995).

2. Materials and methods

2.1 Field trials, New South Wales

Gosford, Spring 1989

Twenty five cultivars were evaluated in observation trials at the Somersby section of NSW Ag Gosford Research Station (33°22'S, 151°18'E - Nguyen 1992).

Seeds were sown at 0.9 m inter-row and 0.2 m intra-row spacing (55,555 plants/ha) on 27/9/98 and roots harvested on 23/11/98, 57 days after sowing. Roots were measured for length, diameter and weight and rated for shape, neck colour, presence of hairs and aphid presence. Yield per hectare was calculated for 55,555 plants/ha.

Gosford spring-summer and autumn-winter trials, 1991-1992

Four cultivars were evaluated for growth and post-harvest performance at the same site as above. Plants were grown in raised beds in a randomised complete block design with four replicates. Seeds were sown at 0.9 m inter-row, and thinned to 0.15 m intra-row spacing (74,074 plants/ha).

Trial 1 was seeded on 1/10/1991 and trial 2 on 17/3/1992. Base fertiliser consisted of 2 t/ha G5 (N:P:K=5:5:5). Trickle irrigation with outlets 30 cm apart was used to irrigate as required.

Five plants from each plot were harvested weekly from day 41 (trial 1) and 37 (trial 2), washed and dried. The fresh weight of each root and leafy shoot were recorded. Plants were assessed for bolting, rated for pithiness and hollowness. A visual rating of 1-5 was used for assessment of pithiness and hollowness (Harris *et al.* 2000).

2.2 Field trials, Western Australia 1998-1999.

Cultivars were planted at 4 to 6 week intervals from February 1998-January 1999 at two sites, Medina and Manjimup. The trials were not replicated and each variety was planted in a 3 m long by 1.5 m wide (Medina) or 1.2 m wide (Manjimup) plot. Seeding at 4 rows per plot with 30 cm inter-row spacing and 25 cm intra-row spacing was carried out by hand. This gave a population of 133,333 plants per hectare.

At both sites harvest date was determined when roots were 50 to 100 mm in diameter at the neck and measured for weight (g), length (mm), green shoulder length (mm), diameter (mm), pithiness and given rots and blemishes and quality ratings.

Details of ratings used for pithiness, rots and blemishes, quality and size classes are given in McVeigh *et al.* 2001. In summary, if one particular root did not fall into a size class due to weight, pithiness, rots or forking it was classed as a reject. This occurred when a root had:

- Weight less than 250 g;
- A pithiness rating greater than 1;
- A rots/blemishes rating greater than 2;
- A quality rating greater than 3;
- Any forking.

In Tables 4-7, quality scores range from 1 equals excellent export quality to 5 equals reject and pithiness, rots and blemishes from 1 equals none to 5 equals very severe.

At the Medina Research Station twenty cultivars were evaluated in a Spearwood sand Uc 4.13, (Northcote 1979). The site was deep ripped and sprayed with pre-emergence herbicide before planting. Pre-plant fertiliser of double superphosphate at 1000 kg/ha and 150 kg/ha of trace elements, was broadcast and incorporated to a depth of 40 cm using a rotary hoe. Post-plant fertiliser, 60 kg/ha ammonium nitrate, 60 kg/ha potassium chloride and 15 kg/ha of magnesium sulphate was applied weekly commencing just after emergence. All weeding was done by hand and insects were controlled as required.

At the Manjimup Horticultural Research Institute twelve to seventeen cultivars were evaluated in a sandy loam soil Dy 3.61, (Northcote 1975) with a previous cropping history of pasture for two years. With the first three plantings, the pre-plant fertiliser was 500 kg/ha triple superphosphate, 1000 kg/ha superspud, 2000 kg/ha gypsum and 2000 kg/ha lime. For the next eight plantings, superspud was replaced with potato E at 1700 kg/ha, approximately halving the total nitrogen applied before sowing. The first application of post-plant fertiliser was six weeks after sowing which was 175 kg/ha of keiserite and 25 kg/ha of ammonium nitrate. After that, ammonium nitrate at 50 kg/ha was applied fortnightly.

Weeds were controlled by Dacthal® at 10 kg/ha which was sprayed just after sowing. Nitofol® was sprayed at 190 mL/ha to control leafhoppers during March to May. The cultivars April Cross and Tsuke Taro were affected by *Xanthomonas* spp. (primary infection) and *Alternaria* spp. (secondary infection), during June to September producing necrotic lesions on the leaves. No control was carried out as the plots were to be harvested at the time the symptoms appeared.

2.3 Post harvest trials

New South Wales, 1991-1992

Three roots from each plot in field trials were trimmed to leave 15 cm leafy shoot and stored at 1°C, 90-95% RH for 25 days. They were then placed at 20°C, 60-70% RH for 3 days and assessed for colour, pithiness, hollowness and Total Soluble Solids as described in Harris *et al.* (1993).

Western Australia, 1998-1999

To export fresh daikon to Japan by sea, it takes about 21 days ex Fremantle to Port Yokohama (Tokyo). During this period, daikon roots can deteriorate rapidly unless suitable post-harvest and handling practices are followed. Daikon will dehydrate unless placed in a plastic bag and kept at 1-2 °C with 95 – 100% relative humidity to extend shelf life. The use of modified atmosphere packaging (MAP) is considered to supplement optimum temperature and humidity control. The potential benefits or hazards of MAP are dependent on the commodity, variety, physiological age, atmospheric composition, temperature and length of storage (Kader 1992).
Two trials investigated the effects of various modified atmosphere (MA) bags on two daikon cultivars held at 1 or 1.7°C for 36 or 28 days respectively.

Daikon for the first MA trial was grown as described above for the field trials. The daikon cultivar, *Narumi* (Mikado International Inc.), was planted on 1.2 m beds with 4 rows at 0.35 m apart. Sowing was done by hand with an intra row spacing of 0.3 m. The trial was planted on 4/5/1999 at Medina and the growing period was 134 days. Plants were harvested and stored on 15/9/1999 and removed from bags on 21/10/1999.

Six modified atmosphere bag treatments (Table 2) were replicated four times. Ten daikon roots, with green tops cut to 10 cm length were placed in each bag (sealed or unsealed) and placed in cardboard cartons. A bag designed for parsnips (LifeSpan® L-144) was included, but the trial did not include an unsealed bag treatment as the manufacturers, Amcor Flexible Films, recommend the bag is sealed for the desired atmosphere to be created in the bag.

Cartons were weighed before placing in a coolroom at 1.0°C with 76% RH and, after 21 and 36 days, were re-weighed to obtain the percentage weight loss. Oxygen and carbon dioxide levels in the sealed bags were monitored twice a week. The sealed bags had a 2 cm piece of electrical tape on the bag with clear silicon hardened on the tape. Using a 3 mL syringe, 2 cc of gas was collected from each sealed bag via the silicon and electrical tape. An LR 4220 Yokogawa Gas Analyser was used to measure oxygen and carbon dioxide levels.

After 36 days, all roots were removed from the coolroom and measured for length (mm), diameter (mm), rating of pithiness, rots and blemishes and quality ratings.

The second MA trial was undertaken to determine whether a different cultivar, planting the crop at the preferred growing time and/or reducing storage time altered the storage outcome.

The cultivar *Takumi Sobutori* (Kaneko Seeds) was planted 6/10/1999 and harvested 14/12/1999, 69 days after planting. The same treatments as the previous trial were imposed except that the coolroom had an average temperature of 1.7°C with 94.4% RH. and storage lasted 28 days.

Data from the trials were subject to analysis of variance using the GENSTAT statistical package, version 5 (Lawes Agricultural Trust, Rothamsted Experimental Station). The level of significance used was P = 0.05.

Table 2: Modified atmosphere bags used in Western Australian trials.

Treatment No.	Treatment description
1	Sealed high density polyethylene bag (HDPE) (15um)
2	Sealed low density polyethylene bag (LDPE) (70um)
3	Sealed LifeSpan® bag (L144 – Parsnip bag)
4	Unsealed high density polyethylene bag (HDPE)(15um)
5	Unsealed low density polyethylene bag (LDPE) (70um)
6	No carton liner at 1°C, 90% RH (Control)

3. Results

3.1 Replicated Field Trials

New South Wales, Gosford 1989.

Estimated yields varied between 6-49 t/ha and root weights of 110- 890 g.
Six slow bolting cultivars and three cultivars suitable for summer and autumn cropping had estimated yields greater than 40 t/ha and root fresh weights of 750-890 g (Table 3). Two of the high yielding cultivars were also resistant to aphids. Two had green neck colour and seven light green colour.

Table 3: Evaluation of daikon cultivars grown in NSW Central Coast, Spring 1989

Table 3. Evaluation of radish cultivars grown in spring (NSW Central Coast).

Cultivar	Source[a]	Root shape[b]	Root diam. (cm)	Root length (cm)	Root weight fresh (g)	Neck colour	Leaf hair	Aphids on leaves
Very slow bolting								
Haruyoshi	TH	1+3	7	26	840	green	yes	less susceptible
Narumi	M,H	2	7	32	830	light green	yes	susceptible
White Ball	TH	5	7	10	460	green	yes	susceptible
Slow bolting								
Aokubi Haruyoshi	TH	1	6	26	480	green	yes	susceptible
Aoyutaka	M,H	1	6	32	540	green	yes	resistant
Haruisami	TH	1+3	6	36	630	light green	yes	resistant
Haruyoshi No.2	TH	1+3	6	28	750	light green	yes	less susceptible
Oshin	T,NW	1	7	36	790	light green	yes	susceptible
Seishun	A	1+3	7	30	830	light green	yes	less susceptible
Tomas	TO	1	7	27	840	green	yes	resistant
Summer crop								
Natsusakari	TH	1	6	37	660	white	yes	susceptible
Summer cross No.3	T,NW	1	5	34	650	light green	yes	susceptible
Summer and autumn crop								
Aosakari	M,H	1	6	31	630	dark green	no	less susceptible
Azuma 6363	TH	6	5	32	540	white	yes	susceptible
Azuma Miyako	TH	6	5	26	330	white	yes	susceptible
Berimaru	TH	4	8	9	230	red	yes	susceptible
Taiyakushin	TH	1	6	34	710	green	no	susceptible
Fukumi	M,H	1	7	34	750	green	no	susceptible
Green summit	A	1	7	31	500	dark green	no	susceptible
Hybrid long white	H,NW,Y	1	6	45	800	white	no	susceptible
Relish cross	T,NW	1	7	36	890	green	no	resistant
Senshinriso	TH	1	4	33	310	white	yes	susceptible
Vitamin	TH	7	4	13	110	dark green	no	susceptible
Wase Shogoin	TH	4	7	12	320	green	no	susceptible
Wase Zumari	TH	1	6	35	660	white	yes	susceptible

[a]TH: Tohoku Seed, Japan; H: Henderson, Australia; A: At Seed, Japan; Y: Yates, Australia; M: Mikado, Japan; T: Takii, Japan; TO: Tomas Food, Australia; NW: New World, Australia
[b]See Figure 3 (previous page)

Medina, Western Australia 1998-1999

The number of days from planting to harvesting ranged from 75 to 119 days depending on the time of year. Six varieties showed potential for the Perth area depending on time of sowing (Table 4). These varieties were chosen based on marketable yield, pithiness- hollowness and quality ratings. The six cultivars, their potential harvest performance and harvest period are shown in Tables 4 and 5.

Table 4: Best performing daikon cultivars at Medina, Western Australia 1998-1999.

Best cultivars Harvest month Days to Harvest	**Average yield (t/ha)**	**Average marketable yield (t/ha)**	**Average weight (g)**	**Average length (mm)**	**Green shoulder length (mm)**	**Average diameter (mm)**	**Pithiness score (1-5)**	**Rots & blemishes score (1-5)**	**Quality score (1-5)**
OCTOBER HARVEST: 88 days:									
Radish F1 No. 14 [c]	104.6	62.7	981	279.0	83.3	75.2	1.5	1.3	1.6
Narumi [b]	85.6	81.4	803	214.2	79.6	78.4	1.0	1.1	1.5
NOVEMBER HARVEST: 78 days									
Radish F1 No. 14 [c]	68.4	53.6	651	275.8	76.5	63.0	1.0	2.0	2.6
Takumi Sobutori [a]	63.9	60.1	625	312.2	72.8	62.0	1.0	1.3	1.4
Narumi [b]	63.5	62.4	752	264.9	81.6	66.6	1.0	1.9	2.0
DECEMBER HARVEST:79 days									
Radish F1 No. 14 [c]	129.7	109.3	1216	322.3	125.6	81.6	1.0	1.9	2.8
Takumi Sobutori [a]	136.0	136.0	1331	371.5	155.2	75.1	1.0	1.2	1.2
Kurazukuri F1 [d]	74.7	70.8	1051	304.7	126.6	76.2	1.0	1.2	1.4
Shinjin Sobutori [a]	133.0	114.0	1304	332.3	137.3	81.7	1.0	1.2	1.5
Narumi [b]	157.7	101.3	1419	322.4	165.6	86.4	1.1	1.8	2.2
JANUARY HARVEST: 81 days									
Radish F1 No. 16 [c]	72.0	62.7	675	244.4	68.1	67.3	1.0	1.3	1.5
Takumi Sobutori [a]	82.7	82.7	841	340.5	111.4	60.0	1.0	1.0	1.2
Kurazukuri F1 [d]	78.9	59.3	806	303.6	103.0	65.7	1.2	1.7	2.0
Narumi [b]	98.8	89.7	926	267.7	101.9	76.8	1.0	1.2	1.3
FEBRUARY HARVEST: 92 days									
Radish F1 No. 16 [c]	86.7	80.2	812	269.2	80.8	71.5	1.0	1.2	3.1
Takumi Sobutori [a]	166.9	109.4	1144	362.0	140.2	67.4	1.1	1.7	1.8
Kurazukuri F1 [d]	116.8	96.4	1051	332.4	134.2	74.6	1.1	1.3	2.0
Narumi [b]	94.7	12.7	888	259.0	110.8	75.7	1.1	2.5	3.0

MARCH HARVEST: 75 days									
Takumi Sobutori [a]	84.3	77.8	678	303.6	73.9	60.7	1.0	-	1.4
Shinjin Sobutori [a]	76.4	67.7	636	258.1	74.8	63.7	1.0	-	1.4
Narumi [b]	83.1	83.1	645	255.9	65.5	68.8	1.0	-	1.6
Kurazukuri F1 [d]	71.3	53.7	573	261.8	81.5	60.7	1.1	-	1.2
MAY HARVEST: 78 days									
Radish F1 No. 16 [c]	71.6	71.6	806	249.5	84.0	74.1	1.0	1.0	1.3
Takumi Sobutori [a]	75.5	63.9	850	290.3	113.3	69.0	1.0	1.0	1.6
Shinjin Sobutori [a]	83.7	70.3	941	263.5	88.0	69.9	1.1	1.1	1.4
Kurazukuri F1 [d]	81.8	73.7	920	295.5	113.3	72.6	1.0	1.0	1.2
JUNE HARVEST: 84 days									
Radish F1 No. 16 [c]	74.2	70.7	795	207.1	50.3	76.4	1.0	1.0	1.3
Kurazukuri F1 [d]	95.1	84.6	930	267.0	82.3	77.3	1.1	1.0	1.1
Shinjin Sobutori [a]	83.1	78.5	779	250.4	55.2	78.5	1.0	1.0	1.1
JULY HARVEST: 90 days									
Kurazukuri F1 [d]	67.2	44.8	796	218.9	53.7	76.7	1.3	0.0	-
Shinjin Sobutori [a]	72.9	59.2	713	193.5	32.4	78.0	1.2	0.5	-
Narumi [b]	81.4	65.8	763	229.6	40.8	74.5	1.2	0.5	-
SEPTEMBER HARVEST: 112 days									
Narumi [b]	74.9	66.5	733	191.5	49.8	85.1	1.0	1.6	1.8

[a] Kaneko Seeds Co. (Japan)
[b] Mikado International Inc. (Japan)
[c] Sakata Seed Corp. (Japan)
[d] The Musashino Co. Ltd. (Japan)

Table 5: Harvest times of six potential cultivars, Medina 1998-99.

	Month											
Potential varieties	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Narumi	■	■	■				■	■	■	■	■	■
Radish No. 14										■	■	■
Radish No. 16	■	■			■	■						
Takumi Sobutori	■	■	■	■	■						■	■
Shinjin Sobutori			■	■	■	■	■					■
Kurazukuri	■	■	■	■	■	■	■					■

Cutivars grown at Medina produced higher total and marketable yields during the summer harvests (except for Narumi at February harvest, which was affected by black beetle damage of the roots). This is an uncommon occurrence and could have been controlled). Narumi was still considered a potential cultivar because of its high total yield of 94.7 t/ha.

Manjimup, Western Australia, 1998-1999.

Days to harvest ranged from 61 to 112 days depending on the time of the year (Table 6).

Highest marketable yields were produced from January to May, i.e., summer to autumn harvests (Table 6). With September and October harvests, SPS 818 and Narumi produced relatively low marketable yields: an average of 40.6 t/ha and 37.1 t/ha. These varieties were included as potential varieties because of their relatively high total yield but downgrading was due to poor root shape, which can be improved through better cultivation.

Bolting was a problem with the majority of varieties planted at Manjimup from June to September. Those varieties that did not bolt still had relatively low marketable yields due to poor shape, forking or insect damage. Although daikon can be produced in Manjimup all year round, better quality and higher marketable yields are more likely in spring and summer.

Table 6: Best performing daikon cultivars Manjimup, 1998-1999.

Best cultivars Harvest month Days to harvest	**Average yield (t/ha)**	**Average marketable yield (t/ha)**	**Average weight (g)**	**Average length (mm)**	**Green shoulder length (mm)**	**Average diameter (mm)**	**Pithiness score (1-5)**	**Rots & blemishes score (1-5)**	**Quality score (1-5)**
OCTOBER HARVEST:91 days									
SPS 818 [e]	64.6	51.7	765	362	0.0	62.7	1.4	1.2	1.8
Narumi [b]	81.0	44.3	828	283	6.1	72.1	1.2	1.8	3.2
NOVEMBER HARVEST: 65-71 days									
Narumi [b]	108.0	76.0	922	313	0.0	73.0	1.5	1.8	2.4
DECEMBER HARVEST: 62 days									
Takumi Sobutori [a]	64.4	56.5	690	348	57.0	58.7	1.0	1.5	2.0
Kurazukuri F1 [d]	59.4	43.9	637	293	65.5	60.3	1.1	1.5	2.1
Narumi [b]	84.8	55.4	829	396	8.7	63.1	1.2	1.6	2.5
JANUARY HARVEST: 65 days									
Kurazukuri F1 [d]	87.0	79.8	932	317	112.2	66.8	1.2	1.8	2.0
Shinjin Sobutori [a]	78.4	54.6	802	324	86.8	63.3	1.1	1.7	2.0
Narumi [b]	143.9	85.4	1480	418	72.5	112.5	1.2	2.1	2.6

MARCH **HARVEST: 61 days**									
Radish F1 No. 14 [c]	78.5	67.4	1039	372	110.7	68.7	1.2	1.2	1.6
Takumi Sobutori [a]	81.4	77.6	872	376	103.0	65.3	1.4	1.0	1.4
Shinjin Sobutori [a]	106.9	95.9	1093	334	97.4	73.2	1.2	1.3	1.6
Narumi [b]	116.6	102.0	1192	369	20.5	78.1	1.0	1.0	2.3
MAY **HARVEST: 76 days**									
Radish F1 No. 16 [c]	90.8	68.9	889	264	95.9	71.9	1.0	1.0	2.5
JUNE **HARVEST: 82 days**									
Radish F1 No. 16 [c]	52.2	40.8	530	202	48.2	70.6	1.0	1.0	2.2
AUGUST **HARVEST: 111 days**									
Takumi Sobutori [a]	60.0	48.9	526	192	41.1	69.1	1.0	1.7	2.4
Shinjin Sobutori [a]	66.2	49.2	594	206	41.5	73.4	1.2	1.8	1.8
SEPTEMBER **HARVEST: 112 days**									
SPS 818 [e]	59.5	29.5	704	301	0.0	93.1	1.1	1.3	3.3
Narumi [b]	77.8	29.9	833	254	0.0	77.6	1.1	1.8	3.8

[a] Kaneko Seeds Co. (Japan) [b] Mikado International Inc. (Japan)
[c] Sakata Seed Corp. (Japan) [d] The Musashino Co. Ltd. (Japan) [e] South Pacific Seeds (Aust)

Table 7: Harvest times of six potential cultivars, Manjimup, 1998-1999.

	Month											
Potential varieties	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Narumi	■	■	■						■	■	■	■
Radish No. 14			■									
Radish No. 16		■			■	■						
Takumi Sobutori			■					■				■
Shinjin Sobutori	■	■	■					■				■
Kurazukuri	■	■										■

At Manjimup most potential cultivars had small windows for harvest such as Radish No. 14 and Takumi Sobutori (Table 7).

Weather conditions during the trial period (February 1998- March 1999) are presented in Table 8.

Table 8. Monthly maximum and minimum temperatures and rainfall during trials in Western Australia.

	Medina			Manjimup		
	Max °C	Min °C	RF mm	Max °C	Min °C	RF mm
Feb 98				31.1	15.5	0.2
Mar	30.7	16.8	67.4	25.7	14.4	94
April	25.3	13.0	16.8	20.0	11.7	48
May	23.9	12.3	721.4	18.8	9.6	138
June	18.8	8.7	156.0	13.6	6.7	149
July	17.5	5.7	81.6	12.7	6.0	188
Aug	20.3	10.9	132.2	15.6	8.8	142
Sept	19.9	7.9	100.0	15.2	7.4	116
Oct	22.4	10.4	50.4	17.7	7.3	77
Nov	25.7	12.9	50.6	21.3	10.1	28
Dec	28.9	15.9	12.8	24.4	11.4	32
Jan 99	30.2	16.9	46.6	25.4	13.0	17
Feb	32.1	17.8	0.8	27.5	13.8	11
Mar	28.6	16.2	18.0	23.5	13.8	25

When comparing Manjimup with the Medina site, it appears that soil type and cooler spring temperatures at Manjimup can affect the growth of daikon. Radish No. 14 harvested during October to December at Medina had average marketable yields of 75.2 t/ha, but at Manjimup did not produce quality roots at the same time of year.

3.2 Post-harvest quality

Percentage weight loss/gain was less than 1% for most treatments with the exception of one replicate of both unsealed high and low density bags (greater than 6% loss) and the room cooled treatment without a carton liner (a 10 - 16% weight loss). Data are not presented.

The high density polyethylene bag, HDPE, had relatively consistent carbon dioxide readings during the storage period, ranging from 1.24% to 2.87%. The oxygen concentrations of the same treatment peaked at Day 29 of storage with 21.96%.

The low density polyethylene bag, LDPE, had higher readings of carbon dioxide but much lower oxygen readings compared with the HDPE. The LifeSpan®L144 bag recorded relatively consistent CO_2 readings ranging from 2.94% to 5.84%. The oxygen concentration within the LifeSpan®L144 bag ranged from 7.19% to 16.67% with a sharp decrease in oxygen after day 33 of storage. Bag gas concentrations are given in McVeigh *et al.* (2001).

The sealed LDPE bag had significantly better ratings for rots, blemishes and quality than any other treatment (Table 9), with no visible CO_2 injuries.

Daikon roots cooled without a carton liner, had the most severe rots and blemishes resulting in reject quality.

Table 9: Daikon quality assessment after 36 days at 1° C storage in different modified atmosphere bags.

Treatment	Length (mm)	Diameter (mm)	Pithiness (1-5)	Rots & blemishes (1-5)	Quality (1-5)
Sealed HDPE	363.2	95.9	1.33	2.98	3.78
Sealed LDPE	315.5	92.2	1.15	2.48	3.45
Sealed LifeSpan®L144	303.0	94.8	1.23	2.95	3.70
Unsealed HDPE	290.3	89.4	1.03	2.80	3.73
Unsealed LDPE	287.8	91.0	1.13	3.33	3.85
Room cooling without carton liner	283.0	90.9	1.05	5.00	5.00
LSD (P<0.05)	**23.5**	**3.37**	**0.16**	**0.27**	**0.25**

After 36 days of storage at about 1°C, the sealed LDPE bag significantly maintained shelf life of daikon roots (Table 8). Therefore, a modified atmosphere of CO_2 and O_2 concentrations of 6.5% and 2.5% respectively, appear to maintain daikon quality suitable for export markets.

In the second trial (Table 10), where daikon was stored for 28 days at 1.7°C, cartons without liners recorded a percentage weight loss of 10.7 to 11.2 % and all other treatments less than 2% weight gain or loss, except for two replicate treatments (data not presented). For each treatment, the ratings for rots and blemishes and quality were considerably lower than in the first trial.

The gas concentrations of each treatment were relatively consistent except for the O_2 levels in the LifeSpan®L144 bag, 12.69% to 17.60% bag O_2 concentrations are given in McVeigh *et al.* (2001). The LDPE bag recorded lower levels of CO_2 and higher levels of O_2 when compared to the first modified atmosphere trial. This may have been due to the different variety used and the different physiological age of the daikon, as these factors affect the potential benefits/hazards of using MA storage (Kader, 1992).

Regardless of the wide range of O_2 levels in the LifeSpan®L144 bag, the quality of root was unaltered during the storage period of 28 days. Roots in the LifeSpan®L144, unsealed LDPE and unsealed HDPE bags had the best quality ratings of 1.63 to 1.68 (export standard) (Table 10). There were no significant differences in the ratings of rots and blemishes between treatments except for treatment six without a carton liner. No CO_2 injuries were detected.

Table 10: Daikon quality assessment after 28 days at 1.7°C storage in different modified atmosphere bags

Treatment	Length (mm)	Diameter (mm)	Pithiness (1-5)	Rots & blemishes (1-5)	Quality (1-5)
Sealed HDPE	355	65.9	1.05	1.85	2.20
Sealed LDPE	343	66.2	1.03	1.83	1.98
Sealed LifeSpan®L144	338	64.9	1.00	1.75	1.63
Unsealed HDPE	342	66.0	1.03	1.65	1.65
Unsealed LDPE	343	65.8	1.00	1.58	1.68
Room cooling without carton liner	329	62.3	1.00	2.90	4.45
LSD (P<0.05)	**13.51**	**1.58**	**NS**	**0.31**	**0.29**

The second trial confirmed that daikon should be stored in a carton liner. Whether the carton liner should be MA packaging, sealed or unsealed, is debatable. In the first MA trial the sealed LDPE bag maintained the shelf life of daikon for more than 36 days. The second MA trial showed unsealed LDPE, unsealed HDPE and sealed LifeSpan®-L144 bags maintaining daikon quality over 28 days.

New South Wales, 1991-1992

Post-harvest pithiness

In trial 1, the cultivar Oshin showed significantly less pithiness at out-turn (after 25 days at 1°C and 3 days at 20°C) with increasing age. In trial 2 there was greater out-turn pithiness with increasing age in two cultivars, Fukumi and Long White (data not presented but available in Harris *et al.* 1993).

Probability of unacceptable levels of post harvest pithiness were much higher in trial 1 (the spring-summer trial) than in trial 2 (the autumn-winter trial).

Total Soluble Solids

There was no significant correlation between TSS and pithiness at harvest or post-harvest, in either trial.

TTS generally declined over time, but was not consistent between cultivars or trials.

4. Discussion

In general, yields obtained in NSW were less than those in WA and average root weights were also somewhat less. In relation to reported yields from other countries, those in NSW and WA were superior at all planting dates. Comparing yields in NSW and WA for the plantings harvested in November the root weights were similar, with cultivars known to be slow bolting performing well, and those known to be more suitable for summer production having lower root weights than the better performing cultivars from the November harvest.

At the November harvest, Narumi was the best cultivar in Manjimup and one of the best in Medina and Gosford. It varied in root weight at the three sites with greatest root weight at Manjimup (922 g), followed by Gosford (830 g) and was least at Medina (751 g). This could be due to temperature or soil type differences; Medina and Gosford are at similar latitudes.

The cultivar Narumi had root weights that reached up to 1400 g in the December harvest at Medina and the January harvests at Manjimup.

The cultivar Narumi was grown in both states and had consistently lower yields in NSW. The number of plants per hectare in the WA field trials was more than twice that of the NSW trials. This would have influenced calculated yields per hectare and mean root weight considerably. Other cultivars grown were quite different in the NSW trials to those grown in WA trials.

There were also differences between yields and days to harvest at the two sites in the WA trials. At Medina, daikon took longer (75-119 days depending on season) to mature than at Manjimup (61-112 days). This was probably related to the different temperatures at each site with Manjimup monthly average maximum and minimum temperatures 5°C and 3-4°C lower respectively, than those at Medina.

Daikon has been called a cool season crop suitable for spring and autumn production with temperatures of 20-25°C described as best (Nguyen 1998a). Higher temperatures cause physiological problems and lower temperatures bolting. At these optimum temperatures it should mature in 50-90 days.

At Medina these temperatures conditions were experienced from April to May and August to November (autumn and spring respectively) whereas at Manjimup suitable conditions occurred from November to January (early summer) and in April. At Medina only the winter grown crop harvested in September took longer than 90 days to mature. At Manjimup winter grown crops took over 90 days to mature for the August to October harvests with maximum temperatures in June and July down to approximately 13°C. Pithiness was greater in Manjimup than Medina for the winter harvest and November spring harvests. Both sites had problems with pithiness at the October harvest after cool winter temperatures.

Medina had 4 months (December to March) in the trials when temperatures were over 25°C and at Manjimup two months (February and March), however, there were no reported physiological consequences due to these higher temperatures at either site. Nevertheless, there was an inverse link between maturity greater than 110 days and quality at Manjimup but not at Medina which generally had better quality ratings than crops at Manjimup.

The WA post-harvest trials confirmed that daikon should be stored in a carton liner for improved quality out-turn with less rots and blemishes. However, it was not clear which type of liner was best.

According to Kader (1992), radish can tolerate a maximum CO_2 concentration of 5.0%. Most of the CO_2 readings of the sealed LDPE bag in the first trial (1°C) were slightly greater than 5% but in the second trial (1.7°C) all were considerably less than 5%. Depending on the commodity, damage associated with CO_2 may be temperature dependent. This could be so with daikon.

The sealed LDPE bag in the second trial recorded lower levels of CO_2 and higher levels of O_2 when compared to the first modified atmosphere trial. This may have been due to the different variety used and the different physiological age of the daikon, as these factors affect the potential benefits/hazards of using MA storage (Kader, 1992).

In the first trial, daikon in the LDPE bags had the best quality with less rots and blemishes than the other treatments but in the second trial they were average quality and average amounts of rots and blemishes compared with other treatments. This may have been due to storage temperature and/or cultivar differences (Kader 1992). The period of storage at these elevated CO_2 concentrations may not have been long enough to produce a very detrimental physiological effect. Other bags had better results in the second trial with shorter storage time.

Storing daikon with 10 cm of green tops may be a problem if trying to obtain premium quality and price. After 36 days of storage the majority of stems had turned yellow which would probably result in downgrading of the product, resulting in reduced financial return.

Obviously, the performance of the various MA carton liners is dependent on length of storage, temperature during storage, variety and physiological age of the daikon. There is a need to develop a more suitable MA bag for daikon so that higher quality product can be achieved after the storage.

The yellowing of the stems greatly limited quality of the daikon after storage. Leaf yellowing and abscission is not acceptable to the Japanese market. Therefore, Japanese consumer acceptance of Australian daikon without leafy stems is important (Harris *et al.* 1993).

The limited domestic market opportunities make it imperative that we can produce a product that the export market wants. With costs associated with transport and extra expense of MA packaging this may not be an option.

These trials have shown that there is potential for growers to produce daikon where average monthly maximum temperatures are in the range 20-25°C and they can grow a year round supply of quality product with minimal time to maturity. If the market only requires a window of supply other areas may be suitable.

Recommended cultivars for southern Western Australia include Narumi, Takumi Sobutori, Radish F1 No's.14 and 16, Kurazukuri F1 depending on season and site. Recommended cultivars for the central coast of New South Wales also includes Narumi and some other cultivars which were trialed more than 10 years ago. The seed companies identified in this report can advise on suggestions for best cultivars for other locations.

5. References

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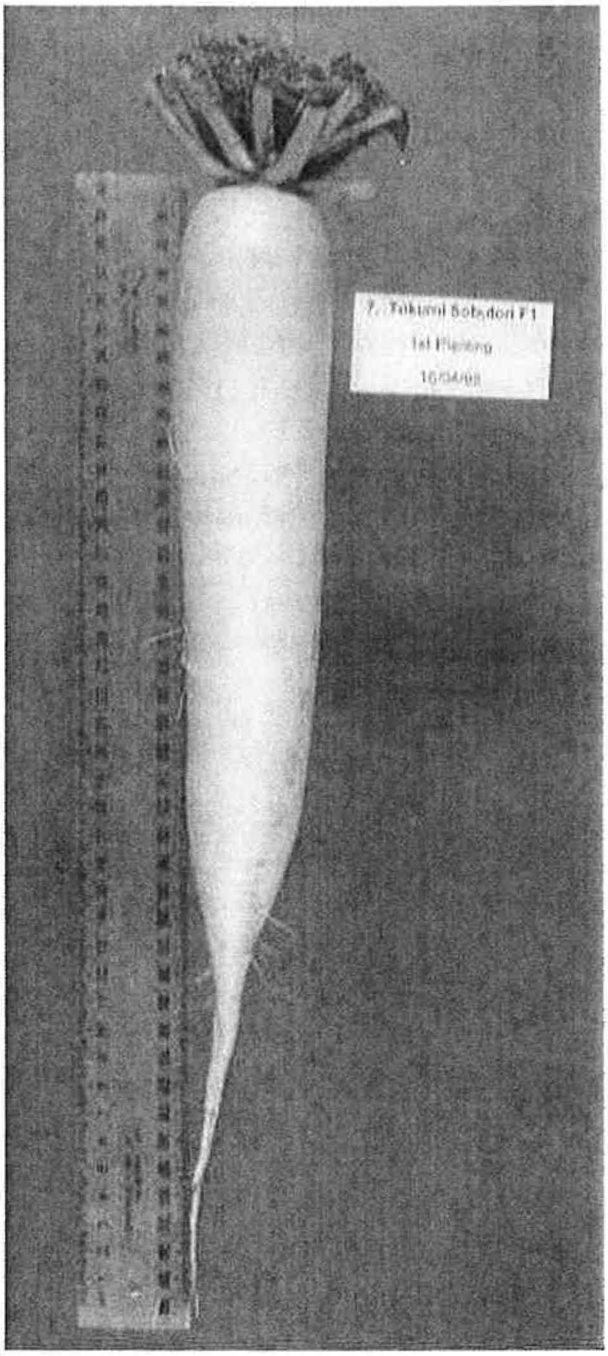
6. Appendix 1



Daikon (cv. Takumi Sobutori) grown at Medina Research Station

Daikon (*Raphanus sativus L.*), also known as Japanese radish, has until recently been grown in a few locations in Australia, in particular the Sydney Basin of New South Wales (NSW), by growers of Chinese background.

Opportunity to export has promoted some large-scale growers in Victoria, Western Australia (WA) and NSW to produce according to the importers' requirements.

This report looks at trials focusing on exports to the Japanese market, as well as enhancing production methods, and varietal suitability, for the domestic market. Post-harvest storage trials were also undertaken.

ASIAN FOODS RESEARCH AND DEVELPMENT

RIRDC's Asian Foods program aims to foster a prosperous, competitive Asian Foods industry in Australia, exporting to Asian markets and replacing imports in the Australian market.

The potential market for Australian grown Asian vegetables in many Asian countries is large. For instance, Japan imports $2.3 billion of fresh, frozen, preserved and dehydrated vegetables each year. Other foods, particularly processed foods, are also popular and opportunities include sauces, ready-made meals, and possibly snacks. The challenge for Australian producers is to be able to develop a reputation for quality and to be able to compete on cost.

Asian Foods is one of 19 research and development programs in RIRDC's portfolio.

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