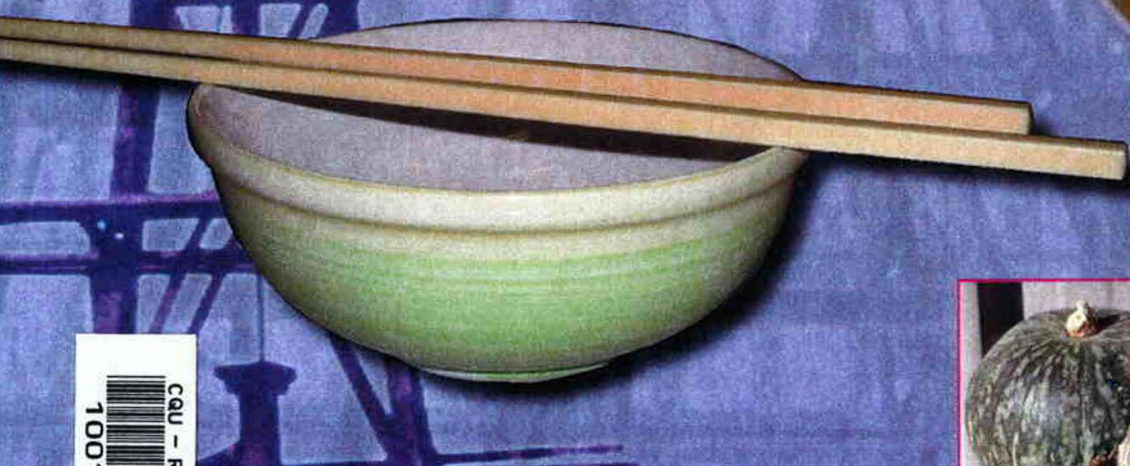
RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

Kabocha and Japanese Pumpkin in Australia

by Wendy Morgan
and David Midmore



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A report for the Rural Industries Research and Development Corporation

by Dr Wendy Morgan and Professor David Midmore

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Foreword

This publication is one of a number arising from the RIRDC project UCQ-10a, which involved collaborative research amongst groups of specialists located across Australia. The aim has been to provide a catalyst to the development of cooperative arrangements for continuous supply of perishable Asian vegetables to satisfy domestic and export markets.

The publication reports on a series of trials of Japanese pumpkin and Kabocha cultivars in NSW, Victoria, Queensland and the Northern Territory.

The project was funded from RIRDC Core Funds which are provided by the Federal Government, with varying levels of co-funding from the cooperating institutions.

This report, a new addition to RIRDC's diverse range of over 800 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:

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Executive Summary

Japanese Pumpkin (*Cucurbita moschata*) and Kabocha (*Cucurbita maxima*) are members of the cucurbit or pumpkin family. In Japan, kabocha is known as nutty flavoured pumpkin (in Japanese - Kuri Kabocha) and commands quite high prices. Fruits are small (1.5-2.0 kg). New hybrids of the two species have smaller fruit, due to the higher fruit set rate. Kabocha is grown in Australia, for the domestic market and as a fresh (from Tasmania) and processed (from mainland Australia) product exported to Japan. Australia is, however, an insignificant supplier of the approximately 130,000 t imported annually to Japan.

A project, funded in part by RIRDC, allowed compilation of earlier data, and establishment of field trials from 1998-2001 in most states of Australia to identify national production capability, and to establish information sought by supply chain managers.

With yields ranging from 16-53 t/ha, kabocha can be grown in all states of Australia. The interspecific hybrids (*C. moschata* x *C. maxima*) tended to be the highest yielding varieties, due to their greater fruit set. Where fruit set was high (eg at Katherine, NT) two harvests could help to maximise yield per unit land area. It may be that the higher temperature range promoted more fruit set there than at other sites. Fruit maturity (time from fruit set to harvest) was also longer at Katherine and Gatton (Qld) where diurnal temperature ranges were greater that at Tatura (Vic) and Mareeba (Qld).

Harvest protocol established in the trials comprised only one harvest, and this may have led to yields less than potential if smaller later-set fruit were not harvested.

Across all trials, the new variety Tetsukabuto out-yielded the traditional Delica and Pacifica, encouraging adoption of this variety for the domestic market. This variety needs either *C. maxima* or *C. moschata* planted nearby for pollination.

When evaluating the effect of site on growth and yields, the Northern Rivers region of NSW was considered unsuitable, due to disease (downy and powdery mildew) most likely induced by high humidity. Likewise, plantings that resulted in harvest beyond January in SE and Central Queensland invited sunburn. Winter plantings in the NT and summer plantings in NSW (Gosford) and Victoria (Tatura) resulted in highly acceptable yields, as did the sowings in Queensland (Mareeba).

As with yield, significant difference between varieties within site, and between sites, for quality measurements were recorded. The varieties often fell into three separate groups; the older varieties Delica, Pacifica; the interspecific hybrids Tetsukabuto (late Potkin); and the Australian varieties Ken's Special. While diameter, height, and therefore shape, was constant for most varieties across sites, this was not so for Tetsukabuto reinforcing the impression that fruit of this variety was not always mature at harvest. Tetsukabuto had also darker rind colour, and fewer skin warts/blemishes, and more total carotene levels than did Delica. Fruit visual characteristics were relatively insensitive to growing location, but the ratio of sucrose, glucose and fructose in the flesh varied between varieties, trials and sites. There is some evidence to support the conclusion that sucrose:glucose ratio increases with fruit maturity, and that fruit age may be a useful tool upon which to base harvest decisions. More research is required under controlled conditions to verify this.

As fresh fruit is exported from Tasmania to Japan, efforts were undertaken to reduce the extent of post-harvest rot (*Fusarium colmorum*) during storage. Older fruits appear to be more susceptible to rots, and this could influence the optimum time for harvest. While heat shock treatment (2, 8 or 16 hours at 36 or 38°C) was ineffective in reducing extent of rot, cold treatment (7°C for 28 days) was more useful. The use of acetic acid was effective at 50 µl/l airspace in reducing spore germination and fungal rot, but it was phytotoxic to the fruit.

In summary, the trials reported confirm that Australia can produce kabocha of acceptable quality year round, if the variation in locations and planting dates is optimised. The newer interspecific variety, Tetsukabuto, offers greater returns to growers. Its acceptance as a processed product for Japan requires verification.

Introduction

Pumpkins are members of the cucurbit family originating from the South American tropics. In this publication we are concerned with *Cucurbita maxima* and *Cucurbita moschata.* There are three other domestic pumpkin related species within the cucurbit family: *C. pepo, C. mixta* and *C. ficifolia.*

Kabocha belongs to the species *C. maxima*. In Japan they label it Kuri Kabocha which means nutty pumpkin.

Japanese pumpkin is a collective term used only for varieties of *C. moschata* originally grown in Japan. In Australia the most popular cultivar is known as Ken's Special which was selected in North Queensland. It is marketed as Japanese pumpkin in most Australian retail fruit and vegetable outlets.

Kabocha varieties are hybrids originally developed from open pollinated *C. maxima* strains. Kabocha pumpkin has a number of colloquial names in Australia and New Zealand including Buttercup Squash, Delica and Early Potkin. In Japan all *C. maxima* are known as Kuri Kabocha.

Delica is one hybrid kabocha (*C. maxima)* variety, bred in Japan by Takii Seed Co. and now grown widely in Australia. It is known as Ebisu in Japan. Another popular hybrid variety grown in Japan is Kurijiman. Both these hybrids have small, flattish, round fruit with a distinctive bottle green skin colour with light green stripes as the fruit approaches maturity. The dark green colour dulls on fruit maturity and the skin often turns yellow, brown or red as the fruit ages. The immature flesh is green/yellow, becoming orange on maturity. These kabochas have been called Green Hokkaido types in older references.

Kabocha varieties that develop an orange skin with paler stripes on maturity also exist (known as orange Hokkaidos in older references). They are similar in size and shape to the green varieties and also have a yellow/orange flesh on maturity. Examples include Golden Debut and Golden Orbit.

Different pumpkin hybrids have also been developed by interspecific crosses between *C. maxima* and *C. moschata*. An example is Tetsukabuto, also known as Late Potkin in Australia as it can mature up to one month later than kabocha varieties. These pumpkins can be deeply ribbed at maturity and have a hard skin enabling a prolonged shelf life. To enable these interspecific hybrids to set fruit they must be planted adjacent to a *C. maxima* or *C. moschata* to ensure viable pollen is available.

All *C. maxima* types are distinguished by the corky nature of the stem attachment which softens as the fruit matures on the vine. The stem is round and striated and does not form an attachment scar on the fruit.

In contrast *C. moschata* stem attachment dries and hardens at maturity. The fruit attachment scar is five cornered.

Kabocha are typically quite small (1.5-2.0 kg) and have a distinct sweet nutty flavour known in Japan as 'haku haku'. Japanese expectations of taste and quality are considered substantially different to Australian.

Kabocha are popular in Japan and Australia because of their excellent storage and culinary properties. When mature they are more solid (less watery) than other pumpkins and have drier, sweeter flesh and a nutty flavor (Larcom 1991).

Japanese varieties have become smaller over time, reflecting family needs, such that newer varieties are now 1.5-2.0 kg/fruit. Most cultivars are hybrids produced in Japan and are now readily available from Australian seed suppliers. No publicly funded breeding is conducted in Australia, despite the potential for creating disease resistant varieties suitable for production in Australia. Seed of the in-bred parent lines has not been obtained for further development in Australia.

Agronomic requirements are similar, but not identical, to pumpkins traditionally grown in Australia. Projects in Australia to develop kabocha production for export to Japan and expansion of the domestic market have been carried out in a number of states. Most notable is the production work conducted in Tasmania (Chung *et al.* 1993), Victoria (Top and Ashcroft 1997 & Top *et al.* 2001) and Northern Queensland (Loader 1998).

Japan is the largest importer of pumpkin with approximately 133,000 tons imported in 2000, half of this from New Zealand.

Marketing opportunity studies conducted for the Queensland Department of Primary Industries (Brown and Breinl 1995, Brown *et al.* 1996), Victorian Department of Natural Resources and Environment (Keenan 1997), Tasmanian Department of Primary Industries (1998) and private industry clearly identify the potential for kabocha exports to Japan. Japanese quarantine regulations with regard to fruit fly have meant that only Tasmania with its fruit fly clean status is able to export fresh kabocha (approximately 1000 tonnes exported in 2000). Despite industry funded projects to investigate low temperature disinfestation mainland Australia is limited to exporting processed product and specifically frozen pumpkin pieces.

Varieties grown in Tasmania for fresh export include Delica, Hokkori (T110), Nishiki, Aijehei and Kurijiman with seed obtained directly from Japan. Tasmania supplies Japan between March and May.

Considerable production research and marketing has occurred in New Zealand to support and improve their industry and export markets. Fruit quality attributes have been looked at from a sensory perspective and to determine the relationship between flesh composition and storage rot incidence during export.

This report draws together Australian research undertaken at a regional, state and national level between 1994 and 2001, to identify national production capability and supply and productivity issues (or solutions) for future supply chain development in domestic and export markets. As well fruit quality attributes and work on reducing storage rots are reported. Recommendations are included for the highest yielding cultivars at each location.

Current Knowledge

1.1 Cultivars

Most common cultivars grown in Australia and some of the better performers in the Australian trials include:

Delica
Delica, also known as Ebisu (registered name), is an F1 hybrid developed by Takii Seed Co. It is one of the Green Hokkaido type pumpkins, an older variety with an average weight of 1.7-1.9 kg/fruit with very uniform vigorous growth. It is very adaptable to various growing conditions and considered early maturing. The fruit has a deep green skin, flat globe shape, thick yellow flesh and a very sweet taste. It is suitable for sea freight (Pan 1995). Delica seed is also supplied by Yates and South Pacific Seeds. New Zealand exports to Japan are primarily Delica and Kurijiman, and their seed is imported from Japan (Brown *et al.* 1996) via Yates (Bryce de Rossi 1999, pers. comm).

Delica can also be used to refer to a type of kabocha.

Kurijiman
Kurijiman was developed by Kyowa Seed Co. (Japan) and is distributed in Australia through Fairbanks. It is similar to Delica. Yield in New Zealand is typically 95% of Delica but becomes higher in later plantings.

Pacifica
Pacifica was developed and is distributed by Yates to combine Japanese fruit quality characteristics with traits suitable for Australian production. It has large fruit and a reasonable yield, and is therefore suitable for processing. Seed is larger than Delica seed, affecting planting density and depth and seed cost (when sold by weight).

Tetsukabuto
Tetsukabuto is an interspecific cross between *C. maxima* and *C. moschata* released by Takii Seed Co. It is characterised by a high yield and very sweet, nutty fruit weighing 2.0-2.5 kg. It is globe shaped with very dark-green skin which is slightly mottled and ribbed. The flesh is thick and yellow. Tetsukabuto is also known as Late Potkin in Australia as it can mature later than the kabocha cultivars at some locations. It outperformed the Delica type kabocha hybrids in production trials in all states. It requires a pollinator to ensure fruit set.

Uchiki Kuri
Uchiki Kuri is one of the orange Hokkaido type kabocha pumpkins (also known as a Hubbard type) and is an open pollinated variety. It is generally smaller than the Delica type with an attractive smooth orange-red skin and light ribbing. The thick flesh is usually a creamy yellow colour with a very sweet and nutty flavour. Uchiki Kuri is recommended for cool areas. It is generally known as Uchiki Kuri or Red Kuri in Japan and the USA. In Australia Golden Nugget is the closest we have in appearance.

Hokkori or T 110
An F1 hybrid from Takii Seed Co. This line was released in the late 1990's under the commercial name of Hokkori Ebisu, an early cultivar. The fruit is similar to the Ebisu (Delica) type (flat) with smaller size, and average 1.6 kg each. The skin of the fruit is deep green with white dots. Hokkori Ebisu is considered better than Ebisu in terms of its thicker

flesh and deep yellow colour. It is very sweet and has a dry taste. This year Hokkori 133 has been released which has the high yield of the Delica and good quality of Hokkori.

Sweet Mama
Sweet Mama is the English name of the cultivar Tsurunashi Yakko, another Takii Seed Co. F1 hybrid kabocha. Sweet Mama can be planted densely, since it is a distinctly bush type and doesn't produce secondary branches, resulting in higher yields. Fruit of Sweet Mama are similar to those of Ebisu with flat shape, 1.7-1.9 kg weight and deep green skin. The flesh is bright yellow, very sweet, nutty and has dry taste.

Ken's Special
Ken's special is a traditional Japanese pumpkin type of the *C. moschata* species, originating from a farmer's selection in North Queensland (as is Butternut pumpkin). The distinctive five pointed star-like attachment of stem to fruit and the drying and hardening of the stem attachment at maturity distinguishes this pumpkin. This is a popular cultivar at supermarkets and Australian farmers like Ken's Special as seed is relatively cheap, yield is high, shelf life is good and quality is reasonable.

1.2 Production

1.2.1 Regions

Kabocha is grown commercially in Queensland, NSW, Victoria, Tasmania (Lee 1995) and Western Australia.

It has been grown in Tasmania since the 1988/89 season (Botwright *et al.* 1998), with approximately 600 ha/year planted on the North West coast for fresh export. Exports reached a peak of 4500 tonnes during the 1992/93 season and between 1999 and 2001 approximately 1000 tonnes have been exported to Japan per annum by Harvest Moon Forth Farm Produce (Hay and Mudford 2001a).

Victorian yields and quality are generally better north of the Dividing Range.
Kabocha is not grown commercially in North Queensland (Loader 1998).

Fruit has been available from Western Australia all year, Tasmania from February to April, Victoria during January to March, and from Queensland for November to January and April to June. On the East coast there is a supply gap during August to October.

Tasmania supplies fresh fruit to Japan from March to May.

1.2.2 Climate

Potential production dates across Australia are given in Table 1. The crop requires a 3-4 month growing season. Brazil reports higher yields in the dry season than the wet season (Resende *et al.* 1996), probably due to higher solar irradiance in the former.

Table 1. Seasonal margins for kabocha and Japanese pumpkin production in Australia*

Planting Dates												
Location	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Katherine				E	+	+	+					
North Qld			+	+				+	+			
Central Qld	+	+	+	E				L	+	+		
South Qld								L	+	+		
Central NSW									+	+	+	
North Vic									M	+	+	L
South Vic										M	+	L
Tasmania											+	+
North WA			L	+	+	+	+	+				
Central WA	M	+	+	+	+	+	+	+	E			
South WA								L	+	+	+	+

Harvest Dates												
Location	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Katherine								E	+	+	+	
North Qld						+	+				+	+
Central Qld	+			+	+	+	E				L	+
South Qld	+										L	+
Central NSW	+	+										+
North Vic	+	+	L									M
South Vic	M	+	L									
Tasmania		+	+	+								
North WA						L	+	+	+	+	+	
Central WA			L	+	+	+	+	+	+	+	+	+
South WA	+	+	+	+								+

* (E: early, L: late, M: mid, +: all). Note that the crop requires a 90-130 day growing season.

1.2.3 Temperature

Mild to warm conditions are preferred, with 20-30ºC days and 15-20ºC nights. Soil temperature should be over 15ºC, and frosts cause severe damage.

1.2.4 *pH*

Optimum pH is 6.0-6.4. A pH below 5.5 produces growth problems, and up to 7.2 is tolerated (Top and Ashcroft 1997).

1.2.5 Salt sensitivity

The crop has medium to low salt tolerance.

1.2.6 Plant density

Total kabocha yield increases with increasing plant density and maximum yields of 29.5 t/ha were achieved with 3 plants/m² in New Zealand (Douglas *et al.* 1990) and 38 t/ha with 6 plants/m² in Tasmania (Chung *et al.* 1992). But both trials reported an increased yield of small fruit at the higher density. Higher densities also result in lower female flower numbers and an increase in aborted fruit (Botwright *et al.* 1998).

Marketable yield (which may well be different for fresh and processing) therefore requires different plant densities. For the fresh market, a marketable yield (fruit of greater than 0.8 kg) of 16.6 t/ha was produced at 1.1 plants/m² (Chung *et al.* 1992). Similarly, a marketable (fruit greater than 1.2 kg) yield of 18 t/ha was achieved with 1.1 plants/m² and declined at higher densities due to increased undersized fruit (Botwright *et al* 1998).

A 1.5-1.8 m spacing between rows and 0.3-0.8 m within rows has been recommended by Top and Ashcroft (1997) and 1.8 m row spacing and 0.6-1.1 m within-row spacing by Botwright *et al* (1998).

1.2.7 Sowing depth

In Tasmania, 2.5 to 3.5 cm (Botwright *et al.* 1998) and in Victoria 3-4 cm (Top and Ashcroft 1997) are the suggested sowing depths. Rule of thumb is that you plant as deep as the seed length which allows for differences between varieties in seed size.

1.2.8 Germination

Temperature range is 15-35°C, with an optimum temperature of 18-25°. Emergence occurs in 5-7 days.

1.2.9 Transplanting

Transplant should be done 6-14 days after emergence, at the first true leaf stage. Direct seeding is preferred in optimal conditions.

1.2.10 Water

Drip tape has been used successfully in these trials. If using overhead sprinklers they are best used in the morning only, so that wet leaves dry quickly, reducing spread of disease (Top and Ashcroft 1997).

1.2.11 Nutrition

High levels of nitrogen are required early in the crop for growth, and high calcium later to improve firmness and colour. Approximately 180 kg/ha N is required, half drilled in at sowing and the rest applied two weeks after emergence (Top and Ashcroft 1997). Excessive nitrogen application can reduce yields by increasing vegetative growth. As with all crops the absolute amount of nitrogen will depend on the soil's ability to supply essential soil nutrients.

1.2.12 Harvest

Use a sharp knife to cut the stem and take care to minimise damage. Stem damage is one source of rot entry (Rubatzky and Yamaguchi 1997). There are typically two harvests for a commercial crop, as it is rare that one harvest date is suitable for the whole field. Tetsukabuto may need more harvests.

Stem dryness is a practical indicator that fruit is suitable for harvest.

The most effective way of estimating the optimum harvest date for shipping fresh fruit is by measuring skin hardness or, by the heat accumulation value of the number of days multiplied by the average daily temperature above a certain minimum. Earliest possible harvest for Delica in New Zealand conditions was at a penetrometer score of 7 kgf, but fruit harvested this early required a postharvest ripening period to optimise sweetness, texture and sensory quality (Harvey *et al.* 1997).

See 1.3.2 below for more information on harvesting.

1.2.13 Yield

Yields average 18-22 t/ha, but 35-50 t/ha is possible. Trials in Cambridge, Tasmania produced marketable yield of 18 t/ha (Botwright *et al.* 1998). Japanese average yields have fallen from 17.71 t/ha in 1975 to 14.63 t/ha in 1996. Variety 'Evis' produced 28.9 t/ha in Korea (Cho *et al.* 1997). Tasmanian yields are around 10-15 t/ha (Frank Hay 1999, pers. comm.) and Victorian marketable yields 15-35 t/ha depending on cultivar.

1.2.14 Margins

A Tasmanian estimate of gross margins, modelled from New Zealand production and a yield of 15 t/ha, came to $1,351/ha at $250/t, and $2,101/ha at $300/t The model is on the website: www.dpif.tas.gov.au/domino/dpif/IndustryProfiles.nsf (DPIF Tasmania 1998).

1.3 Post-harvest

1.3.1 Fungal pathogens

Fusarium species were associated with 80% of all post-harvest storage rots of *C. maxima* in New Zealand (Hawthorne 1988). Six *Fusarium* species were isolated but only *F. culmorum* and *F. solani* were common. *Didymella bryoniae* was isolated from between 6-16% of all rots, and other fungal genera were found in 4-7 % of all rots. Pathogenicity tests showed that the three most commonly found pathogens (*F. culmorum*, *F. solani and D. bryoniae*) caused the most extensive rots in inoculated fruit.

1.3.2 Harvesting

Fruit harvested later in crop life had less storage rot than fruit harvested earlier (Hawthorne 1989) and fruit harvested soon after expansion was completed was less susceptible to storage rots than fruit harvested 2-4 weeks later (Hawthorne 1990).

1.3.3 Handling

Fruit should be handled carefully to prevent wounding (King and Wishart 1991) and not left in sunlight for more than an hour after picking to reduce rots during storage and transport. Wounded fruit are more likely to rot than unwounded fruit (Hawthorne and Sutherland 1991). Fruit is best stored in single layers without touching, with good air circulation around each pumpkin (Top and Ashcroft 1997). Containers are often transported with the doors removed to improve air circulation (JETRO 1992).

1.3.4 Curing

Curing at 30ºC for 2-3 days before storage at 10ºC reduced storage rot numbers (Nagao *et al.* 1991).

Some cuts and bruises can be treated to minimise rots, by storing at 27-30°C and 80% relative humidity for 10 days before transferring to long-term storage (Rubatzky and Yamaguchi 1997).

Although natural wound repair processes were able to slow down rotting, rots developed around edges and beneath scar tissue (Hawthorne and Sutherland 1991).

1.3.5 Chemical controls for rots

Sodium hypochlorite is used to reduce fungal inoculum in wash water and to disinfest fruit surface, with a low pH increasing its effectiveness to kill post harvest fungi (Boyette *et al.* 1993).

Pre-harvest fungicide treatments have been inconsistent for post-harvest rot control (Hawthorne 1989).

1.3.6 Temperature

Store at 10-15°C (Yamaguchi 1983) to maintain fruit quality and minimise chilling injury. At temperatures below 10ºC fruit suffer chilling injury, even if the low temperature is only for a few days (Rubatzky and Yamaguchi 1997). Chilling injury is characterised by blackening and skin pitting, softening of tissue beneath the skin and increased susceptibility to decay (Laamim *et al.* 1998).

1.3.7 Humidity

Store at low temperatures, at <90% R.H. (Hawthorne 1990) 55-60% humidity (Rubatzky and Yamaguchi 1997).

1.3.8 Shelf life

Pumpkins can be stored for 3-4 (Top and Ashcroft 1997) and up to 6 months, depending on variety and conditions (Larkcom 1991). Fruit harvested early are less susceptible to storage rots (Hawthorn 1989, Harvey *et al.* 1997). Reduced time and heat accumulation during transport and storage can significantly improve the quality of early harvested fruit (Harvey *et al.* 1995).

1.4 Processing

Only one Australian company has processed kabocha in commercial quantities, to the authors' knowledge. Mac Fresh Foods process included removing rind and centre, cutting to a 'roast dinner' size and freezing using 'Individual Quick Freeze': liquid CO_2, to -18°C in 8 minutes. The company has since disbanded. Another Queensland company is currently testing the market.

1.5 Pests and diseases

1.5.1 Viruses

Mosaic type viral diseases are common in southern Queensland and northern New South Wales, particularly on the coast, appearing in December to January in warmer years and February to May in cooler years. Control is difficult if conditions favour the disease vectors.

Genetic resistance for Zucchini Yellow Mosaic virus, Papaya Ringspot virus and Watermelon Mosaic virus is available, but has not been bred into kabocha varieties (Herrington 1999, pers. comm). Other resistant germplasm has also been reported (Kristkova and Lebeda 1997). Potential viruses are listed at Plant Viruses Online (Brunt *et al.* 1996).

1.5.2 Bacteria and fungi

Powdery mildew is common throughout the east coast of Australia, destroying the canopy and leaving fruit vulnerable to sun scorch. It attacks older leaves and main stems, producing a circular, white, powdery spot which spreads over the entire leaf, causing it to wilt and die (Top and Ashcroft 1997). Control is difficult if conditions favour the disease. In Victoria the disease tends to establish in January (Top and Ashcroft 1997).

Downy mildew has been observed in northern NSW and Victoria during periods of wet or humid weather. It is characterised by yellow leaf spots which turn brown (Top and Ashcroft 1997).

Penicilium spp. have been observed as a post harvest rot in Victoria (Chew and Morgan (1997).

Japan has occasionally ordered large volumes of fresh kabocha to be sorted and/or destroyed due to rot caused by *Penicillium* and *Fusarium*. This loss may be related to heavy rain during harvesting, careless sorting and improper temperature and humidity control due to inadequate air circulation during transportation (JETRO 1995).

1.5.3 Pests

Heat disinfestation for Queensland or Mediterranean fruit fly (*Ceratitis capitata*), has been studied and appeared promising, but is not ongoing. Cold disinfestation was not successful with Queensland fruit due to chilling injuries, although it did not harm Tasmanian fruit.

Spider mites, leaf roller moths, owlet moths, thrips and armoured scales have often been found on pumpkins exported to Japan. To prevent infestation by such pests, measures such as brushing the surface of pumpkins and squashes, in addition to thorough field control, may be effective (JETRO 1995).

Moderate tolerance to root knot nematode was found in accessions from Malawi (Chigwe and Saka 1994).

1.6 Fruit quality

Japanese consumers prefer firm pumpkins with dark green skin and dark orange flesh. Eastern Japanese prefer drier, crunchier pumpkins than those in Western Japan (Brown *et al.* 1996). A dulled (not shiny), evenly distributed green is most marketable (Jeff Hastings 1998, pers. comm.). Evenness of skin colour is most affected by the earth mark (where fruit sits on the ground) and sunburn. Warts are superficial raised corky lesions thought to be associated with maturity and excessively moist soil conditions. They detract from fresh fruit appearance.

Susceptibility to both warts and sunburn varies among varieties, with sunburn being at least partially dependent on leaf coverage and harvest time. Unebi was very prone to warts, while Ajehei and Early Potkin appeared resistant (Loader 1998).

Seed cavity size can be an issue for fresh fruit consumers, as well as increasing transport costs when based on cargo volume. Delica and Pacifica have large cavities.

Japanese and Australian kabocha appear to differ more in nuttiness than sweetness, and this dictates a huge difference in price (Vong Nguyen 1996).

Brix and β-carotene are both increased by greater exposure to sunlight and diurnal temperature variation. Hence, quality tends to be better when grown inland. β-carotene is considered to have health benefits, so a market could be developed around high nutrition fruit based on carotene levels. A minimum total carotene level of 400 μg/g DW was considered acceptable for export (Hurst *et al.* 1995).

Although there are compositional differences between cultivars (dry matter, starch, sugar and titratable acid), they were not associated with storage life but were related to sensory perception of quality (Hurst *et al.*1995)

Japanese grade kabocha according to fruit size (Table 2) and size issues influencing purchase, were surveyed by Brown and Breinl (1995) (Table 3).

Table 2. Codes used for kabocha sizes in Japan.

Code	**No. fruit/10 kg case**
2L	4-5
L	6-7
M	8-12

Table 3. Japanese kabocha product criteria identified by QDPI trade survey (Brown and Breinl 1995).

	Importer	Wholesaler	Retailer	Consumer
Supply Stability	Y			
Price	Y	Y		
Freshness	Y	Y	Y	
Lack of Damage		Y		
Skin Colour		Y		Y
Size		Y	Y	
Ripeness		Y	Y	
Shape			Y	
Taste			Y	
Free of Disease			Y	
Free of Chemical				
Residues			Y	Y
Firmness				Y
Flesh Colour				Y

1.7 Domestic market

In Australia the domestic market, (supermarket and green grocery), appears to be expanding in volume and range of cultivars, albeit from a low base. Ken's Special is still the most popular pumpkin, usually marketed as "Japanese pumpkin".

1.8 Export market

1.8.1 Japan fresh

Japan is the biggest kabocha importing country (Pan 1995). Mainland Australia is currently restricted from exporting fresh kabocha to Japan due to fruit fly. Until disinfestation procedures have been developed, only Tasmania can export fresh fruit.

Tasmanian first grade has been shipped to Asia and Japan for the last 6-10 years between March and May with current volumes at approximately 1000 tonnes p.a. One exporter supplies this produce. About 30% of harvested fruit are rejected for skin blemishes and sunburn. Australia must produce for a top quality niche market to be competitive against New Zealand which sets the price for southern supply (Austrade 2001). In 1998, Tasmania predicted that a volume of 10,000 t per annum was achievable (DPIF, Tasmania 1998).

Japan imports more than 130,000 t (in 1999 154,000 t) of fresh kabocha annually to supply its off-season market, which lasts from September to April (Anon. 2001a). Pumpkins were 13.7% of Japan's total fresh vegetable imports in 2000. In 2000, Japan imported 133,167 tonnes of kabocha worth ¥ 8.18B (Anon. 2001a).

New Zealand, New Caledonia and Tonga/Fiji are seen as price leaders and although Tasmanian product is considered to be of very good quality the sector of the market supplied is driven by price and timing of supply (Austrade 2001). Mexico was a major supplier until 1999 but had a 30% decrease in 2000 due to high price (Anon. 2001a).

In 2000, Australia exported 1,046 tonnes of fresh or chilled fresh pumpkin, a decrease of 20.9% (1,322 tonnes) on the previous year. This was worth ¥ 91.8M, or 1.12% of the Japanese imports (Austrade 2001, personal communication). This would have been fresh only and from Tasmania. In the same year (2000), New Zealand supplied 64.4% of the Japanese market.

In 1997 Japanese import CIF fresh price averaged ¥ 90/kg but Australian produce averaged ¥ 114/kg, for a short supply period (Figure 1). In 2000 the figures were ¥ 61 and ¥ 88/kg respectively. The 1997 import volume was 135,665 t worth ¥ 12.18 billion of which 1,305 t, worth ¥ 149 million was from Australia (Figure 2).

Figure 1. Monthly prices of fresh kabocha imported to Japan by country, during 1997. This material provided courtesy of the Asia Regional Agribusiness Project/Fintrac Inc. through the Market Asia web site at http://www.marketasia.org.

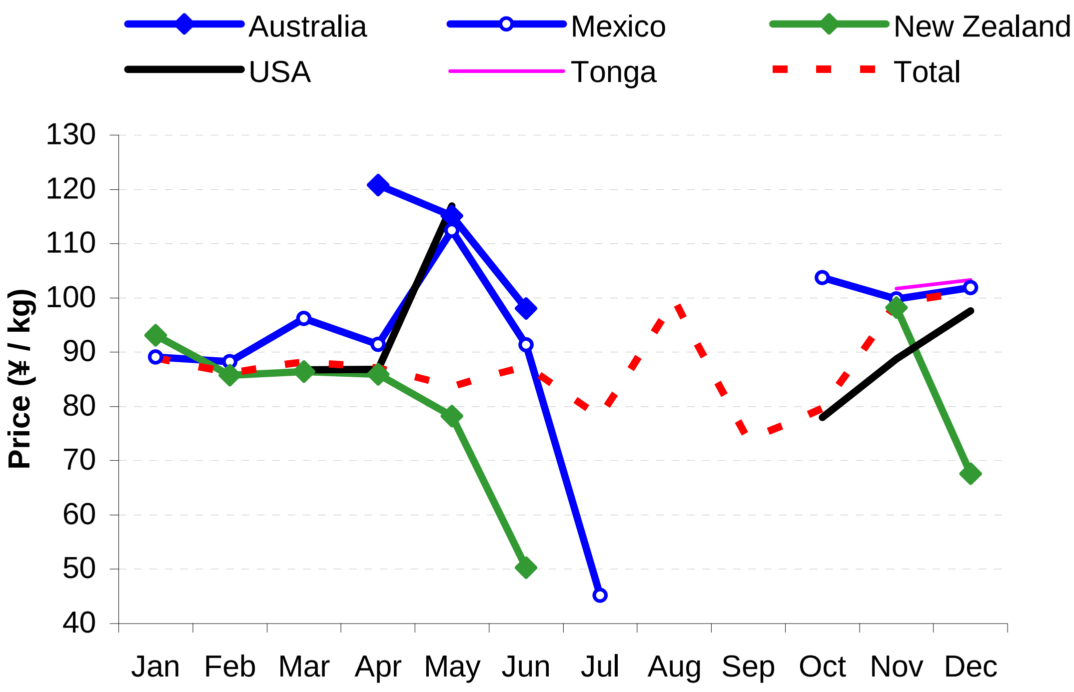
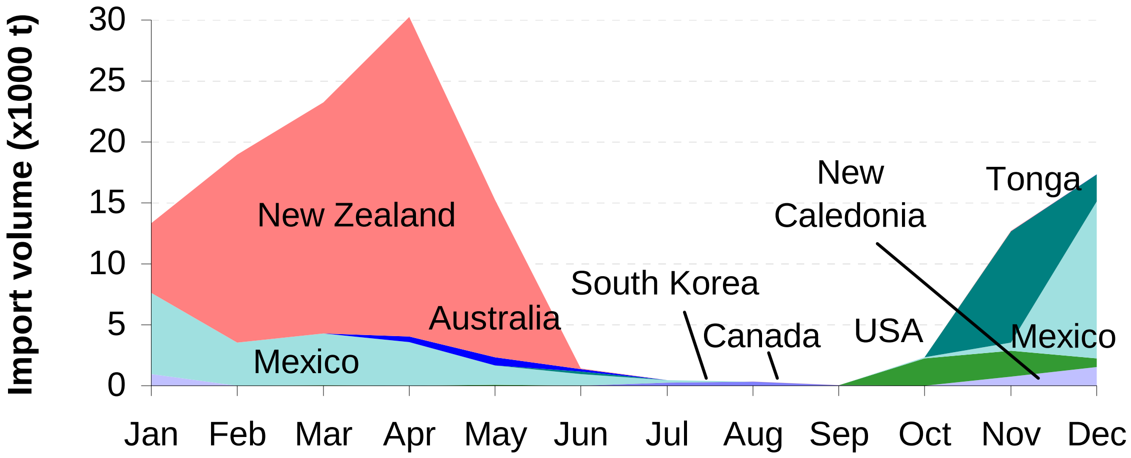
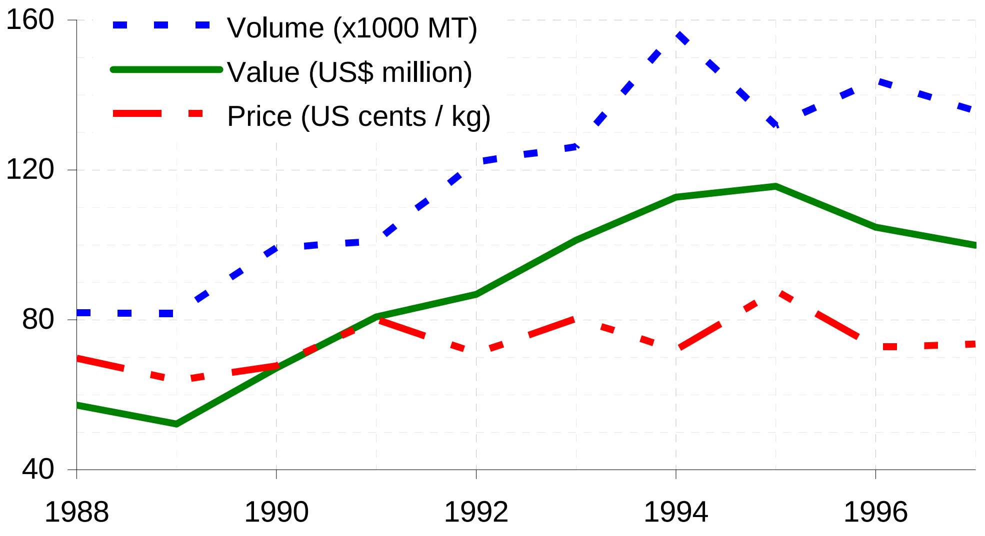


Figure 2. (A) Japanese imports of fresh kabocha from 1988 to 1997 and **(B)** imports by country during 1997. This material provided courtesy of the Asia Regional Agribusiness Project/Fintrac Inc. through the Market Asia web site at http://www.marketasia.org.

(A)



(B)

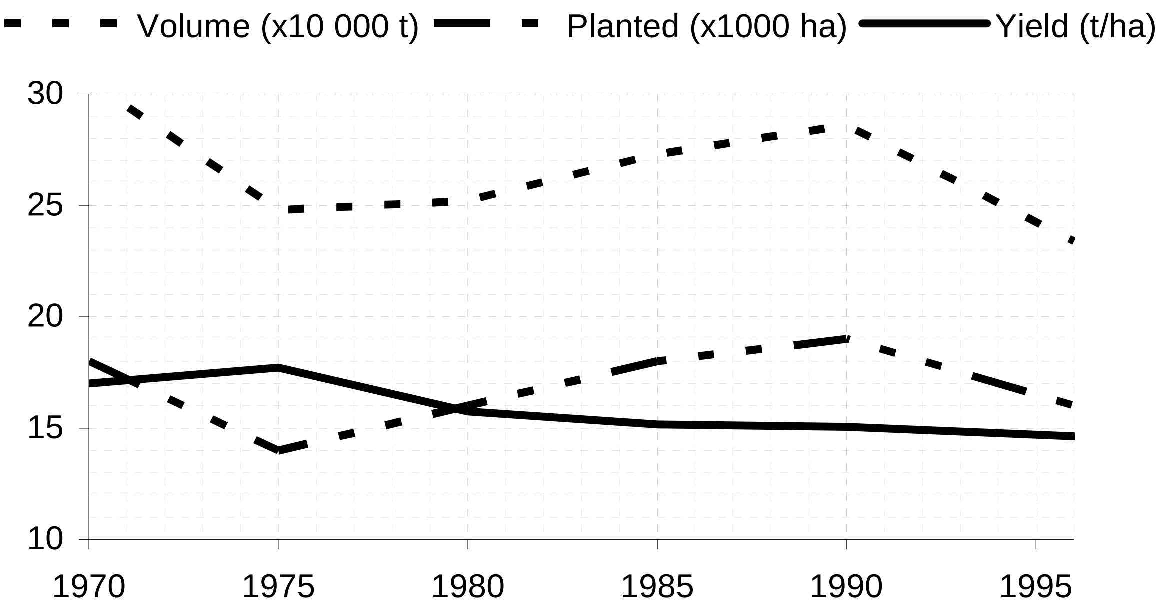


Note (A) The 1997 import volume was 135 665 t worth ¥12.18 billion, of which 1, 305 t worth ¥149 million was from Australia. A 4.7% tax is imposed on the CIF price (Brown *et al.*1996). (B) The 1997 import price averaged ¥89.8/kg, but Australian product averaged ¥114.3/kg

Figures 1 & 2 use the latest available information from MarketAg.com (which uses Market Asia and Regional Agribusiness Project Archives) on monthly prices and volumes of fresh kabocha imported to Japan by country of origin.

Japanese consume approximately 1.7 kg per person annually and this is slowly increasing (Anon. 2001b), but domestic production is fairly static (Figure 3).

Figure 3. Japanese production of pumpkins and squashes (MAFF 1999).



The opportunity for Australia lies at the end of the New Zealand season and before the Japanese season, in May and June (Pan 1995), although other reports recommend competing with existing suppliers from October to January (Brown and Breinl 1995, Brown *et al.* 1996). Australian fresh exports to Japan are small but the price received was high relative to other exporters.

Japanese pay highest prices for domestically produced kabocha, though Mexican produce is considered to be superior in taste (Brown and Breinl 1995). Recently (1998-2000), Holland received the highest price for imported kabocha but the volume was very small. Prices received tend to decline at the end of the season for most countries (Figure 1). The pumpkin market is very price sensitive because consumers have many alternative sources. About 85% of consumers eat the skin (Brown *et al.* 1996).

1.8.2 Japan processed

New Zealand is considered 35% cheaper than Australia for processed kabocha chunks. In NZ, vertically integrated packers have a full process with freezing tunnels. In Australia only one processor has sent frozen product to Japan and in 1999, 65 tonnes were exported. The company has since disbanded.

Approximately 32,300 t of kabocha was processed in Japan in 1999, yet there were few processed imports. Most was processed by freezing and cutting for both food-service and retail markets (Pan 1995). Frozen produce is used for soup, production of sweet cream for cakes and sold in supermarkets for home use (JETRO 1996, Table 4) Australia could well establish a market in this product as long as the price is internationally competitive.

Table 4. Japanese domestic frozen kabocha production (Japan Frozen Food Association via JETRO 1996).

Year	Volume (t)	Value (¥ mill)
1993	11.596	2.839
1994	13.814	3.356
1995	11.343	2.174

Another possible niche is dehydrated pumpkin strips sold in mixed dehydrated vegetable packets (Lee 1996) but this is a small market. Fresh-cut vegetables are attractive to the food service industry as this reduces cost of Japanese labour (Brown *et al.* 1996). Tasmania does not have processing facilities suitable for this.

Materials and Methods

2.1 Cultivar evaluation

Cultivar evaluation replicated and observation field trials were conducted by collaborating institutions around Australia between 1995 and 2000.

2.1.1 Replicated field trials

Replicated field trials were carried out by NSWAg at Gosford, UQ at Gatton, DPIF at Katherine, DNRE at Tatura and Nathalia and QDPI at Mareeba between 1995 and 2000. Various randomised block designs with inter-row spacing 1.5-3.6 m and intra-row spacing 0.65-1.5 m were used.

The location, soil type, maximum and minimum air temperature during the growing period, relative humidity and irrigation method at each site are summarised in Table 5 and cultivars evaluated shown in Table 6A.

Table 5. Location, soil type, weather conditions and irrigation during replicated field trials in Australia, 1995-2000.

Site	**Latitude (S)**	**Longitude (E)**	**Soil Type**	**Max Temp (º C)**	**Min Temp (º C)**	**R.H. (%)**	**Irrigation**
Tatura Vic	36º27'	145º14'	Shepparton Fine sandy Loam	24-29 Ave 26.8	10-14 Ave 12.3		T Tape
Nathalia Vic	36º20'	145º14'	Fine sandy Loam	As above	As above		Overhead Sprinklers
Mareeba Qld	16º 58´	145º 20´	Morganbury sandy loam (granitic)	26.5-29.9	16-20.2	Mean (9.00 am) 75%	Overhead Sprinklers
Gosford NSW	34º 5’	146º 5’	Yellow earth Sandy loam	i) Ave 23.7 ii) Ave 23.7	Ave 15.2 Ave 16.5	Mean (9.00 am) 65%	T Tape
Katherine NT	14º 8’	132º 18’	Red earth soil Tippera type Clay loam	30.1-37.8 Ave 33.0	12.0-23.1 Ave 15.8C	Daily (9.00 am) Max 92% Min. 26%	T Tape
Gatton Qld	27º 32’	150º 20’	Dark brown Light clay	20.9-38.5 Ave 28.8	9.6-20.8 Ave 13.9	Mean (9.00 am) 66%	Hand shift System Overhead

Table 6 A. Cultivars evaluated in replicated trials in Australia, 1995-2000

	Comments	**1995/96 Tatura-V**	**1996/97 Nathalia, V**	**1998 Mareeba, Q**	**1998/99 Gosford, NSW**	**1998/99 Gatton, Q**	**1999 katherine, NT**	**1999/2000 Gatton,Q**	**2000 Katherine,NT**	**1999/00 Tatura,V**
Delica	Most popular and leading Kabocha variety. Yellow-orange flesh with nutty and sweet taste. Dark green skin and flat globe in shape. Early variety. Average fruit weight 1.5-2.0 kg.	X	X	X 3 seed lines	X	X	X	X	X	X
Pacifica	A Delica type pumpkin with bigger fruit. High yield. Peel colour turns to light brown-orange in				X	X	X	X	X	X
Nishiki-Hookou	New Delica type, with lighter green skin colour than Delica. Good yielding in our trials. Average fruit weight smaller than		X							
Hookou	Grey skin colour. Generally small fruit. Orange coloured flesh. Not very popular.	X								
Kurikoshi	Delica type. Dark green skin colour. Good yield. Sweet and delicious taste.	X	X							
Kurijiman	Sweet and nutty taste. Good yield. Exported into Japan from Tasmania.	X	X	X			X and F1		X	X
Tetsukabuto	New black type, suitable for boiling. Appearance looks like Late Potkin. Dark green rind with small yellow spots. Storage life is excellent.				X		X and F1		X	

	Comments	1995/96 Tatura-V	1996/97 Nathalia, V	1998 Mareeba, Q	1998/99 Gosford, NSW	1998/99 Gatton, Q	1999 katherine, NT	1999/2000 Gatton,Q	2000 Katherine,NT	1999/00 Tatura,V
Late Potkin	Light green skin colour with thin stripes and small spots. Nearly round to slightly flattened type. Matures later than Delica. Yield and storage are good.		X	Z early Potkin						
T-110					X				X	
Sweet Mama	Nutty taste and yellow flesh colour. Warted body could be disadvantage in the market. Good yield.		X		X				X	
Ken's Special	Most popular Japanese pumpkin variety in Australia. Fairly soft, mottled yellow and green skin that turns orange at maturity.	X								
Uchikikuri	Attractive orange red rind with some ribbing. Creamy range						X			
Nishiki	Mareeba only			X						
Ajehei				X						
Unebi				X						
4 NW seed lines				X						

Table 6 B. Cultivars evaluated in observation trials in Australia, 1994-2001.

State	**Site**	**Year**	**Cultivars**
NSW	Yanco	1998/99	Tetsukabuto, Delica, T-110, Sweet Mama, Pacifica
	Gosford	2000/01	Tetsukabuto, Delica, T-110, Sweet Mama
Qld	Rockhampton	1999	Delica, Pacifica
	Emerald	1997 & 1998	Delica
	Gatton	1999/00	Tetsukabuto, T110, Delica, Sweet Mama
Vic *	Tatura	1994/95	J3, Ken's Special-OP, Bushfire, Kurikoshi, Hookou
	Dhurringle	1994/95	Kuritomo, Kurikoshi, Ken's Special-OP, J3, Hooku, delica, sweet Mama, Kurimaru, Kurijiman, Kurikko
	Tatura	1995/96	Tetsukabuto, PN 076, squash Jap, J3, Ganko, Nishiki-Hookou, Pacifica, PN030, NW23, PN279, Late Potkin, NW21, Nw007, PN031, Kuro-Black, PN056
	Swan Hill	1996/97	Eden Green, Tetsukabuto, Late Potkin, Sweet Mama, Delica, PN 076, Pacifica, Kurijiman, Kurikoshi, Ken's Special-Hyb., PN 030, NW 21, PN 056, Ken's Special-OP, Nishiki-Hookou, Hookou
	Tatura	1996/ 97	Ken's Special-Hyb., Crown, Tetsukabuto, Pacifica, Delica, NW 21, Bush Fire, Late Potkin, eden Green, PN 076, Sweet Mama, Nishiki-hookou, Ganko, NW 23, PN 030, Ken's Special-OP, PN 056, Nw 007, PN 279, Kuro-Black

(* Victorian cultivars arranged in decreasing order of highest marketable yield per hectare).

Propagation method, year and season of trials, planting date, days to harvest and plant spacing are summarised in Table 7.

Table 7. Location, planting and harvest dates, plant spacing, establishment and days to harvest in replicated field trials in Australia, 1995-2000.

State	Site	Spacing	Establishment (plant no. per plot)	Growth Period	Days to Harvest
QLD	Gatton Spring 2000	1.125 m² (1.5x0.75)	Transplant 20	19/9/00-7/12/00	79*
	Mareeba Autumn-winter 1998	2.5 m² (2.5x1.0)	Seed 12	18/3/98-16/6/98	98
NSW	Gosford Spring-summer 1998-99	3.6 m² (3.6x1.0)	Transplant 2	16/10/98-4/2/99	135*
	Gosford Summer-autumn 1998/99	1.8 m² (1.8x1.0)	Transplant 2	16/12/98-27/4/99	132*
NT	Katherine Winter 1999	1.125 m² (1.5x0.75)	Seed 10	19/5/99-7/7/99	111
	Katherine Winter 2000	1.5 m² (1.5x1.0)	Seed 10	19/5/00-4/10/00	138
VIC	Tatura Summer 1995/96	0.975 m² (1.5x0.65)	Seed 6	15/11/95-15/2/96	123
	Nathalia Summer 1996/97	0.975 m² (1.5x0.65)	Seed 6	15/11/96-12/2/97	120
	Tatura Summer 1999/00	0.975 m² (1.5x0.65	Seed 20	6/12/99-12/3/00	96

* from transplant to harvest

Blocking, plot size, replicate number and plant number per plot, and fertiliser and pesticide use varied between sites (see below for specific site details).

Agronomic management (fertiliser, irrigation and pesticide) at each site was conducted in accordance to cucurbit production for the region.

1995/1996 & 1996/1997 field trials

Victoria

Field trials were carried out at Tatura 1995/96 and on a commercial property at Nathalia 1996/97. The experimental design was a randomised complete block of five and seven cultivars respectively with four replicates, an inter-row spacing of 1.5 m and intra-row spacing 0.65 m. Plot size was 1.5 m by 4.5 m giving 6-7 plants per plot. Irrigation was scheduled to apply 34 mm water per week through peak growth period at both sites. All fruit were hand picked, counted, weighed and size graded. Fruit was considered marketable if greater than 0.5 kg and skin had no or minimal skin blemishes.

At Tatura (Shepparton fine sandy loam), 1 t/ha super (N:P:K:S=0:9:0:11) and 1.5 t /ha gypsum were applied as a base fertiliser. Black plastic mulch with buried (10 cm) drip tape was used on raised beds and one month after planting 150 kg/ha urea was applied through the tape. At Nathalia the soil was a fine sandy loam and 108 kg/ha N, 120 P, 75 K was applied before sowing. Water was applied using overhead sprinklers.

1998 field trials

North Queensland
At Mareeba, a randomised complete block design with 12 plants of 12 cultivars grown in each of 3 replicate plots, with inter-row spacing 2.5 m and intra-row spacing 1m was used. Plot size was 2.5 m by 12 m.

A base fertiliser applied was CK tobacco 6 Mg at 1.2 kg per 20 m. Calcium nitrate was applied at flowering and Curamil and Carbaryl were applied as required.

1998/1999 field trials

Northern Territory
At Katherine, ten plants of seven cultivars were grown in each of 2 replicate plots, 7.5 m long, on black plastic mulch with tee tape emitters every 30 cm, an inter-row spacing of 1.5 m and intra-row spacing 0.75 m.

The soil was a red earth of Tippera family (clay loam). Plants were side dressed with single superphosphate at 1 t/ ha and fertigated with ammonium sulphate @ 190 kg/ha at 23, 40 and 47 days after sowing (DAS), potassium nitrate @ 50 kg/ha at 65 DAS and additional fertiliser 200 g/20 m KNO_3 and 600 g/20 m KNO_3. Trace elements were applied as foliar spray applications at 15, 23, 36 and 40 DAS of 1 g/l $MnSO_4$, 1 g/l $ZnSO_4$, 2 g/l $MgSO_4$, 0.5 g/l NaMo and 3 ml/l Wuxal Calcium and were applied until runoff.

Maldison @ 2 ml/l for the control of pumpkin beetle and cabbage moth was used twice during crop growth and Afugan @ 0.5 ml/l for powdery mildew.

New South Wales
At Gosford, in the spring, two plants of five cultivars were transplanted (24 DAS) into each of four replicated plots 2 m long with inter-row spacing of 3.6 m and intra-row spacing of 1 m. A second trial was transplanted, in the summer (21 DAS), differing from the first only in an inter-row spacing of 1.8 m.

Plants were fertilised with G5 (5N:5P:5K) at 2 t/ha. Rubigan (fenamirol) was used as required and no pesticides were used. Mancozeb 80% at 2g/l was used for control of downy mildew.

Queensland
At Gatton the effect of nitrogen on performance of Delica was evaluated.

Replicated field trials initiated at Cudgeon and Kyogle (NSW) and Woodford and Texas. (QLD) were inconclusive due to inclement weather.

1999/2000 field trials

Northern Territory
At Katherine, ten plants were grown in each of 3 replicate plots 10 m long on black plastic mulch with tee tape emitters every 30 cm, an inter-row spacing of 1.5 m and intra-row spacing 1.0 m. Soil type and fertiliser details were the same as 1998/99 except that less nitrogen was used in early growth. An early harvest on 15/9/00 occurred (19 days before final harvest) to remove split fruit. Marketable yield results include both harvests.

Queensland
At Gatton, the effect of nitrogen and calcium nutrition on performance of two cultivars was evaluated in separate experiments. A blocked split-plot design was used with N application rate treatments as main plots and Ca treatments as sub-plots. The two cultivars were set out in three randomized complete blocks. This gave 5 N x 2 Ca treatments with 3 replicates: 30 experimental units for each cultivar. Each plot was 11 m long and 7.5 m wide and sub-plot 4.5 m long with a 2 metre space. Transplants were planted on raised beds in each sub-plot, in four rows with five pumpkins per row. Rows were 1.5 m. apart and the intra-row spacing was 0.75 m.

A base fertiliser of 110 kg ha^{-1} of GF450 (Analysis N:13%, P:1.8%, K:14.1%, S:19.4%) was applied. Zinc, as Librel Zn (14% Zn EDTA) at 500 g/ha and Boron as Solubor (17.5% Boron) at 250 g/ha were applied 23, 47 and 62 days after transplanting.

Five nitrogen treatments: 0, 30, 60, 90 and 120 kg/ha were applied as urea in four split-dressings of equal size for each N rate. The first two applications were applied as side dressings and the remainder broadcast by hand. Calcium fertilizer was applied as a foliar spray, Ca160 (16% Ca), at 6 l/ha at each of four applications.

The second, third and fourth plants (3 m x 2.25 m quadrat) from the two inner rows were harvested. For each subplot of both cultivars all pumpkins (both inside and outside the quadrat) from the third plant in rows 2 and 3, were also harvested. The number and weight of pumpkins in each 3 m x 2.25 m quadrat, were determined and used to estimate the number and yield of pumpkins per ha. Number and yield of pumpkins of the two plants sampled *in toto* in each subplot were also obtained. Mean diameter of the pumpkins from the quadrat in each subplot was determined

Victoria
Field trials were carried out at Tatura with a randomised complete block design of three cultivars in four replicates. Plot size was 1.5 m by 13 m giving 20 plants per plot. Plant spacing, sowing, irrigation, fertiliser, harvest details and marketable yield estimation was the same as described for 1995/96 trials at Tatura. A fungicide was used to control powdery mildew during late stages of plant growth.

2.1.2 Observation trials

Observation trials were carried out between 1994 and 2001. Cultivars evaluated at each site are listed in Table 6B.

Queensland
At Rockhampton (hydroponic) protected cropping was undertaken in 1999 with two cultivars, Delica and Pacifica, evaluated.

At Emerald, Delica was compared with two other pumpkin types for costs of production. In 1998 yield estimates of Delica were carried out at two sites in overhead-irrigated commercial crops. Harvested areas comprised 10 m x 2 m. Virus incidence was quantified.

In 1998, crops were sown on March 20 at one central Queensland site and mid-April at another, with the aim of processing the pumpkin fruit.

At Gatton, (1999/00) four cultivars were observed for growth characteristics.

Victoria and New South Wales
At Tatura from 1995-2000 30 cultivars in six field trials, at Yanco (1998/99) five cultivars and Gosford (2000/01) four cultivars were assessed for marketable yield.

2.1.3 Marketable yield calculation

Each location determined marketable produce and yield differently. Processing methods can use fruit greater than 0.5 kg weight and mainland Australia currently cannot export fresh fruit to Japan.

At Katherine (1999 & 2000), marketable fruit were those greater than or equal to 0.5 kg and unmarketable fruit were split or showed some sign of breakdown.

At Tatura and Nathalia, marketable yield was assessed as fruit greater or equal to 0.5 kg weight and skin free of warts or blemishes.

At Gatton, fruit were considered marketable if weight was at least 0.7 kg and if sunburn had not softened tissue or exposed flesh and was restricted to less than 20% of the fruit surface.

At Gosford, fruit size and weight were assessed on five fruit.

At Mareeba, marketable (sound) fruit were mature, free of warts and without sunburn or bleaching.

2.2 Quality Assessments

2.2.1 Pumpkin sampling

A total of 408 individual samples from eight cultivars were tested. Pacifica and Delica comprised 70% of the samples (Table 8).

Table 8. Location, cultivar and fruit sample number for quality assessments.

Cultivar Location	Pacifica	Delica	Tetsukabuto	T-110	Sweet Mama	Nishiki	Kurijiman	Uchikikari
Gatton Jan '99		14 and 12						
Gosford Feb '99	4	4	4	4	4			
Tatura Mar '99	11							
Swan Hill (A) Mar '99	12							
Swan Hill (B) Mar '99	12							
Gosford Apr '99	4	4	4	2	4			
Tatura May '99	11							
Teesdale May '99		11						
Lara May '99								
Katherine Sep '99	6	7	7 (6)*				7 (6)*	8
Tatura Apr '00	12	12					12	
Katherine Oct '00	10	10	10	9	10		10	
Gatton Dec '00	54	54 and 3	3	3	3			
Laidley Dec '00		4						
Gosford Feb'01	3	3	3	3				
Tasmania Feb '01		10						
Tasmania Mar '01						10		

***** Katherine 1999, F1 hybrid number in parenthesis

1999
Samples were taken from replicated plots in Gatton, Gosford and Katherine, from farmers crops in Lara, Swan Hill and Teesdale in Victoria and observation plots at Tatura. (Table 8).

2000
Samples analysed were from replicated plots at Tatura, Katherine and Gatton, observations plots at Gatton and from a processing plant at Laidley, Queensland.

2001
Samples were taken from observation trials in Gosford and from the grading line of a commercial packing and export business in Tasmania.

Sampling procedures (Table 8):
* At Gatton in 1999 one fruit from each block of two cultivars, and in 2000 for each of two cultivars three fruit from each of three replicates of the 0, 60 and 120 kg/ha N treatments, both with and without added Ca. Similarly, three pumpkins of four cultivars in observation trials were sent.
* At Tatura, 2000 three fruit from each of four replicates of three cultivars were sampled.
* At Katherine, 1999 three fruit from two replicates of seven cultivars and in 2000, three fruit from three replicates of six cultivars**.**
* At Gosford, 1999 one fruit from four replicates of six cultivars. In 2001, three fruit from each of four cultivars, with no replication were sampled from a first of five harvests.
* At Lara, Swan hill and Teasdale in 1999 individual fruit were taken from commercial crops.

2.2.2. Quality assessment methodology

1999/00
Quality characteristics of harvested mature pumpkins were assessed after 20 days storage at 15^{o}C (at IHD).

A. Colour
Skin (ie. Rind) colour background lightness /darkness was evaluated. Striping (striping could be darker or lighter than the ground colour) and blotching of the skin (over the back ground colour) were not considered.

Five subjective categories of skin darkness (1 = pale, 2 = light, 3 = medium, 4 = dark, 5 = very dark) were established and linked by eye to colours from the Royal Horticultural Society (RHS) colour chart. Evenness of ground colour darkness was assessed Even = 1 or Uneven = 2. The category and colour chart assessments refer to a perceived 'mean' of each individual fruit.

ii) Flesh colour characteristics were deemed more important than skin colour and consequently these were investigated more fully.

'Mean' flesh colour was assessed using the RHS chart (Table 9) and an electronic colour meter (Chroma meter, Minolta model CR-200). The colour meter returns a number for each of L* (value = lightness/darkness), a* (colour) and b* (saturation, or vividness / dullness). Hue and chroma were calculated:
Hue = $\tan^{-1}(b/a)$
Chroma = $(a^2 + b^2)^{1/2}$

Table 9. Fruit flesh colour (subjective and RHS colour chart) ratings.

Category	Subjective description	RHS Colour chart approximation
1	Pale	137C
2	Light	137B
3	Medium	136B
4	Dark	136A
5	Very dark	Darker than 136A, ranging to black

B. Skin "warts" or blemishes
The presence of warts and/or blemishes on the skin was noted as present = 1 or absent = 2. The point of ground contact was not deemed a blemish.

C. Sugar content and composition
An enzymatic method of sugar analysis gave detailed and quantitative results.
Sample preparation and sugar analysis:

Frozen (2000) or fresh (1999) peeled pumpkin (50 g) was blended with 50 ml water for 1.5 minutes. 5 ml of Carrez-I solution (3.60 g $K_4[Fe(CN)_6.3H_2O$/100 ml) was added and mixed in, followed by 5 ml of Carrez-II solution (7.20 g $ZnSO_4.7H_2O$/100 ml). NaOH (0.1 M) was then added to adjust the pH to 7.0-7.5. This mixture was quantitatively transferred into a 250 ml volumetric flask and filled to volume with water.

A Bohringer Mannheim kit for the determination of Sucrose/D-glucose/D-fructose in foodstuffs using UV method was used. The procedure followed was that outlined in the instructions.

D. Flesh carotenoid level
Total carotenoid levels of 20 flesh samples were determined, with numbers analysed being limited due to the expense.

Total carotenoids were determined for fruit samples after saponification with 100% w/v potassium hydroxide under reflux for 30 minutes. Carotenoids were then extracted with hexane. Hexane extracts were analysed for total carotenoids using UV spectrophotometry at 450 nm (Siong and Lam 1992).

2000/2001
Storage prior to assessment and sample preparation and analysis for quality parameters were the same as for the previous year except where indicated below.

Changes in sample preparation
After quality assessment, a 50 g sample of each pumpkin was rapidly frozen by placement in liquid nitrogen. The frozen samples were stored at -70^oC until such time that the sugar content was analysed.

Sample dilution changes
From the 250 ml volume, the sample was further diluted (1/4) and some of the solution filtered, using a 0.45 µm syringe filter.

E. Additional measurements
Additional measurements were completed for the fruits received from Gatton, Gosford, Laidley and Tasmania in 2001: Total Soluble Solids (TSS) as º brix was determined using a refractometer and fruit weight, diameter, height, shoulder thickness and base thickness were quantified. These measurements were used to derive the fruit shape (proportion of height to diameter expressed as a percentage, ie. 100 x height/diameter) and estimate average flesh thickness.

Estimated average flesh thickness =
(4 x shoulder thickness) + (2 x base thickness)
÷ 6

F. Statistical analysis of quality data.
Replicated field trials: At Gatton, Gosford and Katherine in 1999 and Tatura, Katherine and Gatton 2000 trials were randomised complete block designs. Plot means were used in analysis of variance which allowed for block differences.

Collected fruit: There was no replication of the experimental unit (ie plot) at Katherine 1999 & 2000, Tasmania 2001, Gosford 2001 and Gatton (the four cultivar comparison) 2000. Therefore, variation between fruit collected from the plots was used to compare the varieties. This will be an underestimate of the plot variation so care should be used in interpreting the *P* values of these tests.

2.3 Postharvest storage rots

2.3.1 Rot development in the field and during storage

1999
Eleven commercial crops of cultivars Delica, Ajehei and Nishiki, four, three and four crops respectively, were surveyed between 3 March 1999 and 23 April 1999. Crops were planted from early November to late December between Sassafras and Kindred, Tasmania within 5 km of the coast. Crops were surveyed prior to commercial harvesting. Field surveys were conducted by walking four 30 m transects in a W pattern, through the middle of a crop. All fruit (100-180) within 0.5 m of the transect line were inspected for rot. After harvest, fruit were mechanically brushed to remove dirt, washed in a 4% sodium hypochlorite solution, graded into export quality, second quality and waste (injuries and rots) fruit. Following grading, a half tonne bin of 105-266 second grade fruit (size and no obvious rots) for each of the eleven crops was stored for four weeks at ambient temperatures (14-22°C).

Fungal rots found in the field and after storage, were identified *in situ* or isolated and identified in the laboratory. Isolations were made from visible hyphae, conidia or small pieces of tissue placed on water agar (2%) in petri plates. Blocks of agar containing developing hyphae were placed onto potato dextrose agar (PDA) in petri dishes and incubated for further identification by microscopic examination.

2.3.2 Postharvest storage temperature effects on quality

1998 & 1999
In 1998, storage conditions for fresh export were investigated using a factorial design to assess the effect of five conditioning temperatures (2, 7, 12, 30 and 45°C) for one or seven days duration, followed by storage for up to 28 days at 7 or 12°C on the incidence of fungal rots and keeping quality of Tasmanian kabocha. Ten fruit per treatment combination were

used. After 28 days fruit were assessed for rots (scale 0=no rot, 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100% surface rotted) and skin colour (1=light green, 2=medium and 3=dark green). Fruit were weighed prior to and at seven day intervals during storage. Flesh colour (Wilson Colour Chart) was recorded.

In 1999, fruit were heat-treated at 36 or 38º C for two, eight or 16 hours. Half the fruit from each treatment were artificially inoculated with *Fusarium culmorum* (isolated from rotting fruit and grown on PDA for one month prior to inoculum preparation by flooding plates with sterile water). Inoculation was achieved by wounding (making a depression with its base punctured by a needle) the fruit shoulder in two locations near the stalk and adding a 50 µl spore suspension. Fruit were then stored at 2 or 12ºC for up to nine weeks. Fruit were weighed fortnightly and extent of fruit rotting and pitting (chilling symptom) were recorded. Pitting was rated on scale from 1-5 (1=nil, 2=1-25%, 3=26-50%, 4=51-75% and 5=76-100%).

2.3.3 Postharvest acetic acid (AA) vapour fumigation effects on quality

1998 & 1999

Glacial acetic acid (AnalaR grade 99.8% from BDH Supplies) was used for this and all experiments in this report.

In 1998, *Fusarium culmorum* exposure to three rates of acetic acid (AA) vapour (zero, 111 or 556 µl AA/l) for 2 hours at ambient room temperature, was measured after 3 days at 20ºC by the area of mycelial growth on five PDA plates previously inoculated with a 200 µl spore suspension (approximately 202 *F. culmorum* spores) and exposed to AA vapour.

In 1999, acetic acid vapour effects were tested on fruit (unknown cultivar) inoculated with 100 µl aliquot spore suspensions of *F. culmorum* or *Rhizopus stolonifer* isolated from rotting fruit and grown on PDA at 20ºC for one month prior to inoculum preparation. The aliquot contained 56,000 or 119,000 *Fusarium* spores/ml or 575,000 *Rhizopus* spores/ml depending on treatment. Five acetic acid rates (zero, 1, 10, 50 and 100 µl AA/l) were applied for 30 or 60 minutes at 20ºC. Twenty fruit were allocated to each of the ten treatments. Fruit were weighed fortnightly and after 95 days were assessed visually for percent skin covered by rot, chilling symptoms, skin colour, flesh firmness, moisture content and colour.

In a second experiment twenty fruit, cultivar Nishiki, were allocated to each of eight treatments. Inoculum was prepared by blending *F. culmorum* mycelium grown on PDA, with 200 ml water. An aliquot of the suspension was added to 20 l water to achieve a concentration of 100,000 spores/ ml. Fruit were dipped in spore solution, dried overnight, fumigated with acetic acid (19.5 ml) vapour for 60 minutes and then wounded as described above. Fruit were stored at 12ºC and assessed fortnightly for presence of rot. After 43 days percentage of skin surface affected by rot and chilling damage, skin colour, fruit firmness, flesh colour and moisture content were assessed.

2000

In 2000, a series of experiments were undertaken:
The first examined acetic acid (0.5 and 5 µl AA /l free airspace for 24 hours and one and 24 hours respectively) and ammonia (0.5 for one hour and 5 µl AA for one and 24 hours/l free airspace) as fumigants at ambient temperature and then stored at 12ºC for 65 days. There were 22 fruit per treatment. Assessments were made fortnightly as described previously.

The second looked at maintaining a sealed environment of 0.5 µldistilled water, 0.5 µl ammonia/l free airspace and 0.5 µl AA/ l free airspace at ambient temperature until assessment as described previously after 30 days. There were 30 fruit per treatment.

The third examined dipping fruit in 0.5% acetic acid for 5 minutes plus or minus a rinse and a water dip control. Fruit were dried overnight and stored at 12ºC with assessment at 14 and 28 days. Twenty fruit were used per treatment.

The fourth experiment examined acetic acid concentration of zero, 0.01, 1 and 10 µl AA/l total airspace on *F. culmorum* macroconidia at approximately 103 spores / PDA plate. Four replicate PDA plates were used per treatment which was applied for one, 24 and 96 hours at 20ºC. Colony number per plate was assessed.

A two factor experiment examined seven AA concentrations (0, 12.5, 25, 50, 100, 200, 400 µl AA/l free airspace) and treatment duration (24 or 96 hours) on *F. culmorum* macroconidia (approximately 100 spores per plate) germination *in vitro.* Five replicate plates per treatment were assessed for colony number and extent of growth after 96 hours incubation at 20ºC.

Similarly, ammonia concentration (0, 0.05, 0.5, 5 and 50 µl /l free airspace) for three or 24 hour duration was assessed as above except that six replicate plates were assessed per treatment.

Results

3.1 Cultivar evaluation and production: replicated field trials

Replicated trials undertaken in four states over five years have shown that Australia can supply "kabocha" pumpkins all year round (Table 1). Kabocha can be grown in all Australian states and over a range of temperature conditions.

All pumpkin types grew on a range of soil types from fine sandy loam to light clay.

Plant establishment was good at all sites with no significant cultivar differences.

Average maximum and minimum temperatures were similar at each site during the growing periods with Tatura, Vic and Mareeba, Qld temperatures, particularly the minimum, being less variable (both 4ºC variation) than Katherine, NT and Gatton, Qld. (both 11ºC) (Table 5).

There was also a wider range between highest daily maximum and least daily minimum temperatures at Gatton (up to 29ºC) and Katherine (26ºC) compared with Tatura (19ºC) and Mareeba (14ºC). Gosford had the lowest variation between average maximum and minimum temperatures (from 7-8.5°C).

Fruit at Mareeba matured (Table 7) from 13 to 40 days and at Tatura from 15 to 42 days earlier than at Gosford (132-135 days) and Katherine (111-138 days depending on year). Harvest could have been 7 to 10 days earlier at Mareeba making this difference bigger.

Fruit at Katherine in 2000, took 27 days longer to mature than in 1999 whereas at Gosford the 1998/99 season (spring or summer sowing) only added three days to maturity.

At Tatura (1995/96), Ken’s Special matured 42 days after the four kabocha cultivars which matured in 123 days. In some years (in observation trials), it required a second harvest. In addition the open pollinated variety took longer to mature than the hybrid**.**

Sunburn was observed when radiation levels increased, especially in the spring Queensland crops and continued to increase as leaves senesced and high radiation continued.

3.1.1 Marketable yield (the definition of marketable fruit varied at each location)

Marketable yield varied with location, cultivar, season and previous production experience (Table 10). Tetsukabuto had consistently higher yields at Gosford (summer 1998/99) and marketable yields at Katherine (1999 and 2000) and in Victoria (see data on observation trials). Late Potkin had significantly higher yields than other cultivars at Nathalia, Vic.

Table 10. Marketable yield (t/ha) of better cultivars at trial sites in Australia, 1995-2000.

Cultivar	**NSW Gosford Summer 1998/99**	**NT Katherine 1999**	**NT Katherine 2000**	**QLD Gatton 1999/00**	**QLD Mareeba 1998 ##**	**VIC Tatura 1995/96**	**VIC Nathalia 1996/97**	**VIC Tatura 1999/00**
Tetsukabuto	42.6	32.2 34.2 °	53.4 °° 66.0			48.5*		
Late Potkin						54.7**	52.9	
Nishiki					13.8			
Delica	26.4	25.9	33.9 °° 35.8	18.4	10.6 #	33.9	28.5	31.3
Kurijiman		22.5 32.1 °	23.7 °° 33.7		14.8	34.5	31.0	32.2
Ken's Special						11.5		
T-110	4.4		18.3 °° 30.7					
Sweet Mama	13.6		35.2 ° 43.0					
Pacifica	16.6	23.4	38.4 °° 41.2	17.2				34.5
LSD	NA	NA	NA °°°	NA	NA	11.0	25.4	NS.

° Katherine 1999, higher yield was for F1's.
°° At Katherine 2000, the lower marketable yield was calculated for fruit greater than 1 kg and the higher for fruit greater than 0.5 kg. Cultivars varied in number of fruit in 0.5-1 kg range.
°°° LSD was calculated on marketable weight per plot, Testukabuto had greater (P=0.090) yield than all other cultivars except Sweet Mama. There were no differences between the other cultivars.
Marketable yield calculated from data in report (Loader 1998).
Mean of three Delica seed lots (range 10.2-11.8 t/ha)
* Mean of 3 years observation trials at Tatura (1995/96, 1996/97 and 1998/99). In another observation trial at Swan Hill , Vic. 1996/97 marketable yield was 46.3t/ha.
** Mean 3 years observation trials at Tatura (1996/97, 1997/98 and 1998/99). At Swan Hill, 1996/97 yield was 45.2t/ha.

At Katherine, marketable yields of all cultivars were greater in 2000 than 1999. Tetsukabuto had the greatest increase of 99%, Pacifica (76%), Delica (38%) and Kurijiman (17%). Results are presented for 2000, showing marketable yield calculated with fruit greater than 1 kg and greater than 0.5 kg. The data show that Tetsukabuto had highest yield for both determinations and that Kurijiman and T-110 had greater numbers of smaller fruit than other cultivars.

At each location and in each season, Delica and Kurijiman had the same total and marketable yields. Pacifica had the same marketable yield as Delica and Kurijiman at Tatura, Gatton and Katherine (1999) and higher at Katherine (2000) and lower at Gosford (1998/99).

3.1.2 Average marketable fruit weight

Fruit weight varied with cultivar, season and location (Table 11). The actual weights varied between seasons suggesting a seasonal effect such as weather and/or agronomy.

Table 11. Average fruit weight (kg) of better cultivars in Australia, 1995-2000.

Cultivar	NSW Gosford Spr-Sum 1998/99	NSW Gosford Sum-Aut 1998/99	NT Katherine 1999	NT Katherine 2000	QLD Gatton 1999/00	QLD Mareeba 1998	VIC Tatura 1995/96	VIC Nathalia 1996/97	VIC Tatura 1999/00
Tetsukabuto	1.9	1.99	1.81 (1.74)*	1.43					
Late Potkin								1.7	
Nishiki						1.75			
Delica	2.5	1.43	1.88	1.46		1.81	1.8	2.0	2.5
Kurijiman			1.94 (1.81)*	1.41		1.83	1.9	2.1	2.5
Ken's Special							2.8		
Pacifica	2.7	1.72	2.50	1.81					3.1
Sweet Mama	2.3	1.28		1.84					
T 110	2.6	0.79		1.22					
LSD	NA	NA	NA	0.192	NA	0.211	0.2	1.0	0.6

* F1 hybrid

Delica and Kurijiman had similar fruit weight at each seasonal trial in Katherine, Victoria and Mareeba.

Pacifica had heavier fruit than Delica at Katherine (2000) and Tatura (1998/99). At Katherine (1999) and Gosford (1998/990) it appeared that fruit size was similar between varieties (significance not known). At Gosford, Pacifica fruit were considered too big (> size grade 2L) to pack into a 10 kg box for export but suitable for fresh domestic and processed markets. At Gatton (2000), Delica had heavier fruit than Pacifica (significance not known).

At Gosford (spring/summer planting) and Tatura (1999/00) Pacifica, Delica, T-110 and Sweet Mama had heavier fruit than at other sites.

3.1.3 Fruit number per plant

Fruit number per plant varied with cultivar, location and season.
Delica and Kurijiman had similar fruit numbers per plant at each trial in Katherine, Mareeba and Victoria (Table 12). The fruit number varied between season, with twice as many fruit per plant at Katherine in 2000 than in 1999 and more at Tatura in 1995/96 than 1999/00.
Tetsukabuto had greatest fruit number per plant at Katherine, 2000 and a similar result (with significance unkown) was observed at Gosford and Katherine (1999). At Nathalia, Vic, Late Potkin had greater fruit numbers than Delica and Kurijiman.

Fruit number was greater at Katherine than at other locations.

Table 12. Average fruit number per plant of better cultivars in Australia, 1995-2000.

Cultivar	NSW Gosford Sum-Aut 1998/99	NT Katherine 1999	NT Katherine 2000 #	QLD Gatton 1999/00	QLD Mareeba 1998 #	VIC Tatura 1995/96	VIC Nathalia 1996/97	VIC Tatura 1999/00
Tetsukabuto	4.5	2.0 (2.2)*	7.0					
Late Potkin							3.1	
Nishiki					1.97			
Delica	3.3	1.6	3.7		1.50 ##	2.2	1.8	15
Kurijiman		1.3 (2.0)*	3.6		1.08	2.2	2.0	1.6
Ken's Special						1.0		
Pacifica	3.3	1.1	3.4					1.4
Sweet Mama	2.0		3.5					
T 110	1.0		3.8					
	NA	NA	0.25		NS	0.8	0.7	0.5

* F1 hybrid
# Data calculated from (Number sound fruit per plot) / (Number plants per plot) for each cultivar
mean of 3 Delica types (1.38-1.68)

3. 1. 4 Disease

Mosaic virus symptoms and evidence of powdery and downy mildew were observed at Gatton. Pumpkin beetle was also observed there.

Downy and powdery mildew were observed at both Cudgen and Kyogle during the early stages of crop development, and were not able to be controlled. Powdery mildew was also observed at Rockhampton and Katherine and downy mildew at Tatura.

3.1.5 Nutrition

Nitrogen rates from 0-120 kg/ha had no significant effect on yield or fruit number (P=0.05) of Delica and Pacifica. The addition of calcium also had no effect on these parameters in either cultivar.

3.2 Cultivar evaluation and production: observation field trials

Observation trials confirmed that Kabocha and Japanese hybrid pumpkins could be grown in all states in a range of temperature conditions and soil types.

In observation trials at Tatura between 1995 and 2000, Tetsukabuto had the highest and most consistent yields. In observation trials over four seasons in Victoria the marketable yield ranged from 46.3-49.0 t/ha whereas in the same trials, seasonal variation of all other cultivars was at least two-fold. Late Potkin had even higher yields than Tetsukabuto in some seasons but appeared to be more sensitive to season with a range from 35-79.2 t/ha over six seasons. Average yields of these two cultivars over the three years were similar (Tetsukabuto 48.5 and Late Potkin 54.7 t/ha).

In the same trials these cultivars had the same fruit weight and same number of marketable fruit each season particularly in 1996/97 and 1998/99 (data not presented).

Similarly at Yanco in spring-summer 1998/99 and at Gosford in spring-summer and summer-autumn 2000/01, Tetsukabuto had considerably higher yields than other cultivars. Yield of all cultivars was greater from the later than earlier sown trial at Gosford. Yields from summer-autumn trial at Gosford were similar to Yanco spring-summer trial.

At Gatton Tetsukabuto had better and more rapid germination and differed in vegetative growth and fruit shape to other cultivars. Yield was not recorded.

Delica and Kurijiman and to a lesser extent Pacifica had similar marketable yields and Ken's Special lower yields. Ken's Special hybrid performed better in terms of marketable yield and fruit size than the open pollinated cultivars.

At Emerald, 1997 and 1998, Delica was compared with Sweet Grey and Jarradale on two occassions. Both trials in 1998 had severe virus (the first 22% crop infection and the second 25%). Total yield ranged from 20.7-29.2 t/ha with fruit size an average 1.2 kg at one site and 3.5 kg at the other. For both plantings the cost/ha to grow kabocha was more than twice that of the other pumpkin types. However, seed costs were only included for Delica, in the calculations.

A number of general observations were reported at Gatton:

* Germination percentage and rate varied between cultivars. Tetsukabuto and T110 had a 95% germination with most Tetsukabuto seeds germinating in less than a week. Delica and Sweet Mama were slower to germinate and had 65% and 60% germination respectively.
* Flowering time also varied between cultivars with Delica flowering two weeks earlier than Tetsukabuto.
* Tetsukabuto matured later than kabocha cultivars at Gatton possibly due to its later flowering.
* Summer harvested (December) crops in the Lockyer Valley suffered severely from sunburn except Tetsukabuto. Unlike the other varieties, its leaves had not senesced and still provided shade.
* Kabocha with sunburn developed rots in strorage with severity directly related to severity of sunburn. Tetsukabuto stored well even in warm, humid conditions.
* Late plantings may be affected by mosaic virus unless cultivars with more foliage are suitable.

Other observations:

- * Kabocha grown in early summer at Mareeba were susceptible to sunburn, particularly those with flatter shapes (height to width).
- * Kabocha was considered unsuitable for the Cudgen and Kyogle sites, due to an excessive incidence of pathogens and poor fruit development.

3.3 Post harvest quality

3.3.1 Fertiliser

At Gatton, nitrogen rates from 0-120 kg/ha had no significant effect on shape, yield, flesh sugar content and ratios, flesh colour, TSS or skin colour measurements of Delica and Pacifica. Pacifica fruit grown with 120 kg/ha N had more even skin colour than fruit grown with 60 kg/ha N and no calcium. Similarly with 120 kg/ha N and Ca, Pacifica fruit had fewer warts and blemishes than fruit with no N but added Ca (Table 13).

Table 13. The effects of nitrogen and calcium application rates on the visual appearance (skin colour, evenness and warts/blemishes presence) of kabocha cultivar Pacifica from Gatton, 2000.

Pacifica	**0 kg/ha Nitrogen**		**60 kg/ha Nitrogen**		**120 kg/ha Nitrogen**		**LSD (*P*=0.05)**
	Calcium	**No calcium**	**Calcium**	**No calcium**	**Calcium**	**No calcium**	
Skin colour	3.78	3.89	3.89	3.89	4.00	4.00	NS
Evenness	1.33	1.33	1.22	1.56	1.00	1.11	0.37
Warts and Blemishes	1.22	1.33	1.33	1.33	1.67	1.44	0.42

Skin colour: lower value= lighter green, eveness: 1= even and 2=uneven, warts and blemishes: 1=present and 2=absent.

3.3.2 Fruit size and shape

All measurements were undertaken on fruit from non-replicated sites and ANOVA was performed using data from individual fruit. Fruit received from Gatton were consistently heavier than fruit of the same cultivar from Gosford. From Gatton, Delica fruit were heavier than T-110, Sweet Mama and Tetsukabuto, and had higher size code (2L-L) than T-110 and Tetsukabuto (L). There were no cultivar differences in fruit weight from Tasmania or Gosford (Data for fruit weight not presented).

Shape values are shown in Figure 4. Shape (height:diameter ratio) was similar for a cultivar grown at different locations (except Tetsukabuto), with significant differences between cultivars at the same location (Table 14). Tetsukabuto generally had height equal to width, T-110 and Sweet Mama height equal to 0.6 width and Delica height equal to half width.

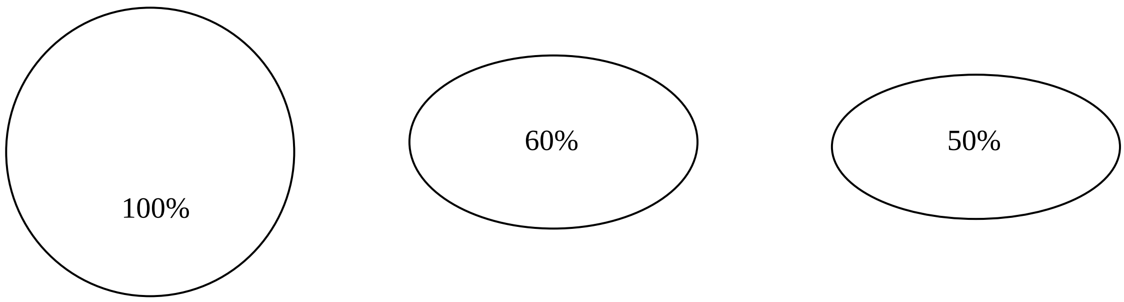
Table 14. Cultivar and location effects on fruit diameter, height and shape (Gatton 2000, Gosford 2001 and Tasmania 2001).

Gatton	**Tetsukabuto**	**Delica**	**T-110**	**Sweet Mama**	**LSD (*P*=0.05)**
Diameter (mm)	168.3	209.0	172.3	193.7	17.3
Height (mm)	136.7	95.0	105.3	112.3	15.87
Shape (%)	81.2	45.6	61.0	58.0	7.67
Gosford	**Tetsukabuto**	**Delica**	**T-110**	**Sweet Mama**	**LSD (*P*=0.05)**
Diameter (mm)	165.7	178.7	161.7	173.3	NS
Height (mm)	109.3	92.7	101.3	101.0	NS
Shape (%)	65.9	51.9	62.6	58.4	8.65
Tasmania	**Delica**		**Nishiki**		**LSD (*P*=0.05)**
Diameter (mm)	181.0		178.9		NS
Height (mm)	97.4		108.7		7.33
Shape (%)	53.7		60.85		3.53

From Gosford over three seasons Tetsukabuto had a consistent diameter of approx 16.5 cm (data not presented), very similar to statistical results from Gatton and Gosford (Table 14), but varied considerably in height between sites which altered its shape.

There were no differences between cultivars in shoulder thickness, base thickness and flesh thickness.

Figure 4. Fruit shape values: visual representation.



a. height = width   b. height = 3/5 width   c. height = 1/2 width

3.3.3 Sugar content

3.3.3.1 TSS (ºBrix)

Total soluble solids (TSS) analyses from three sites indicate cultivar differences. Delica had the same ºBrix as T110 at Gatton and Gosford and higher levels than Tetsukabuto and Sweet Mama at Gatton but the same at Gosford (Table 15). In Tasmania, Delica had higher TSS than Nishiki. Tetsukabuto consistently had low TSS.

Table 15. Cultivar effect on kabocha fruit total soluble solids (°brix) from three locations (Gosford 2001, Gatton 2000 and Tasmania 2001).

	Tetsukabuto	Delica	T-110	Sweet Mama	LSD (P=0.05)
Gosford February 2001	8.30	10.40	9.70	12.60	2.19
Gatton December 2000	6.70	11.00	9.45	5.70	2.17
	Delica		Nishiki		
Tasmania Feb/March 2001	11.97		10.15		0.67

The mean TSS for Laidley Delica samples was 13.3% which was higher than Delica and all other cultivars, from the other three sites.

3.3.3.2 Sugar levels

Sugar content varied with season, locality and cultivar. No significant differences in sugar content between cultivars occurred at Gosford (February 1999), Gatton (both years) or Tatura (May 2000) or with fertiliser treatment (nitrogen rate or calcium use).

New South Wales
At Gosford (May 1999) with fruit produced over summer-autumn all cultivars except T-110 had greater levels of glucose than sucrose and significant cultivar differences in all four sugar concentration parameters (Table 16).

Table 16. Cultivar effect on sugar content (g/100 g) of kabocha fruit from Gosford, 1999.

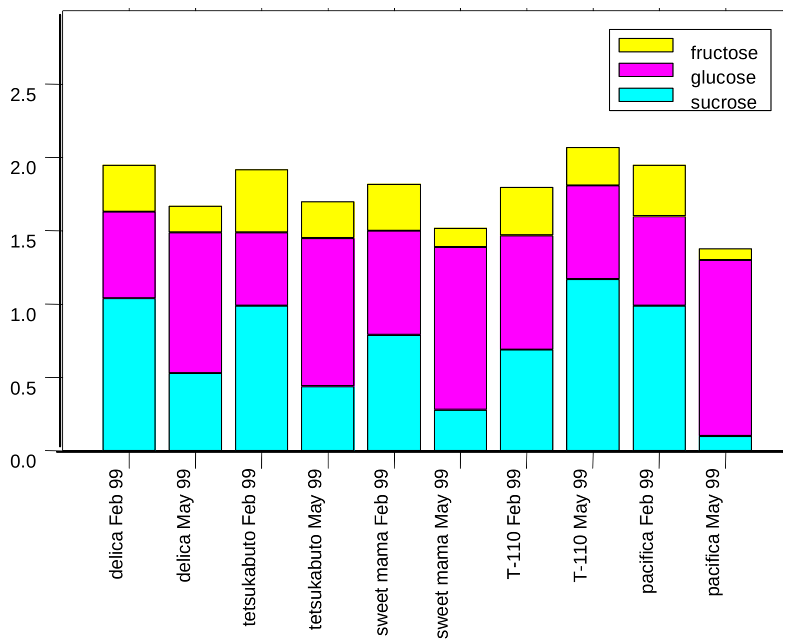
	Delica	**Tetsukabuto**	**Sweet Mama**	**T-110**	**Pacifica**	**LSD (P=0.05)**
Sucrose	0.53	0.44	0.28	1.17	0.10	0.53
D-glucose	0.96	1.01	1.11	0.64	1.20	0.30
D-fructose	0.18	0.25	0.13	0.26	0.08	0.12
Total	1.66	1.69	1.51	2.06	1.34	0.31

T-110 had a higher ratio of sucrose to glucose than all other cultivars (Table 19).
However in spring-summer grown fruit, harvested in February 1999, all cultivars except T-110 had greater levels of sucrose than glucose (Figure 5). Comparing fruit sucrose to glucose ratios from February and May showed cultivar and seasonal effects.

In 2001, T-110 had a higher fructose content (0.44g/100g) than Tetsukabuto, Delica and Sweet Mama (0.15, 0.2 and 0.2g/100g respectively).

Figure 5. Effect of variety and trial on the sucrose, glucose and fructose content of kabocha received from Gosford, February and May 1999.

(Sucrose content, LSD (P=0.05) = 0.53, glucose LSD = 0.28, fructose, LSD =0.13, total LSD = 0.33)



Northern Territory

At Katherine (1999), the ratio of sucrose to glucose varied with Tetsukabuto having higher ratio than three other cultivars, and Pacifica lower than them (Figure 6 and Table 19). Tetsukabuto had higher total sugars than all other cultivars except Tetsukabuto F1, and Pacifica lower than all cultivars except Uchikikari (Table 17).

Table 17. Cultivar effect on sugar content (g/100 g) of kabocha fruit from Katherine, 1999.

	Kurijiman	Uchikikari	Tetsukabuto	Delica	Pacifica	Tetsukabuto F1	Kurijiman F1	LSD (P=0.05)
Sucrose	1.06	0.53	1.46	0.83	0.16	1.23	0.98	0.59 0.55 no max
D-glucose	0.65	0.96	0.55	0.97	1.25	0.55	0.70	0.31 0.29 no max
D-fructose	0.31	0.18	0.47	0.22	0.09	0.40	0.33	0.16 0.15 no max
Total	2.01	1.67	2.48	2.02	1.49	2.18	2.02	0.44 0.41 no max
No. reps	7	8	7	7	6	6	6	

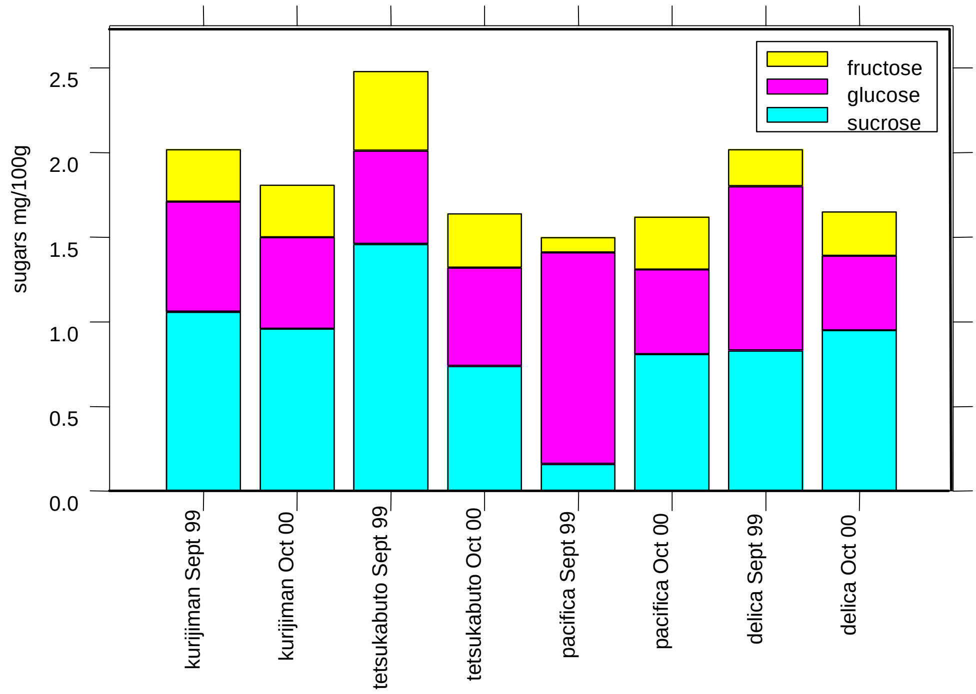
In 2000, sucrose content was higher than glucose for all cultivars. T-110 had higher sucrose and lower glucose content than all cultivars except Sweet Mama. Kurijiman had higher total sugar than T-110 and Sweet Mama (Table 18).

Table 18. Cultivar effect on sugar content (g/100 g) of kabocha fruit from Katherine, 2000.

	Kurijiman	Tetsukabuto	Pacifica	Delica	T-110	Sweet Mama	LSD (*P*=0.05)
Sucrose	0.96	0.74	0.81	0.95	1.24	1.16	0.28
D-glucose	0.54	0.58	0.50	0.44	0.19	0.21	0.15
D-fructose	0.31	0.32	0.31	0.26	0.09	0.13	0.09
Total	1.81	1.63	1.61	1.64	1.52	1.50	0.24

Comparing the two years (Figure 6), total sugar, sucrose, glucose and fructose content was higher in Pacifica in 2000 and Delica glucose and fructose contents were higher in 2000. However, Tetsukabuto glucose and fructose contents, and total sugar content of Tetsukabuto and Kurijiman were higher in 1999.

Figure 6. Cultivar and trial effects on the sucrose, glucose and fructose content of kabocha received from Katherine, September 1999 and October 2000
(Sucrose content, LSD (*P*=0.05) = 0.41max-min, 0.35max, glucose LSD = 0.21max-min, 0.18max, fructose LSD = 0.11max-min, 0.10max, total LSD = 0.33max-min, 0.29max).



Queensland
There were no cultivar or fertiliser (nitrogen rate and calcium) effects on sugar contents at Gatton (1999 & 2000). However, Delica had a higher sucrose to glucose ratio than Sweet Mama and Tetsukubuto (Table 19).

On a single fruit analysis of Delica from Laidley, sucrose content was higher than glucose (ratio 3.11).

Table 19. Cultivar effect on the sucrose: glucose ratio of kabocha fruit from three locations (Gosford 1999, Katherine 1999 and 2000).

	Delica	**Tetsukabuto**	**Sweet Mama**	**T-110**	**Pacifica**			**LSD (*P*=0.05)***
Gosford May 1999	0.72	0.44	0.26	2.54	0.08			1.39
	Kurijiman	**Uchikikar**	**Tetsukabu**	**Delica**	**Pacifica**	**Tetsukabu F1**	**Kurijiman F1**	
Katherine September 1999	2.37	0.90	2.94	1.49	0.15	2.88	1.70	1.83 min 1.72 max-min 1.59 max
Rep. No.	7	8	7	7	6	6	6	
	Kurijiman	**Tetsukabut**	**Pacifica**	**Delica**	**T-110**	**Sweet Mama**		
Katherine October 2000	2.89	1.36	1.94	3.81	7.66	6.77		2.69
Gatton 2000		0.62		2.42	1.46	0.96		1.103
Tatura 2000	0.158		0.024	0.183				NS

* Max and min refer to number of replicates for use when comparing means of different cultivars

Victoria
At Tatura (2000), there were no cultivar differences in sugar content or ratio. Glucose was considerably higher than sucrose content in all three cultivars (ratios 0.024 -0.183).

Tasmania
There were no significant differences between cultivars.

3.3.4 Carotenoids

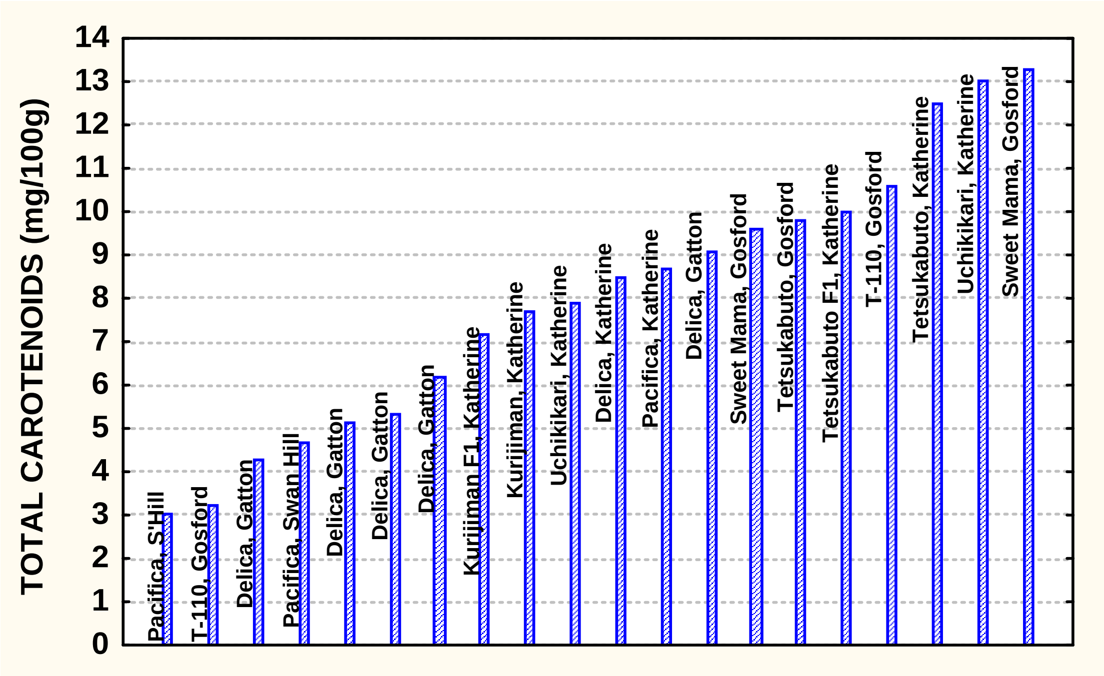
Variation in total carotenoids of twenty fruit sampled from four sites was considerable and possibly reflected some varietal and site differences (Figure 7).

There was considerable variability between individual samples. The lowest reading was 3 mg/100g for a Pacifica sample from Swan Hill (1999) while a Sweet Mama sample from Gosford (1999) yielded over 13 mg/100g (The mean for the 20 samples was 8 mg/100g).

Delica and Pacifica generally had lower carotenoid levels than the newer cultivars such as Tetsukabuto. An interaction with site location is likely but the small sample numbers from each trial site prohibits rigorous analysis. In general, samples from Katherine and Gosford had higher carotenoid levels than those from Gatton and Swan Hill.

There appeared to be no correlation between intensity (degree of orange/yellow), measured as L*, of the flesh and its level of carotenoids.

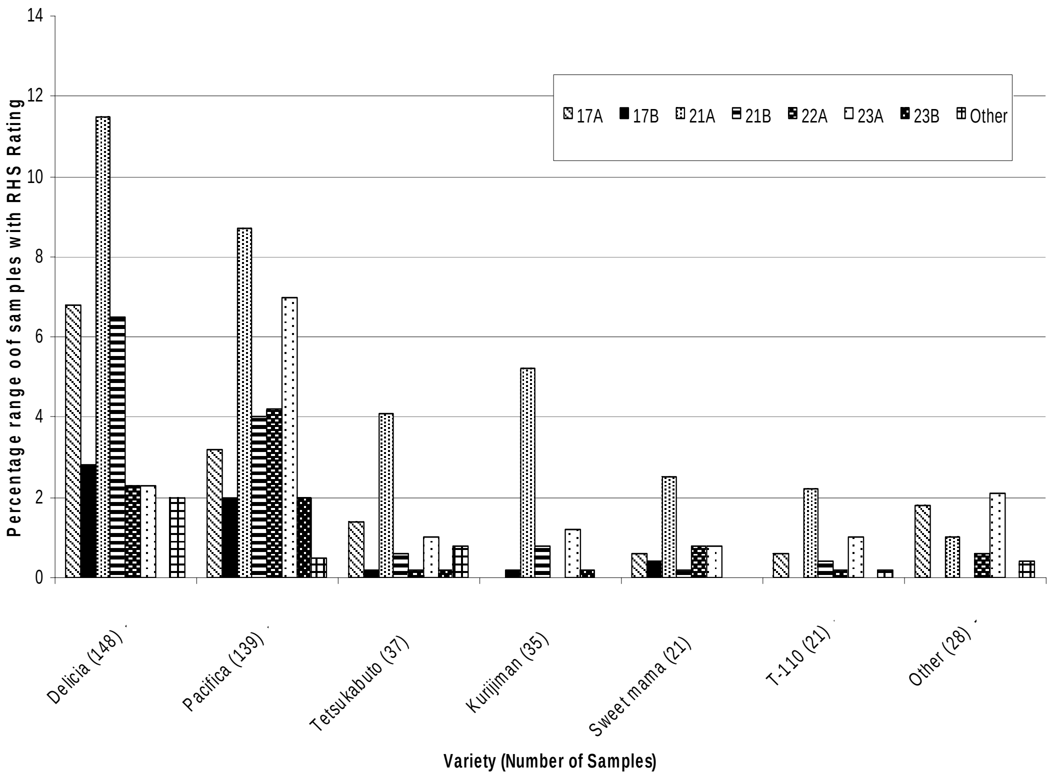
Figure 7. Carotenoid content of twenty individual kabocha fruit from different locations in 2000/01



3.3.5 Flesh colour

Flesh colour of all samples was within the Royal Horticultural Society (RHS) yellow-orange group. Thirty-five percent of all samples matched RHS 21A which has an electronic description of L* 80.71, a*11.13, b*80.52 (Figure 8). Sixteen percent had a RHS chart 23A rating which is considered highly desirable with a bright orange flesh with electronic colour description of L* 77.88, a*16.14, b*80.80. Other colours consisted of 16A, 20A, 22B and 23C which were generally less intense. Flesh colour measurement with CR-200 meter detected differences not always visible with the human eye. The flesh colour of all fruit was within the yellow/orange group. Very few samples were considered undesirable.

Figure 8. Royal Horticultural Society Colour Chart Values for fruit flesh colour.



Queensland

At Gatton in 1999 there were no cultivar differences in flesh colour.

In 2000, Tetsukabuto had higher L* (lighter flesh) and lower chroma readings, both less desirable than all the other cultivars (Table 20). Flesh colour was not affected by nitrogen or calcium treatments.

New South Wales

There were no cultivar differences in flesh colour assessments in 1999 at Gosford but in 2001 Tetsukabuto had higher L* (lighter/less desirable) readings than T-110 and Sweet Mama (Table 20). Delica had more desirable hue reading than Sweet Mama but less desirable L* (lighter) than T-110.

Victoria

Visual flesh colour differences were not obvious but Pacifica was darker (lower L and hue readings) than Delica at Tatura 2000 (Table 20). Delica had hue ratings less desirable (higher) than Kurijiman and Pacifica but a better (higher) chroma reading than Pacifica.

Tasmania

Delica L* value was lower (darker flesh) and all other measurements more desirable than Nishiki (Table 20).

Table 20. Cultivar effect on the flesh colour (L*,a*,b*, hue and chroma) of kabocha fruit from four locations.

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Tatura May 2000	Kurijiman	Delica	Pacifica	LSD (*P*=0.05)
L*	67.09	67.28	64.37	2.30
A*	15.12	13.38	15.34	1.92
B*	70.92	73.28	69.23	2.30
Hue	77.96	79.65	77.48	1.61
Chroma	72.52	74.51	70.95	2.21

Gatton Dec. 2000	Tetsukabuto	Delica	T-110	Sweet Mama	LSD (*P*=0.05)
L*	74.12	71.59	69.29	69.20	2.35
a*	8.67	10.21	8.78	8.49	NS
b*	69.57	73.09	74.23	72.29	2.76
Hue	82.94	82.04	83.25	83.27	NS
Chroma	70.19	73.86	74.79	72.82	2.57

Gosford Feb. 2000	T-110	Tetsukabuto	Delica	Sweet Mama	LSD (*P*=0.05)
L*	66.15	69.94	69.43	66.44	3.18
a*	8.53	12.41	11.96	12.08	NS
b*	72.00	72.52	73.46	70.65	2.43
Hue	83.22	80.29	80.75	80.33	NS
Chroma	72.54	73.59	74.42	71.71	2.41

Tasmania 2001	Delica	Nishiki	LSD (*P*=0.05)
L*	71.21	73.31	1.25
a*	9.06	3.18	1.29
b*	77.84	76.24	0.91
Hue	83.36	87.61	0.95
Chroma	78.38	76.32	0.92

Northern Territory
Visual flesh colour differences were not obvious, however, forty percent of Pacific samples matched RHS 21B which is less strong/bright than other colour matches for the Katherine samples.

Tetsukabuto had more desirable or darker (lower L* reading) flesh colour than all cultivars except T-110 in 2000 and than Delica and Kurijiman F1 in 1999 (Table 21).

Kurijiman had a lighter flesh colour than Tetsukabuto, T-110 and Sweet Mama in 2000
Flesh colour of the three cultivars trialled in both years (as L*values) did not differ over two years.

Hue readings showed Tetsukabuto F1 had less desirable flesh colour (higher hue) than all other cultivars in 1999. In 2000, T-110 had more desirable flesh colour than Kurijiman, Pacifica and Sweet Mama.

Tetsukabuto and Delica had more desirable (lower hue) flesh colour in 2000 than 1999.
Flesh colour as measured by hue was strongly related to external colour of the fruit. Higher values for hue were associated with an uneven rind colour and a lighter rind colour. Flesh colour was not related to a presence of warts and blemishes.

Table 21. Cultivar and year effect on the flesh colour (L*, a*, b*, hue and chroma) of kabocha fruit from Katherine 1999 and 2000. (Variety abbreviation as per Table 22).

L*	**P**	**T**	**D**	**K**	**U**	**TF**	**KF**	**T1**	**S**	**LSD (*P*=0.05)+**
1999 (no.reps)	70.78 (6)	68.73 (7)	73.98 (7)			70.48 (6)	71.95 (6)			2.49min 2.41max-min 2.31max
2000 (no.reps)	72.67 (10)	67.57 (10)	71.35 (10)	74.17 (10)				69.10 (10)	71.01 (10)	2.95
LSD (*P*=0.05)	3.15 max-min 2.73 max									

a*	**P**	**T**	**D**	**K**	**U**	**TF**	**KF**	**T1**	**S**	**LSD (*P*=0.05)**
1999 (no.reps)	14.41 (6)	11.83 (7)	13.06 (7)			8.58 (6)	11.71 (6)			1.68min 1.62max-min 1.56max
2000 (no.reps)	13.55 (10)	15.70 (10)	14.35 (10)	12.41 (10)				17.49 (10)	14.43 (10)	2.13
LSD (*P*=0.05)	2.54 max-min 2.20 max									

b*	P	T	D	K	U	TF	KF	T1	S	LSD (*P*=0.05)
1999 (no.reps)	73.22 (6)	70.65 (7)	74.90 (7)			72.24 (6)	74.66 (6)			2.88min 2.77max-min 2.66max
2000 (no.reps)	69.73 (10)	73.40 (10)	69.19 (10)	69.73 (10)				75.22 (10)	72.80 (10)	3.48
LSD (*P*=0.05)	3.70max-min 3.21 max									

Hue	P	T	D	K	U	TF	KF	T1	S	LSD (*P*=0.05)
1999 (no.reps)	78.86 (6)	80.47 (7)	80.12 (7)			82.44 (6)	81.10 (6)			1.31min 1.27 max-min 1.22 max
Year 2 (no.reps)	79.08 (10)	77.91 (10)	78.32 (10)	79.95 (10)				76.91 (10)	78.80 (10)	1.51
LSD (*P*=0.05)	1.86max-min 1.61max									

Chroma	P	T	D	K	U	TF	KF	T1	S	LSD (*P*=0.05)
1999 (no.reps)	74.63 (6)	71.66 (7)	76.03 (7)			72.89 (6)	75.57 (6)			2.88min 2.78max-min 2.67max
2000 (no.reps)	71.09 (10)	75.11 (10)	70.70 (10)	70.84 (10)				77.24 (10)	74.23 (10)	3.61
LSD (*P*=0.05)	3.83max-min 3.31max									

+LSD's are given to compare means of same minimum or maximum number of reps and to compare means of minimum with maximum reps.

3.3.6 Skin Appearance: Warts/blemishes

Most samples contained warts or blemishes (Tables 22 & 23), with none observed on Tetsukabuto and Tetsukabuto F1 samples from Katherine (1999). There were fewer on Tetsuakabuto than Sweet Mama at Katherine 2000 and than on all other cultivars at Gosford (2001).

At Katherine and Gosford the only difference between cultivar performance in different seasons was with Tetsukabuto which had no warts one season and few in another.

At Gatton (2000) warts or blemishes were unaffected by nitrogen/calcium treatments for Delica but Pacifica receiving 120 kg/ha nitrogen and calcium had fewer than those receiving no nitrogen/no calcium (Table 24). There were no differences between the four cultivars compared in observation trials.

Table 22. Cultivar and year effect on the visual appearance (skin colour, evenness and warts/blemishes) of kabocha fruit from Katherine, 1999 and 2000.

Skin colour[1]	K	T	D	P	U	TF	KF	T1	S	LSD (*P*=0.05)
1999 (no.reps)	2.71 (7)	4.00 (7)	2.29 (7)	2.50 (6)	-	3.83 (6)	2.50 (6)			0.53 min 0.51 max-min
2000 (no.reps)	1.70 (10)	4.00 (10)	2.30 (10)	2.10 (10)				3.78 (10)	1.70 (10)	0.66
LSD (*P*=0.05)	0.70 max-min 0.61 max									

[1]: skin colour rating scale one to five: lower value = lighter green

Evenness[2]	K	T	D	P	U	TF	KF	T1	S	LSD (*P*=0.05)
1999 (no. reps)	1.43 (7)	1.13 (7)	1.43 (7)	1.33 (6)	1.13 (8)	1.00 (6)	1.33 (6)			NS
2000 (no. reps)	1.90 (10)	1.40 (10)	1.50 (10)	1.60 (10)				2.00 (10)	1.40 (10)	0.40
LSD (*P*=0.05)	0.51 max-min 0.44 max									

[2]: even = 1 and uneven = 2

Warts and Blemishes[3]	K	T	D	P	U	TF	KF	T1	S	LSD (*P*=0.05)
1999 (no. reps)	1.00 (7)	2.00 (7)	1.29 (7)	1.00 (6)	1.63 (8)	2.00 (6)	1.17 (6)			0.38 min 0.35 max-min
Year 2 (no. reps)	1.40 (10)	1.50 (10)	1.30 (10)	1.30 (10)				1.33 (10)	1.00 (10)	0.41
LSD (*P*=0.05)	0.44 max-min 0.38 max									

[3]: warts/blemishes present = 1, warts/blemishes absent = 2

K = Kurijiman, T = Tetsukabuto, D = Delica, P = Pacifica, U = Uchikikari, TF = Tetsukabuto F1, KF = Kurijiman F1, T1 = T-110, S = Sweet Mama

Table 23. Cultivar and year effects on the visual appearance (skin colour, evenness and warts/blemishes) of kabocha received from Gosford 2001, February and May 1999.

2001

	T-110	Tetsukabuto	Delica	Sweet Mama	LSD (P=0.05)
Skin colour	3.67	4.33	3.33	4.00	0.94
Evenness	1.00	1.00	2.00	1.33	0.54
Warts/blemishes	1.00	1.67	1.00	1.00	0.54

February and May 1999

Skin colour	Delica	Tetsukabuto	Sweet Mama	T-110	Pacifica	LSD (P=0.05)
Feb	3.25	5.00	3.25	3.75	3.50	0.88
May	4.00	5.00	3.50	4.00	4.00	0.44
LSD (P=0.05)	0.68					

Evenness	Delica	Tetsukabuto	Sweet Mama	T-110	Pacifica	LSD (P=0.05)
Feb	1.00	1.00	1.25	1.00	1.00	NS
May	1.50	1.00	1.75	1.31	1.50	0.74
LSD (P=0.05)	0.56					

Warts/blemishes	Delica	Tetsukabuto	Sweet Mama	T-110	Pacifica	LSD (P=0.05)
Feb	1.00	2.00	1.00	1.00	1.00	NS
May	1.00	1.25	1.00	0.94	1.00	NS
LSD (P=0.05)	0.24					

1: skin colour rating scale one to five: lower value = lighter green
2: skin colour eveness: even = 1 and uneven = 2
3: warts/blemishes present = 1, warts/blemishes absent = 2

Table 24. Cultivar and fertiliser treatment effects on the visual appearance of Pacifica fruit (skin colour, evenness and warts/blemishes) of fruit from Gatton, 2000.

	Tetsukabuto	Delica	T-110	Sweet Mama	LSD (P=0.05)
Skin colour	4.67	3.67	4.00	3.33	0.94
Evenness	1.00	2.00	1.33	1.33	0.77
Warts/blemishes	2.00	1.33	1.67	1.67	NS

Pacifica	0 kg/ha nitrogen		60 kg/ha nitrogen		120 kg/ha nitrogen		LSD (P=0.05)
	Calcium	No calcium	Calcium	No calcium	Calcium	No calcium	
Skin colour	3.78	3.89	3.89	3.89	4.00	4.00	NS
Evenness	1.33	1.33	1.22	1.56	1.00	1.11	0.37
Warts/ Blemishes	1.22	1.33	1.33	1.33	1.67	1.44	0.42

Skin colour rating scale one to five: lower value = lighter green
Skin colour eveness: even = 1 and uneven = 2
Warts/blemishes present = 1, warts/blemishes absent = 2

3.3.7 Skin appearance: colour

Dark kabocha skin colour is preferred, with sixty-eight percent of the total number of samples rated as medium, dark or very dark for skin colour. Of the remaining fruit, thirty percent were rated as light. The two percent rated pale were Kurijiman, Pacifica and Sweet Mama all received from Katherine (2000).

Tetsukabuto skin was consistently darker than other cultivars with significant differences for fruit from Katherine (1999 & 2000), Gatton (2000) and Gosford (Feb & May 1999 and 2001). In addition, Tetsukabuto F1 (1999) and T-110 (2000) were significantly darker than other cultivars at Katherine (Table 22). Sweet Mama samples received from Gosford (May 1999) were observed to be significantly lighter than all other varieties (Table 23).

Skin darkness appeared to be more dependent on the source than the cultivar, with generally lighter skin fruit from Katherine.

Cultivar skin colour did not differ (except for Kurijiman) due to year at Katherine or (except for Delica) season at Gosford (1999).

Skin colour was not affected by fertiliser treatments in the Gatton trials.

3.3.8 Skin appearance: colour evenness

In general, fruit from Katherine (1999) had a higher percentage with even skin colour than in 2000 (Table 22). In 2000, Tetsukabuto and Sweet Mama samples had the most even coloured skin compared with Kurijiman and T-110.

From Gatton (December 2000), Tetsukabuto was the only cultivar with all fruit having an even skin colour, significantly different to samples of Delica with all fruit having uneven skin colour.

Pacifica receiving 120 kg/ha nitrogen, with or without calcium treatment, had significantly more even skin coloured fruit than 60 kg/ha nitrogen with no calcium. Other nitrogen rates did not affect evenness.

All Tetsukabuto and T-110 fruit received from Gosford (February 2001) had even, and Delica uneven, skin colour. Similarly, all Tetsukabuto samples collected in February and May 1999 had even skin colour. Differences between cultivars were observed for May 1999 samples. Skin colour evenness was unaffected by season in 1999 samples.

3.4 Post harvest treatment for storage rot.

3.4.1 Type and incidence of field and storage rots

3.4.1.1 Field rots

In Tasmania, *Fusarium culmorum*, *Rhizopus stolonifer*, *Botrytis cinerea* and two species of *Penicillium* were present on fruit that was rotting in the field. There was no cultivar difference in field rot incidence (but Delica had more than twice the rots of other cultivars). The highest incidence of field rot (36.5%) occurred in crop 1 (Figure 9A). Seventy percent of the field rots were associated with *F. culmorum,* which was the dominant fungal pathogen at all three sites, with highest rot incidence.

R. stolonifer was rarely the sole fungal pathogen on rotten fruit and was often found in association with *F. culmorum*.

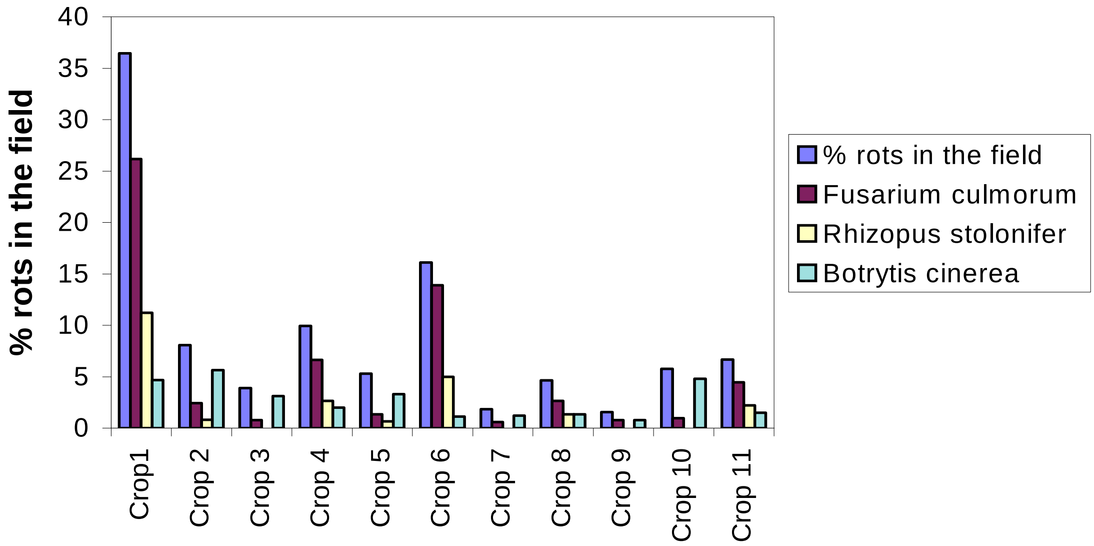
B. cinerea was present at approximately the same percentage at all sites, irrespective of the total number of rots found. In the field, *B. cinerea* was often associated with aborted fruit and did not usually occur on mature fruit. *Penicillium* rots occurred less commonly and were often associated with other fungal pathogens on fruit.

3.4.1.2 Storage Rots

Fungal rot incidence in storage ranged from 3% to 64% (Figure 9B). There was no significant cultivar effect on storage rot incidence (even though Delica had less than 50% incidence of other cultivars). The same fungi that were found in the field rots were also found in storage rots. *F. culmorum* was most common, followed by *Rhizopus stolonifer* and *B. cinerea. Penicillium* species were also found in nearly all the crops kept in storage, but made up only a small percentage of the total rots found (data not shown).

Figure 9. Fruit fungal rot incidence at harvest and after storage for four weeks.

A. In the field at harvest



B. After ambient temperature storage for four weeks

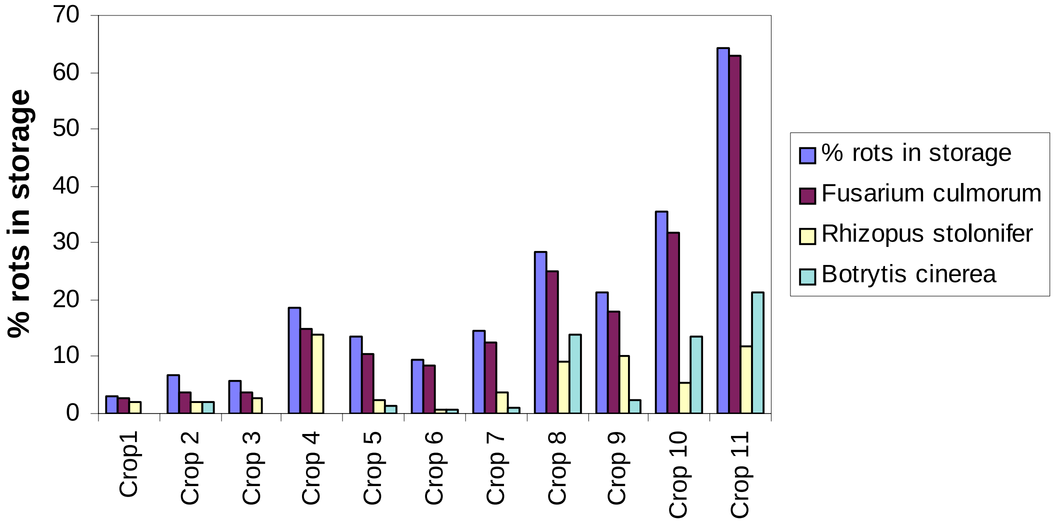
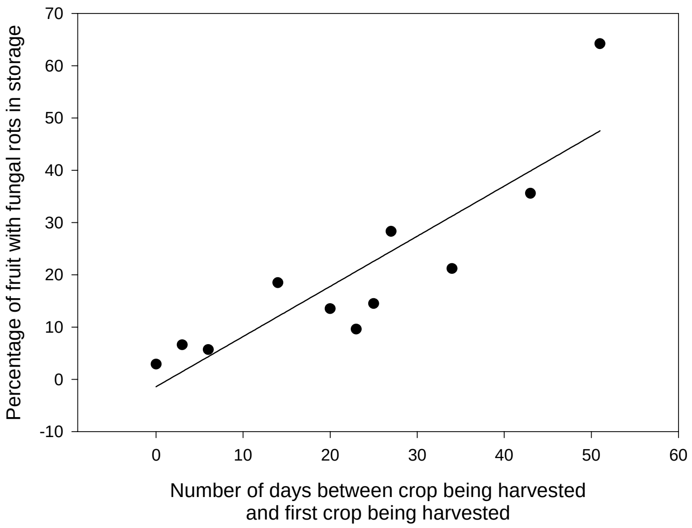
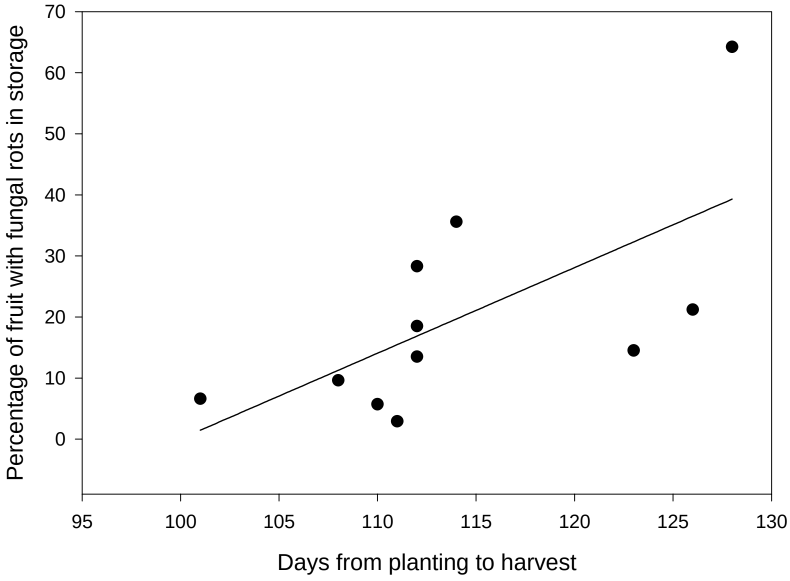


Figure 10. Relationship between fruit fungal rots of kabocha in storage and harvest time and crop life

A. Time interval between harvest and harvest of the first crop of the season .



B. Relationship between crop life and incidence of fungal rots in storage.
Y= -140.1 + 1.40 x P=0.03, r^2=0.41



There was an increased percentage of storage rot as the harvesting season progressed. Storage rot incidence significantly (P<0.001, Y = -1.41 + 0.96 x, P<0.001, r^2=0.77) increased with increasing time intervals between first harvest and later harvests for the season. Crops harvested earlier in the season developed fewer rots in storage than crops harvested later in the season.

There was also a significant (P=0.03, Y= -140.1 + 1.40 x , r^2=0.41).) increase in storage rot with crop life. There was a high degree of multicollinearity between crop life and time interval between harvest and harvest of the first crop of the season (P=0.01)

There was no relationship between incidence of rot in the field and that in storage (P=0.31).

3.4.2 Heat conditioning to prevent chilling injury and low temperature storage to reduce fruit rot.

3.4.2.1 Chilling injury

Chilling injury was affected by conditioning temperature and duration and storage temperature and duration.

Conditioning at 30°C prior to storage led to less weight loss between 7-28 days storage in comparison to conditioning at 2°, 7°, 12° or 45°C. Weight loss was highest in fruit conditioned at 45°C between 0-7 and 7-28 days storage (Table 25).

Conditioning for seven days compared to one day resulted in greater weight loss, reduced fruit firmness and increased brix levels (Table 26).

Fruit stored at 7°C had no visual chilling injury, such as surface pitting or blackening, after 28 days and, compared to fruit stored at 12°C, had less weight loss in storage, a higher brix (%), darker green skin and lighter orange flesh (Table 27).

Table 25. The effect of conditioning temperature on percentage weight loss, fruit firmness, brix (%), skin colour, flesh colour and disease rating of stored kabocha.

	Conditioning temperature (°C)					
	2	7	12	30	45	*P*
Mean weight loss (%) between day 0-7	0.6a	0.6a	0.9b	2.7c	17.2d	<0.001[1]
Mean weight loss (%) between day 7-28	1.8b	1.7b	1.7b	1.2a	3.8c	<0.001[1]
Mean penetrometer reading (kg)	8.8a	8.1b	8.4ab	8.4ab	5.3c	<0.001[1]
Mean brix level	8.0ab	7.4ab	7.4ab	8.6a	6.5b	0.05[1]
Mean skin colour	2.7a	2.9a	2.9a	2.6a	2.4b	<0.001[2]
Mean flesh colour	1.4a	1.4a	1.5a	1.5a	1.8b	<0.01[2]
Mean disease rating	1.1a	1.1a	1.0a	1.1a	2.4b	<0.001[2]

[1]Probability of significant difference between treatments according to F-test, means within rows followed by the same letter are not significantly different according to LSD.
[2]Probability of differences in treatments being due to random chance according to χ^2 analysis, means within rows separated by orthogonal partitioning of contingency table.

Table 26. The effect of duration of conditioning on percentage weight loss, fruit firmness, brix level, skin colour, flesh colour and disease rating of stored kabocha.

	Duration (days)		
	1	7	*P*
Mean weight loss (%) between day 0-7	2.3a	6.5b	<0.001[1]
Mean weight loss (%) between day 7-28	1.9a	2.3b	0.037[1]
Mean penetrometer reading (kg)	8.1a	7.5b	0.005[1]
Mean brix level	6.9a	8.3b	0.005[1]
Mean skin colour	2.6	2.7	ns[2]
Mean flesh colour	1.5	1.6	ns[2]
Mean disease rating	1.2	1.5	ns[2]

[1]Probability of significant difference between treatments according to F-test, means within rows followed by the same letter are not significantly different according to LSD.
[2]Probability of differences in treatments being due to random chance according to χ^2 analysis, means within rows separated by orthogonal partitioning of contingency table.

Table 27. The effect of storage temperature on percentage weight loss, fruit firmness, brix level, skin colour, flesh colour and disease rating of stored kabocha.

	Storage temperature (°C)		
	7	12	*P*
Mean weight loss (%) between day 7-28	1.4a	2.7b	<0.001[1]
Mean penetrometer reading (kg)	7.8	7.7	ns[1]
Mean brix level	8.2a	7.0b	0.002[1]
Mean skin colour	2.7a	2.6b	<0.001[2]
Mean flesh colour	1.7a	1.3b	<0.001[2]
Mean disease rating	1.3	1.4	ns

[1]Probability of significant difference between treatments according to F-test, means within rows followed by the same letter are not significantly different according to LSD.
[2]Probability of differences in treatments being due to random chance according to χ^2 analysis, means within rows separated by orthogonal partitioning of contingency table.

3.4.2.2 Skin colour

Conditioning temperature and duration of conditioning had a significant effect on skin colour of fruit stored at 12°C but not 7°C. Fruit conditioned for 1 day at 45°C and then stored at 12°C were lighter green in colour than fruit conditioned at 2, 7, 12 and 30°C (Table 28). For fruit conditioned for 7 days and then stored at 12°C, those conditioned at 7°C and 45°C had darker green skin than those conditioned at 30°C.

3.4.2.3 Reduction of storage rots

Conditioning temperature and duration and storage temperature influenced disease rating (Table 29). For fruit conditioned for 1 day, disease rating was similar for all conditioning temperatures and the two storage temperatures. When conditioned for 7 days the disease rating for fruit conditioned at 45°C was higher than that for fruit conditioned at all other temperatures, at both storage temperatures.

Heat treatment of fruit at 45°C and storage for 7 days led to fruit of poor quality (skin colour) and increased rot incidence, caused by opportunistic fungi, at 28 days (Tables 28 & 29) and to the development of white layers in the fruit flesh.

Heat treatment at 36ºC or 38ºC for 2-16 hours failed to prevent chilling injury when stored at 2ºC with all treatments having high levels of fungal rot (data not presented).

Table 28. Effect of conditioning duration and temperature on fruit skin colour (lower value = lighter green) following storage at 7° or 12°C for 28 days in kabocha.

Conditioning temperature (°C)

	2	7	12	30	45	*P*[1]	
Storage at 7°C							
	1 day conditioning	2.7	2.8	2.6	2.7	2.5	ns
	7 days conditioning	2.6	2.7	2.9	2.4	3.0	ns
Storage at 12°C							
	1 day conditioning	2.8a	2.9a	3a	2.9a	1.1b	<0.001
	7 days conditioning	2.6ab	3.0a	2.9ab	2.2b	3.0a	<0.001

[1] Probability according to χ^2 of differences in treatment means being due to random chance.

Table 29. Effect of conditioning temperature and duration on fruit disease rating (lower value = less disease) following storage at 7°C or 12°C for 28 days in kabocha.

Conditioning temperature (°C)

	2	7	12	30	45	*P*[1]	
1 day conditioning							
	Storage at 7°C	1.2	1.1	1.0	1.0	1.7	ns
	Storage at 12°C	1.0	1.3	1.0	1.0	1.2	ns
7 days conditioning							
	Storage at 7°C	1.0a	1.0a	1.0a	1.0a	2.8b	<0.001
	Storage at 12°C	1.1a	1.0a	1.1a	1.2a 3.9b	<0.001	

[1] The probability according to χ^2 of differences in treatment means being due to random chance.

3.4.2.4 Fungi isolated during heat conditioning and storage trials

After 28 days in storage numerous small fungal colonies including *Cladosporium* and *Penicillium* spp. had developed on the fruit surface after conditioning at 45ºC, especially those treated for seven days. They developed slowly and were considered to be opportunistic pathogens, developing on skin damaged by high temperature conditioning.

Some fruit also treated at 45ºC were infected with *R. stolonifer* which was able to completely rot the fruit within one week of first observation. It was considered pathogenic with skin damage contributing to infection.

F. culmorum occurred infrequently and appeared not to be related to treatment but rather to have been present from early fruit development.

3.4.3 Fumigation with acetic acid or ammonia vapours.

Exposure to acetic acid vapour for 2 hours was effective at reducing *F. culmorum* spore germination. The mean estimated area covered by fungal mycelium after 3 days was 3.8, 21.6 and 61.1 cm^2 for 556 µl AA/l, 111 µl AA/l and 111 µl sterile water/l total airspace respectively.

Further *in vitro* studies determined that germination was reduced only by exposure to 100 µl AA/l airspace for 24 or 96 hours. This rate is unsafe to use and would probably cause phytotoxicity.
Acetic acid at 50 µl/l airspace for up to 60 minutes reduced fruit surface covered with fungal rots after 14, 29 and 43 days storage (Table 30) but was associated with skin blackening.

The interaction of injury and acetic acid fumigation was significant after 43 days storage, with injury causing greater fruit surface area with rotting and this was reduced by acetic acid fumigation (Table 31).

Ammonia and low rates of acetic acid were ineffective at reducing surface fungal rots and skin blackening (Table 32).

Table 30. Effect of acetic acid fumigation on the mean percentage area of kabocha fruit surface covered by fungal rots after different times of storage

14 days	**29 days**	**43 days**	
Control	3.7	20.6	24.9
Acetic Acid	0.5	4.1	8.9
P=	<0.001	<0.001	0.001
LSD (5% level)	1.6	7.5	9.7

Table 31. Interaction between fumigation and kabocha fruit injury on mean percentage area of kabocha fruit surface covered by fungal rot on 15/7/1999 (43 days) (P<0.001, LSD 5 % level =13.7)

	Uninjured	**Injured**
Control	0.9	48.9
Acetic acid	2.8	14.9

Table 32. Effect of acetic acid or ammonia vapour on the percentage of surface area of kabocha covered by fungal rots and blackening at 65 days after treatment.

	No. fruit	No. rotten	Surface rot (%)	Blackening (%)	Brix (%)
Control	21	6	6.7	1.3	12.5
AA 5 µl/l for 24 h	21	8	4.7	2.8	12.4
AA 0.5 µl/l for 24 h	21	4	5.7	1.8	11.9
AA 5 µl/l for 1h	22	6	7.5	2.8	11.8
Ammonia 0.5 µl/l for 1 h	22	9	12.2	2.0	11.6
Ammonia 5 µl/l for 1 h	20	10	8.4	2.0	10.7
Ammonia 5 µl/l for 24 h	22	7	7.1	1.1	10.3
LSD (5% level)			0.689	0.13	0.37

Discussion

Kabocha and Japanese pumpkin can be grown in all states of Australia with marketable yields equal to or considerably greater than those in recent literature (10-30 tonnes/ha). In Australia, yields vary between site, season, plant spacing and cultivar with the range in these trials being 16-53 t/ha. Genetics (or cultivar) had the greatest influence on yield with the inter-specific hybrids of *C. maxima* by *C. moschata* having highest marketable yields due mainly to more fruit per plant. The kabocha types all had a similar yield and the only Japanese pumpkin type evaluated (at one site only), Ken's Special, had yields less than the two other types.

Tetsukabuto, also known as Late Potkin, outperformed the older kabocha cultivars with higher yields. Significantly more fruit per plant were set at each location, but the same weight per fruit was produced. The kabochas had market yields less than the inter-specific crosses but greater than the Japanese pumpkin. Delica and Kurijiman yields did not differ significantly within each trial (except at Mareeba) and fruit weight and number were also similar. The other kabochas had a similar or higher yield to them depending on location. The Japanese pumpkin, Ken's Special, had a lower marketable yield, fewer fruit but greater average fruit weight than the kabochas. However, it was only grown in one season so it is not known whether this would occur at all locations or in all years. It appears there is an inverse relationship between fruit weight and number for the kabochas and Japanese pumpkin.

Within each location all cultivars were grown at the same plant density. It is known that higher plant densities increase number of small fruit (Douglas *et al.* 1990 and Chung *et al.*1992) and can affect female flower numbers (Botwright *et al.* 1998). As well, fruit size increased with higher plant densities (Botwright *et al.* 1998). This suggests that each cultivar may have an optimum plant spacing and/or agronomic requirements for maximum yield, fruit weight and fruit number. Genetics is also a factor in determining yield, with selection aimed at fruit weight and/or fruit number. Plant type also influences fruit number with most cultivars evaluated having vine type habit, except for Sweet Mama which has a semi-bush habit and may require different plant spacing and agronomy for maximum yield and performance.

The number of fruit per plant was greater at Katherine 2000 (and for most cultivars at Gosford) than at all other sites probably due to greater diurnal temperatures than other sites rather than difference in plant spacing. This suggests that two harvests could be an option there for growers to maximise yield per hectare.

Fruit matured earlier at Tatura and Mareeba than other sites indicating that lower diurnal temperature variation and/or less variation in minimum temperatures could decrease time to maturity. Other sites with longer time to maturity such as Katherine and Gatton had greater diurnal temperature and greater variation in minimum temperatures during the growing season. As well, plant spacing was closer (4.1 plants/m^2) in Victorian trials and plant spacing affects maturity. At Mareeba plant spacing (1.6 plants/m^2) was probably not the reason for earlier maturity (which could have been 7-10 days earlier with harvest delayed due to labour issues).

Season appeared to have little effect on time to maturity, with fruit at Gosford planted in spring or summer 1998, maturing 132 or 135 days after transplanting respectively. Similarly, with two years trials at Katherine, although yield and fruit number were greater in 2000 than 1999, days to maturity were not.

Ken's special matured up to 42 days later than the other cultivars tested. This is not surprising as it is a different species than other cultivars evaluated. The Late Potkin type, Tetsukabuto can be up to one month later maturing than the kabochas (K. Jackson personal communication). This was supported by the observation that Tetsukabuto flowered two weeks later than Delica at Gatton. At most sites however, differences in time to maturity between cultivars were not detected as trials were harvested once only. This once only harvest for all cultivars may have masked yield characteristics of some cultivars eg. marketable yields of Tetsukabuto could be expected to increase if given extra time for smaller fruit to reach maturity. Two harvests may be best for some cultivars.

However, Tetsukabuto still outperformed the older varieties Delica and Pacifica at each location where all three were grown (Gosford, Katherine and Victoria). Yields were higher, external appearance was better, and fruit size was in the smaller range preferred by the Japanese for fresh fruit. The industry should therefore be encouraged to consider moving on from the older varieties currently grown to capitalise on higher yields for the domestic market.

Variation in Tetsukabuto yields between years in NT (much higher in 2000) may have been due to inexperience in growing, plant spacing which was denser in 1999, low temperature reducing fruit set, and/or excessive nitrogen fertiliser. Although all cultivars had lower yields in 1999, Tetsukabuto had a 66% increased yield in 2000 suggesting that it could require different agronomic practices than the kabochas to maximise yields. The results presented in this report compare performance of cultivars grown under the same conditions at each site.

Due to Tetsukaboto's inability to set fruit unless there is a *C. maxima* or *C. moschata* cultivar growing with it, care must be taken when recommending use of Tetsukabuto and Late Potkin. This needs to be managed if deciding to grow it commercially.

Tetsukabuto's similar yields to Late Potkin are not surprising as both cultivars are of the same type and would be expected to have similar fruit number and weight just as Delica and Kurijiman which are also of the same type (but a different species to the former), do.

Harvesting in January / February in south-east Queensland invites problems of excessive heat and sunburn, and this conclusion was supported by the trial at Gatton. Cultivars with a greater canopy may provide shade (Loader 1998) but could lead to increases in fungal problems. Plant population may also affect sunburn incidence but crops with closer spacing would have to be regularly monitored for disease problems.

The Northern Rivers region of NSW was considered to be unsuitable for "kabocha" production due to the proliferation of disease. This is consistent with other studies of the crop in low coastal areas of Queensland which have suffered the same problem and may be related to high humidity. However, disease can be managed if anticipated.

The nitrogen rates investigated in these studies had no significant effect on yield characteristics. It appears that higher rates should have been looked at as recommended nitrogen rates for pumpkins start at 120 kg/ha.

An assessment of production factors that positively affect quality is difficult, as there is no clear consensus as to what constitutes good quality. However, fruit postharvest quality assessment based on comparing cultivars grown at individual sites highlighted cultivar differences and suggested trial and location had some influence on final quality.

As with yield characteristics, significant differences in quality traits were frequently observed between the old cultivars, such as Delica, and new ones such as Tetsukabuto which consistently had the preferred appearance qualities of even, dark rind colour and fewer skin warts/blemishes. Other cultivars with no warts at Mareeba were Ajehi and Early Potkin. Warts are associated with maturity as well as moist soil conditions (Loader 1998) again supporting the suggestion that these cultivars were less mature at harvest.

In addition, total carotenoid levels were higher in Tetsukabuto than Delica. It is likely that these characteristics may have been selected for by Japanese plant breeders.

Skin appearance did not appear to be dependent on trial location but addition of high nitrogen and calcium fertiliser reduced warts and blemishes on Pacifica at Gatton.

Skin colour is important because of its effect on sunburn susceptibility with dark skin being less susceptible at Gatton.

With the exception of Tetsukabuto, physical properties of fruits such as diameter, height and shape were similar for the same variety grown at different sites. The fact that Tetsukabuto had similar width at all locations but varied in height again suggests incomplete growth.

Flesh colour of the three cultivars evaluated over two years in NT did not differ suggesting differences were due to cultivar rather than seasonal factors. However, at some locations there were no cultivar effects in some years but differences in other years.

Although not statistically analysed, L* readings at Tatura were lower than those at Katherine and Gatton suggesting that pumpkins grown in southern states had darker and more desirable flesh than those from the northern states. Gosford readings were intermediate suggesting that L* values may be affected by latitude.

Fruit flesh colour and sugar content from the one variety often varied at one location and between growing locations, which suggests that fruit maturity at harvest affects these attributes. This supports findings of Harvey *et al.* (1997), that sugar content varied throughout the harvest period.

Proportions of sucrose, glucose and fructose in flesh varied between varieties, trials and sites. At Katherine, 1999 fruit were harvested 111 days after transplanting and some cultivars had higher glucose than sucrose suggesting that these cultivars may not have been mature. In 2000, fruit were harvested 138 days after transplanting and all cultivars had very high sucrose to glucose ratios with T-110 and Sweet Mama having values of 7.7 and 6.8 times more sucrose. Conversely, at Gosford May 1999, in fruit harvested 132 days after planting only one of four cultivars, T-110, had higher sucrose:glucose ratio suggesting the others may have been immature at harvest. At Gosford plant spacing was generous and fruit may be expected to take longer to mature than at closer plantings. The weight of fruit on T110 was 0.79 kg with only 1 fruit per plant which may also have hastened its maturity. When harvested in February 1999, T110 had a higher flesh glucose to sucrose ratio and its fruit weight was 2.6 kg and may have been still growing.

However, as T-110 had different sugar contents across seasons, which were also different to the other cultivars in three seasons at Gosford, the differences may be genetic.

Harvey *et al.* (1997) also found that sucrose levels varied with site and season and that sucrose levels were higher in pumpkins left on the vine for longer after flowering. At Gatton the four cultivars varied in sucrose to glucose ratios with the ratio for Delica 2.4 and Tetsukabuto 0.57. In this trial it was observed that Delica flowered two weeks earlier than Tetsukabuto but they were harvested at the same time. Sweet Mama had a ratio of 0.97 and flowered one week after Delica. Again this supports the findings of Harvey *et al.* (1997) that sucrose content is related to time from flowering to harvest.

These results suggest that flowering time could be used as a scheduling event to harvest fruit as they mature to get the required ratio of sugars (or flavour) and meet specific customer demands. More research needs to be carried out to develop a tool to make decisions on when to harvest.

Flesh colour was affected by cultivar and in general the older kabocha types had more desirable (darker) flesh colour than the new hybrid Tetsukabuto. Flesh colour appeared to show the same cultivar trends at all locations (that is it was not markedly affected by location).

Flesh colour may also be related to the duration of the period from flowering to harvest as Tetsukabuto was significantly different to Delica in L* and chroma values (with Delica having the more desirable flesh colour) in the same trial. Tetsukabuto flesh colour may have been more desirable if it was harvested two weeks later.

Tasmanian fungi associated with postharvest rots in the field and during storage differ to those described for New Zealand (Hawthorne 1989). *F. culmorum* was the dominant fungal pathogen at sites with high rot incidence and *Rhizopus stolinifer* was often found in association with it. Generally crops had less than 10% fruit rot in the field but some crops, particularly those harvested later in the season, had higher levels. It is not known whether this is a seasonal effect (more inoculum present later in season and/or conducive environmental conditions) or due to late harvested crops having a longer crop life. Cultivars may differ in susceptibility. Previous research has shown that rot incidence was greater in fruit harvested late in crop life than fruit harvested earlier (Hawthorne 1989) and suggested increased physiological rot susceptibility of older fruit.

There could be a conflict in harvest timing between the need to decrease rot incidence and to produce a desirable flesh colour and sugar content. If future research is undertaken on harvest scheduling not only yield should be considered but reducing rot incidence would also be an important objective.

This research has indicated that heat treatment or "shocking" was ineffective against storage rots but that cold storage treatment (around 7ºC) for up to 28 days may be useful. However, fruit used in this study had been stored at 15ºC for 3 weeks prior to the cold storage treatment which may have had a pre-conditioning effect. Similarly, field temperatures may influence fruit ability to withstand lower temperature storage. Fruit stored for 20 days at 15ºC for quality assessment showed no chilling injury.

In addition fruit stored at 12ºC after heat treatment did not develop chilling injuries but developed storage rots earlier than fruit stored at 2ºC. There is a need for more work in this area to develop a viable treatment for storing kabocha and related species.

Work at the Queensland Department of Primary Industries on Queensland Fruit Fly disinfestation indicated that cold treatment resulted in chilling injury but that heat treatment appeared promising. There was no preconditioning temperature and field conditions would have been warmer than in Tasmania but are unknown. Post harvest temperature control may need to be tailored to the production region, as the effectiveness of a treatment appears to be related to the environment in which the fruit is produced.

Whilst acetic acid at very high rates reduced *F. culmorum* spore germination and fungal rots on the fruit skin, the effective rate (50 µL AA/l airspace) was phytotoxic. Acetic acid appeared to be associated with skin blackening in some experiments but not in others suggesting that a better understanding of factors contributing to skin blackening and higher, but safer, rates may be effective.

F. culmorum usually appeared some time after storage, often growing around the stalk or button end of the fruit, suggesting that it could exist as a quiescent infection within fruit tissues, where it is protected from surface disinfestation.

With *in vitro* studies *F. culmorum* macroconidia germination was only reduced by exposure to 100 µl AA/l airspace for 24 hours or more suggesting that *F. culmorum* may be more resistant to acetic acid than has been reported for other storage fungi.

Conclusions

The trials reported in this study have shown that these pumpkins can be grown in all Australian states to give year round supply and that pumpkin type (genetics), maturity, season and location can affect yield, post harvest quality and rot susceptibility. However, the newer inter-specific cross type pumpkins generally had higher yield, desirable appearance and if harvested when mature, flesh colour and sugar content may be more desirable and yields even higher. More agronomic and market research is needed to maximise returns from this cultivar type.

Best performing cultivars at each location

NSW Gosford	**NT Katherine**	**QLD Gatton**	**QLD Mareeba**	**VIC**
Tetsukabuto	Tetsukabuto	Tetsukabuto	Kurijiman Nishiki	Tetsukabuto Late Potkin

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Japanese Pumpkin and Kabocha are members of the cucurbit or pumpkin family and command quite high prices. Kabocha is grown in Australia, for the domestic market and for export to Japan.

Field trials were conducted from 1998-2001 in most states of Australia to identify national production capability, and to establish information sought by supply chain managers.

The trials confirm that Australia can produce kabocha of acceptable quality year round, if the variation in locations and planting dates is optimised.

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