A REVIEW OF PAST R&D WORK BY THE DEPARTMENT OF RESOURCES FOR THE VEGETABLE INDUSTRY IN THE NORTHERN TERRITORY AND RECOMMENDATIONS FOR FUTURE WORK

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BACKGROUND

The purpose of this Technical Bulletin is to provide policy makers, program managers, researchers and the Northern Territory (NT) vegetable industry with a summary of past Department of Resources' (DoR) activities in vegetable research, development and extension (RD&E). This follows a similar paper (Anonymous 1997a); its purpose was to "assist with the setting of future research priorities" . This is pertinent as the Plant Industries Group of DoR has embarked on a renewed effort to use RD&E to enhance the value of the NT vegetable industry to capitalise on new opportunities in local and interstate markets.

Although the following discussion will provide the basis for recommendations on themes of future RD&E work for the NT vegetable industry, it is recognised that industry stakeholders have an important role in setting priorities for this work and will continue to be consulted during the development and conduct of any NT Government-sponsored program.

Technical, scientific and extension work for the NT vegetable industry has been conducted by DoR in its various forms from the early 1900s until the present. Most of the earlier work was on traditional European vegetables, such as asparagus, dwarf beans, broccoli, cabbage, capsicum, carrots, cauliflowers, eggplants, lettuce, onions, pumpkins, squash, sweet corn, sweet potatoes, potatoes, tomatoes, cucumbers and zucchini (Anonymous 1997a). More recent work has focussed on Asian vegetables (Anonymous 2007).

It appears that DoR's work on specific Asian vegetables did not begin until the mid- 1990s, according to Technical Annual Reports from 1995 to 2010. Asian vegetables grown in the NT included okra, snake beans, Asian melons (bitter melon, winter melon, hairy melon, luffa and sinquar) and Chinese cabbage (Anonymous 2007).

Most of the work done on vegetables can be divided into:

a) Post-harvest technology development
b) Agronomic practices
c) Variety/cultivar evaluation
d) Entomology
e) Plant pathology
f) Extension and capacity building.

This Technical Bulletin will first summarise the information given in "Annual Vegetable Crops Research – Past and Present Research Projects" (Anonymous 1997a), then present a summary of written information on work done post-1997 in more detail. Anonymous (1997a) included sweet melons in their summary. Work on sweet melons post-1997 will not be analysed, as the focus will be on vegetables.

PRE-1997 DEPARTMENTAL WORK ON VEGETABLES AND ANNUAL CROPS

INTRODUCTION

Most of the work previous to 1997 is well summarised (Anonymous 1997b) (Note: DPIF File 95 /1045 identifies Malcolm Smith as the coordinator of this document). It outlines the many projects completed for annual crops during the twentieth century (the earliest reference in the paper is 1913). One of the intentions was to 'provide researchers with a summary of what has already been done and by doing so, to assist with future research priorities'. It should be noted that work in Central Australia was not included in this document, but was reported in miscellaneous publications and Technical Annual Reports.

Projects were divided into the six themes or groups described above.
These are discussed in turn below. All references to work in this Section can be found in Anonymous (1997a) except where work is specifically referenced. Note that the analysis of this will be dealt with as a discussion at the end of this Technical Bulletin.

POST-HARVEST TECHNOLOGY DEVELOPMENT

A series of post-harvest experiments on rockmelons and other melons were conducted by Margaret Landrigan in the late 1980s, who assessed handling and storage techniques (Landrigan et al. 1990). Five trials were also done by Kevin Blackburn and Mark Traynor on various aspects of post-harvest handling and storage of rockmelons, onions and sweet potatoes from 1987 to 1991.

AGRONOMIC PRACTICES

Agronomic investigations in Darwin before 1997 covered the following topics:

- Plastic mulch (seven trials)
- Plant nutrition (17 trials)
- Ripening with growth regulators (five trials)
- Irrigation (17 trials)
- Fungicides and post-harvest dips (five trials)
- Tomato trellising (one trial)
- Pruning grafted tomato (one trial)
- Nematode control (one trial)
- Production scheduling (two trials)
- Plant spacing (one trial)
- Root selection and cutting production for sweet potatoes (one trial).

In Katherine, the following topics were covered:

- Yield decline in zucchini (one trial)
- Asparagus droughting (one trial)
- Irrigation (one trial)
- Plant nutrition (four trials)
- Green manure (three trials)
- Herbicide use (two trials)
- Plant density (one trial)
- Pollination (one trial)

- Brassica seed production (one trial)
- Asparagus planting density/depth (two trials).

In Central Australia, agronomic work covered:

- Surface crusting of soils in the Alice Springs region (Anonymous 1982)
- Harvest timing of asparagus (Hoult and Freeman 1990)
- Direct sowing of asparagus (Donnelly and Slinger 1990a).

VARIETY/CULTIVAR EVALUATION

From 1979 to 1995, 110 cultivar and variety evaluation trials were completed by Kevin Blackburn and Mark Traynor in the Darwin region. These trials evaluated the following crops. As some trials evaluated more than one crop at a time, there were more than the 110 trials listed below.

- Asparagus (three trials)
- Bamboo (one trial)
- Beans (one trial)
- Broccoli (five trials)
- Cabbage (four trials)
- Capsicum (four trials)
- Carrots (one trial)
- Cauliflower (four trials)
- Cherry tomatoes (one trial)
- Chinese cabbage (four trials)
- Cucumber (one trial)
- Eggplant (one trial)
- Green flesh melons (five trials)
- Honeydew and Hami melons (12 trials)
- Lettuce (one trial)
- Okra (one trial)
- Onions (six trials)
- Oriental melons (one trial)
- Potatoes (eight trials)
- Pumpkins (three trials)
- Rockmelons (18 trials)
- Squash (one trial)
- Strawberries (two trials)
- Sweet corn (five trials)
- Sweet potatoes (seven trials)
- Tomatoes (eight trials)
- Watermelons (eight trials)
- Zucchini (two trials).

Variety and cultivar evaluation in Katherine during this period was not as extensive, comprising 22 trials conducted by Jeremy Bright, Ray Thompson and Bryce Merrett from 1984 to 1993 on the following crops:

- Asparagus (one trial)
- Cabbage (one trial)
- Capsicum (two trials)
- Carrots (one trial)

- Cauliflower (one trial)
- French beans (two trials)
- Honey dew melons (one trial)
- Lettuce (two trials)
- Onions (one trial)
- Potatoes (two trials)
- Rockmelons (three trials)
- Sweet corn (two trials)
- Tomatoes (two trials)
- Watermelons (one trial).

Variety work in Central Australia was conducted by Michael Donnelly, Wayne Tregea, Shirley Freeman, Peter Slinger and Mark Hoult. The trials were conducted on the following crops:

- Watermelons (Donnelly and Slinger 1990b)
- Rockmelons (Donnelly and Slinger 1990b)
- Butternut pumpkins (Tregea and Donnelly 1990a)
- Button squash (Tregea and Donnelly 1990b)
- Tomatoes (Tregea and Donnelly 1990c)
- Asparagus (Hoult et al. 1990) (Hoult et al. 1993).

ENTOMOLOGY

The work reported on annual vegetable crop entomology in (Anonymous 1997a) was focussed on the Darwin region. The work covered the following:

- Surveys and identifications (nine projects)
- Chemical control and integrated pest management (27 trials)
- Extension (two projects)
- Fruit flies (11 projects)
- Melon thrips (*Thrips palmi*) (nine projects).

PLANT PATHOLOGY

Plant pathology work during this period related to the following areas:

- Tomato leaf roll disease (two projects)
- Cucurbit virus (two projects)
- Sweet potato feathery mottle virus (one project)
- Cucurbit stunting (one project).

EXTENSION

From 1994 to 1995, a list was prepared of Asian vegetables, herbs and spices and their pests and diseases. Nematodes were identified as a major pest in this group. It was also determined that Asian vegetable extension should focus on sustainable production systems, in particular green manure crops, lime and dolomite, selection of soil cultivation implements, pest and disease control and packaging, and post-harvest. The provision of entomology extension services, particularly with management advice, was also mentioned as an activity.

POST-1997 DEPARTMENTAL WORK ON VEGETABLES AND ANNUAL CROPS

INTRODUCTION

Work from 1997 to 2011 is catalogued in Tables 1 to 6 below. This was from Technical Annual Reports (which were published separately for the Horticulture Division from 1989 to 2004), with some externally published articles. Reports were grouped as follows:

a) Post-harvest technology development
b) Agronomic practices
c) Variety/cultivar evaluation
d) Entomology
e) Plant pathology
f) Extension and capacity building.

Table 1. Post-harvest technology development

Year	Title	Reference
1998	Studies on the effects of storage temperature and packaging on the shelf-life of selected Asian vegetables	(Lim et al. 1998)
1999	Post-harvest handling of Asian vegetables – Vegetable cool chain	(Gosbee 1999c)
1999	Effect of temperature and packaging on the shelf-life of bitter melons and okra	(Gosbee 1999b)
1999	Bitter melon harvest maturity	(Gosbee and Marte 1999)
1999	Post-harvest handling of Asian vegetables in the Northern Territory	(Gosbee and Lim 1999)
1999	Bamboo post-harvest	(Gosbee 1999a)
2000	Optimising storage conditions for selected Asian vegetables	(Gosbee and Marte 2000a)
2000	Vegetable cool chain	(Gosbee and Marte 2000b)

Table 2. Agronomic practices

Year	Title	Reference
1997	Legumes as a green manure crop	(Smith et al. 1997)
1997	Productivity responses of asparagus to droughting in a tropical environment	(Bright et al. 1997)
1998	Plant nutritional studies on a host of annual crops – Farm production efficiency improvement – Petiole sap monitoring of cucurbit crops	(Blackburn and Traynor 1998c)
1998	Asparagus response to droughting	(Bright and McAlister 1998)
1998	Asparagus post-harvest field herbicides	(Bright 1998b)
1999	Farm productivity efficiency improvement – Petiole sap monitoring of cucurbit crops	(Blackburn and Traynor 1999c)
1999	Asparagus response to droughting	(Bright 1999c)
1999	Asparagus post-harvest field herbicides	(Bright 1999b)
2000	Alternative growing techniques double production of bitter melon	(Traynor and Crowson 2000)
2000	Plant nutritional studies on a host of annual crops – Petiole sap monitoring of annual crops in the Katherine region	(Bright and McAlister 2000)
2000	Management of annual crops and asparagus	(Bright 2000c)
2005	Taro fertiliser rate trial	(Traynor 2005)
2008	Commercial scale production of *Solanum centrale* inputs and methods	(Hargreaves 2008)
2009	A preliminary investigation into commercial scale production of *Solanum centrale* (bush tomatoes) – the role of irrigation and weed competition on yield	(Ellis 2009)
2010	Challenges and opportunities for commercial scale bush tomato production	(Ellis et al. 2010)

Table 3. Variety/cultivar evaluation

Year	Title	Reference
1997	Bamboo research	(Blackburn and Traynor 1997)
1998	Evaluate bamboo cultivar considered suitable for culinary, wind break and timber purposes	(Blackburn and Traynor 1998b)
1998	Asparagus cultivar evaluation	(Bright 1998a)
1999	Bamboo research	(Blackburn and Traynor 1999b)
1999	Asparagus cultivar evaluation	(Bright 1999a)
2000	Bitter melon (*Momordica charantia*) selection trial	(Blackburn and Traynor 2000)
2000	Kabocha variety trial	(McAlister et al. 2000)
2000	Cultivar evaluation of a host of annual crops – Katherine component	(Bright et al. 2000)
2000	Asparagus cultivar evaluation	(Bright 2000b)
2001	Bitter melon hybrid yield evaluation trial	(Traynor and Gosbee 2001)
2001	Kabocha variety trial	(Kinnaird et al. 2001)
2001	Development of vegetable production systems – snake bean variety evaluation 2000	(Traynor et al. 2001)
2001	Improved management strategies and vegetable products for the NT (Identify vegetable types suitable to the Helen Springs region)	(Bright et al. 2001)
2001	Bamboo	(Traynor 2001)
2002	Japanese taro observation trial 2002	(Traynor and Hopkinson 2002)
2002	Bamboo research 2001-02	(Traynor 2002)
2003	Bamboo research 2002-03	(Traynor 2003)
2004	Bamboo research 2003-04	(Traynor 2004)
2004	Sweet potato variety trial	(Traynor et al. 2004)
2004	Potato observation trial	(Bird 2004)

Table 4. Entomology

Year	Title	Reference
1997	Monitoring poinsettia whitefly, *Bemisia tabaci* type-B in protected cultivation	(Young and Zhang 1997d)
1997	Root knot nematode *Meloidogyne* spp.	(Young et al. 1997)
1997	Parasites of the cowpea aphid and the melon aphid	(Young and Zhang 1997e)
1997	Bean fly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae)	(Young and Zhang 1997a)
1997	Integrated pest management of vegetables with particular reference to snake beans (*Vigna unguiculata*)	(Young and Zhang 1997b)
1997	Melon thrips integrated pest management on eggplant	(Young and Zhang 1997c)
1998	Root knot nematode *Meloidogyne* spp.	(Young and Zhang 1998c)
1998	Parasites of the cowpea aphid and the melon aphid	(Young and Zhang 1998b)
1998	Integrated pest management of vegetables, with particular reference to snake beans (*Vigna unguiculata*)	(Young and Zhang 1998a)
1998	*Thrips palmi* Karny (Thysanoptera: Thripidae) integrated pest management on eggplant	(Young and Zhang 1998d)
1999	Integrated pest management of vegetables with particular reference to bean flies attacking snake beans (*Vigna unguiculata*)	(Young and Zhang 1999a)
1999	*Thrips palmi* Karny (Thysanoptera: Thripidae) Integrated pest management on egg plant	(Young and Zhang 1999b)
1999	Trials of soft chemicals against pests with multiple resistance to chemical insecticides	(Young and Zhang 1999c)
2000	Asian vegetable extension service	(Crowson 2000)
2000	Integrated pest management of vegetables with particular reference to bean flies attacking snake beans (*Vigna unguiculata*)	(Young and Zhang 2000a)
2000	*Thrips palmi* Karny (Thysanoptera: Thripidae) integrated pest management on eggplant	(Young and Zhang 2000b)
2000	Trials of soft chemicals against pests with multiple resistance to chemical insecticides	(Young and Zhang 2000c)
2001	Pest management of tropical vegetables	(Zhang et al. 2001)
2002	Pest management in tropical vegetables	(Thistleton et al. 2002)
2003	Pest management of tropical vegetables	(Thistleton and Neal 2003)
2004	Pest management in tropical vegetables	(Thistleton and Neal 2004)

Table 5. Plant Pathology

Year	Title	Reference
1997	Crop disease surveys – asparagus	(Conde et al. 1997c)
1997	Asparagus anthracnose disease	(Conde et al. 1997a)
1997	Management practices for disease control in Asian vegetables	(Conde et al. 1997b)
1998	Asparagus *Colletotrichum* control	(Bright and Conde 1998)
1998	Crop disease surveys – Asian vegetables	(Conde et al. 1998b)
1998	Management system for asparagus anthracnose	(Conde et al. 1998a)
1998	Management system for major diseases of Asian vegetables	(Conde and Pitkethley 1998)
1999	Asparagus *Colletotrichum* control	(Bright and Conde 1999)
1999	A management system for asparagus anthracnose	(Conde et al. 1999a)
1999	A management system for major diseases of Asian vegetables	(Conde et al. 1999b)
2000	Asparagus *Colletotrichum* control	(Bright 2000a)
2000	Management system for diseases of asparagus	(Conde et al. 2000b)
2000	Management system for major diseases of Asian vegetables – Fusarium wilt and base rot of basil	(Conde and Arao-Arao 2000b)
2000	Management system for major diseases of Asian vegetables – Cucurbit mosaic viruses	(Conde and Arao-Arao 2000a)
2000	Management system for major diseases of Asian vegetables – Snake bean wilt	(Conde et al. 2000a)
2001	Management system for diseases of asparagus	(Conde et al. 2001)
2001	Snake bean *Fusarium* survey	(Gosbee and Bui 2001)
2001	Management systems for diseases of Asian vegetables – Fusarium wilt of snake beans	(Conde and Arao-Arao 2001c)
2001	Management system for diseases of Asian vegetables – Fusarium wilt of basil	(Conde and Arao-Arao 2001a)
2001	Management system for major diseases of Asian vegetables – Cucurbit mosaic viruses	(Conde and Arao-Arao 2001b)
2002	Management systems for diseases of Asian vegetables	(Conde and Arao-Arao 2002b)
2002	Management system for Fusarium wilt of snake beans	(Conde and Arao-Arao 2002a)
2003	Management systems for diseases of Asian vegetables	(Conde and Arao-Arao 2003a)
2003	Management systems for Fusarium wilt of snake beans	(Conde and Arao-Arao 2003b)
2004	Management systems for diseases of Asian vegetables	(Conde and Arao-Arao 2004b)
2004	A management system for Fusarium wilt of snake beans	(Conde and Arao-Arao 2004a)
2005	Management systems for diseases of Asian vegetables	(Conde and Arao-Arao 2005b)
2005	A management system for Fusarium wilt of snake beans	(Conde and Arao-Arao 2005a)
2006	A management system for Fusarium wilt of snake beans	(Conde and Arao-Arao 2006a)
2006	Management systems for diseases of vegetables – Tomatoes	(Conde and Arao-Arao 2006b)
2006	Management system for diseases of vegetables – Cucurbit powdery mildew	(Bhuiyan *et al.* 2006)
2009	Best practice IPM strategies for the control of major soil borne diseases of vegetable crops in Australia – Fusarium wilt of snake beans in the NT	(Conde et al. 2009)
2010	Controlling snake bean Fusarium wilt in the NT	(Conde et al. 2010)

Table 6. Extension and capacity building

Year	Title	Reference
1997	Asian vegetable grower group	(Greenwell 1997)
1998	Asian vegetable research – RIRDC project	(Blackburn and Traynor 1998a)
1999	Asian vegetable research	(Blackburn and Traynor 1999a)
2000	Provide assistance to the vegetable industry and assist with its future expansion	(Bright 2000d)
2001	Asian vegetable demonstration plot	(Owens et al. 2001)
2001	Vegetable management trial 2000	(Darcey et al. 2001)
2001	Improved management strategies and vegetable products for the NT (vegetable grower discussion groups – Katherine)	(Bright 2001)
2003	Asian vegetables – Industry development	(Walduck et al. 2003)
2004	Asian vegetables – Best practice	(Walduck et al. 2004)
2005	Asian vegetables – Best practice	(Walduck et al. 2005)
2006	Asian vegetables – Best practice	(Walduck et al. 2006)
2007	Product description languages for Asian vegetables and minor tropical crops	(Walduck et al. 2007)

DISCUSSION

As the bulk of this discussion refers to the papers outlined in Tables 1 to 6, specific references will not be used.

POST-HARVEST TECHNOLOGY DEVELOPMENT

Pre-1997

Little post-harvest vegetable work was reported before 1997, except work on rockmelons, sweet potatoes and onions.

Post-1997

The major achievement in post-harvest technology development post-1997 was to determine optimum storage temperature and preferred packaging to maximise shelf-life of bitter melons, okra, sinquar, snake beans, kang kong, basil and bamboo. Temperature logging work also showed that there were weak links in the cool chain for vegetables, especially from the field to the transport accumulators (small transport companies that consolidate small consignments into refrigerated containers for interstate transport), and occasionally also from the point of accumulation to interstate markets.

Although the requirements for cool storing of Asian vegetables have been well articulated, there is still scope for the development of simple ways to immediately cool hot produce after harvest. An extension program is needed to educate growers about the best ways of handling produce immediately post-harvest until despatch from the property.

AGRONOMIC PRACTICES

Pre-1997

Darwin

Plant nutrition, irrigation and the use of plastic mulch were extensively studied in Darwin, especially for rockmelon crops. Standards for sap testing were developed. Crops are now grown with plastic mulch and drip tape using the technology developed. Irrigation scheduling practices were also developed. Post-harvest dips and ripening agents received some attention, and there were various other small trials.

Katherine

In Katherine, extensive work was done in the asparagus industry. Variety evaluation, droughting and the management of disease were important R&D areas. There were two growers with large areas at the time.

Hybrid brassica seed crops were also evaluated in Katherine for two seasons. Then they were abandoned due to difficulties with pollination and synchronisation of flowering between the parent lines of the crops being grown.

Some green manure research was also completed, along with herbicide, plant density, plant nutrition and pollination work.

Central Australia

In Central Australia, some work was done on direct sowing and harvest time of asparagus. Direct sowing was found to be viable and alternative harvest regimes were warranted to spread harvest time. Asparagus was grown commercially in Central Australia for some time but there is no industry at present.

Post-1997

Darwin

Investigations of techniques, methods and standard nutrient levels for petiole sap monitoring continued in both Darwin and Katherine, especially with cucurbit crops, until 2000. Recommended nutrient levels were developed for Lebanese cucumbers, button squash and rockmelons. Since then, no further work was completed. Nutrition work on taro in 2005 refined the fertiliser program for this crop.

Many growers still use petiole sap monitoring, sending samples both to interstate laboratories and to DoR's chemistry laboratory. There are still problems with interpreting of the results. For example, growing conditions and time of day affect composition of the cell sap. The validity of sap monitoring should be studied in its own right, and used as a research tool to refine the nutrition program for a range of vegetables.

Katherine

A growing system for asparagus was developed in the Katherine area, including droughting and the use of herbicides, carrying on from work done pre-1997. Unfortunately, asparagus growers discontinued operations in the area and R&D stopped.

Central Australia

Work began on cultivation of the native species *Solanum centrale* in Central Australia, with little success so far. A wild harvest industry currently exists. This industry is in an early stage of development and there is a large scope for further development.

VARIETY/CULTIVAR EVALUATION

Pre-1997

Darwin

The work done on sweet melons (rock, water, honeydew, and hami melons) was substantial during this period with the result that this is now a significant industry in the Darwin region, with $8.2 million worth of fruit produced in 2009 (Anonymous 2010). However, as no cultivar evaluation has been done post-1997, this work needs to recommence.

Tomatoes, brassicas, onions, sweet corn, potatoes and sweet potatoes, each had five or more trials dedicated to their evaluation during this time. These vegetables are now in demand by local supermarkets who have adopted a policy of procuring local produce where possible. However, little of this produce is currently grown in the Darwin region (Patti Flannery, pers. comm., 13 January 2011). This demand for locally-grown produce may attract growers of these crops.

Very few Asian vegetables were evaluated, with only one trial each on Asian melons, bamboo and okra. This probably reflects the lack of development in this industry during this period. However, starting from 1995, the industry has grown substantially and is now valued at approximately $18.7 million (Anonymous 2010).

Katherine

As in Darwin, Katherine supermarkets are now looking for local sources of these and other vegetables (Patti Flannery pers. comm. 13 January 2011). The existing annual crop industry in Katherine is dominated by sweet melons (water and rock melons) and pumpkins, which had an approximate value of $16.2 million in 2009 (Anonymous 2010). Some other commodities, such as onions, potatoes, cabbages and cauliflower are also grown in Katherine on a small scale.

Central Australia

Asparagus was evaluated extensively in Alice Springs and was found to produce commercial yields of high quality (Hoult and Martin 1989). However, there is no asparagus industry in Alice Springs at present.

Many other vegetables were trialled in Central Australia, including watermelons, rockmelons, butternut pumpkins, button squash and tomatoes but only small amounts are now grown in this area. However, other forms of pumpkin are grown commercially at Ali Curung, approximately 400 km north of Alice Springs.

Post-1997

Darwin

Several culinary bamboo cultivars were evaluated, including *Dendrocalamus latiflorus* and *D. asper.* A growing system was developed for NT conditions. It included fertilising, manipulation of culm number and post-harvest management. Unfortunately, the culinary bamboo industry in the NT is still quite small.

Bitter melon varieties were screened and evaluated in conjunction with growers. As a result, most of the industry moved from a local open-pollinated selection to a higher-yielding hybrid selection, which is still used extensively today. This is one of the more successful cultivar evaluations, perhaps as a result of an existing industry that was prepared to engage itself in the evaluation, resulting in its subsequent adoption.

Sweet potato cultivar screening in 2004 revealed that several cultivars were well suited to NT growing conditions, including cultivars recently developed in Queensland. Beauregard was identified as the superior orange flesh/orange skin variety and Northern Star as the best purple-skin, white-flesh variety. There is no commercial sweet potato industry in the NT at present. However, there are emerging opportunities for supplying local supermarkets (to replace imports from interstate) and remote Indigenous communities with locally-grown sweet potatoes.

A number of Kabotcha cultivars were screened. These are now only grown on a small scale on some melon-growing properties.

Although 39 snake bean varieties were screened, there has been no change in the variety used in the local industry (green pod Kaoshing) despite its susceptibility to soil-borne diseases and nematodes. There is scope for continuing to investigate snake bean varieties developed overseas. There is no current breeding activity in Australia. Because of the difficulty of importing seed, it may be best to attempt to breed superior snake beans in the NT and to continue the work already started in plant pathology.

Katherine
Observations at Katherine determined that potatoes could be grown there, but with quite low yields.

General comment
The number of varieties and cultivars evaluated in the past has been high, but the last trials were done so long ago that newly-developed cultivars make previous recommendations obsolete. In future, cultivar trials of vegetables that are now grown (cucumbers, okra, bitter melons and snake beans) and those demanded by supermarkets (tomatoes, brassicas, onions, sweet corn, potatoes and sweet potatoes) but not now grown, would be advisable to update recommendations.

ENTOMOLOGY

Pre-1997

Chemical control, integrated pest management (IPM), surveys and identifications were major foci. Several projects were dedicated to the study of fruit flies and melon thrips, establishing the importance of these pests during this time.

Chemical control and IPM work led to effective recommendations for the vegetable industry. Some of these will need to be updated due to available new soft pesticides, more specific for pests and safer to beneficials.

Post-1997

Major pests investigated post-1997 were poinsettia whiteflies (*Bemisia tabaci* type-B), root-knot nematodes (*Meloidogyne* spp.), melon thrips (*Thrips palmi*), cowpea aphids *(Aphis craccivora*), melon aphids (*Aphis gossypii*), bean flies (*Ophiomyia phaseoli*) and two-spotted mites (*Tetranychus urticae*).

Major achievements included the development of a system to control two-spotted mites with the Chilean predatory mite and the use of potassium soap to control aphids, whiteflies and melon thrips. Many parasitoids and predators of the major pests were identified.

A major extension effort delivered this technology to growers. Because of this work, most of the pests mentioned above are now well controlled in vegetable crops with soft control options. Pests that are still problematic include *Spodoptera litura*, and *Meloidogyne* spp. (root-knot nematodes). Melon aphids

also transmit cucurbit viruses, such as the cucurbit strain of papaya ring-spot virus (PRSV-W) and zucchini yellow mosaic virus (ZYMV). They can be a problem for cucurbits in some seasons.

PLANT PATHOLOGY

Pre-1997

Most of the work on vegetable virus identification in the NT was done during this time. Some of the important viruses identified included ZYMV, the tomato leaf curl virus and the sweet potato feathery mottle virus.

Post-1997

A number of vegetable diseases have been studied by DoR in the NT since 1997. The major vegetable diseases are listed in Table 7.

Major achievements from this work included the development of a management system for anthracnose on asparagus, which involved burning of native asparagus, the use of drip tape, removing trash, regular fungicide sprays and deep-ripping to encourage asparagus growth at the expense of the disease. However, the screening of asparagus cultivars for disease resistance was not successful.

Fusarium on snake beans (Table 7) was discovered in the 1998-99 season. Three distinct isolates based on culture characteristics have been identified. Many cultivars of both snake beans and cow peas have been screened for resistance. Some cowpeas (especially “iron” cowpea) were found to be resistant. These were used as rootstocks for grafting scions of commercial varieties, especially green pod Kaoshing. Although quite successful, it had a low level of adoption. There is presently no marketable *Fusarium*-resistant variety. Crossing of resistant cowpeas with the commercial variety has commenced. However, it appears that the resistance gene is recessive; so further backcrossing and screening will be necessary to develop a resistant cultivar.

Basil is affected by another race of *Fusarium* that has caused major losses. After screening by DoR, the Israeli cultivar “Nufar F1” has expressed some resistance to the disease but has not been well accepted in the market. The small number of basil growers in the Top End use crop rotation to manage the disease.

Table 7. Major diseases investigated in the vegetable industry post-1997

Crop	Disease	Scientific name
A range of cucurbit crops	Zucchini yellow mosaic virus	ZYMV
A range of vegetables	Root knot nematode	*Meloidogyne incognita* and *M. javanica*
Asparagus	Anthracnose	*Colletotrichum gloeosporioides*
Asparagus	Crown rot	*Fusarium*
Basil	*Fusarium* wilt	*Fusarium oxysporum* f. sp. *basilici*
Basil	Leaf spot	*Cercospora guatemalensis*
Bitter melon	Leaf spot	*Cercospora citrillus*
Lettuce	Tomato spotted wilt virus	TSWV
Snake beans	Powdery mildew	*Sphaerotheca fuliginea*
Snake beans	Cercospora leaf spot	*Pseudocercospora cruenta*
Snake beans	*Fusarium* wilt	*Fusarium oxysporum* f. sp. *tracheiphilum*
Snake beans	Rust	*Uromyces appendiculatis*
Snake beans	Tomato big bud phytoplasma	
Tomatoes	Tomato leaf curl geminivirus	TLCV – Au
Watermelon	Powdery mildew	*Podosphaera xanthii* f. sp. *citrillus*
Watermelon	Leaf spot	*Cercospora citrullina*

A number of virus diseases have been investigated by the Plant Pathology Group. ZYMV has been consistently detected in cucurbit crops over the years, particularly in long melon, which is highly susceptible. Farm hygiene, destruction of host crops, together with the control of aphid vectors have been recommended to growers as a way to manage this disease. The tomato leaf curl virus, which is transmitted by whiteflies in tomatoes, has also been a problem; however, there are no commercial plantings to warrant work on this disease.

The tomato big bud phytoplasma, which had also been recorded in snake beans, was rediscovered affecting up to 20% of plants in a snake bean crop in 2011.

EXTENSION AND CAPACITY BUILDING

Pre-1997

Priorities for extension, particularly amongst Asian vegetable growers, were identified in the mid 1990s. Issues included the introduction of sustainable production systems, pest and disease control, and post-harvest management of crops. The Entomology Section worked with the extension group on a number of pest problems.

Post-1997

Extension activities in the vegetable industry have been intermittent since 1997. An Asian Vegetable Grower Group was formed in 1997 in the Darwin region, which identified a number of issues, including pests and diseases, local promotion of Asian vegetables and an investigation of export opportunities. In 1998 and 1999, after a survey of growers, a number of sustainability issues were identified by DoR, especially with regard to soil management. Plots were set up on grower properties to demonstrate

better practices. The number of demonstration sites was expanded in 2000 and 2001, with plots set up on neutral ground to demonstrate recommended technologies, such as the use of plastic mulch, drip tape and wet season cover cropping. This approach met with some success, as many growers visited the sites and adopted the technology. At this time, funding was secured for a Vietnamese speaking Asian vegetable industry development officer, based at the NT Horticultural Association. Posters were designed by DoR on pests and diseases of Asian vegetables; Agnotes and other publications were translated into Vietnamese and distributed.

Demonstrations were also conducted of new crops. For example, a sweet potato demonstration at Coastal Plains led to some attempts at planting on a commercial scale. However, there are no commercial sweet potato growers at present. Later, product description languages, in the form of posters that describe quality parameters of produce for all parts of the supply chain, were developed for snake beans and Lebanese cucumbers. They were translated into Vietnamese and Cambodian.

A vegetable discussion group set up in Katherine had a few meetings and identified problems for the region in the areas of nutrition, irrigation, cultivars, post-harvest, entomology, pathology, management, weeds and water resources. There is no record of ongoing discussions beyond the initial meetings in 2000 and 2001.

Current extension needs are different from those in the 1990s. The size of vegetable farms has increased, most of which now use better growing techniques. For the Darwin area at least, product quality is an ongoing problem. So better handling, grading and post-harvest temperature management are also high priorities.

CONCLUSIONS

DoR needs to promote improved practices to NT vegetable growers and to conduct R&D activities to discover new knowledge to fill gaps where current growing systems are inadequate. These can be arranged under the current drivers of DoR's Plant Industries business plan (R. Williams pers. comm.). These drivers are:

- Increase productivity, production efficiency and product quality.
- Develop and maintain markets.
- Strengthen business adaptability.
- Enhance sustainability and natural resource management.

RECOMMENDATIONS

Increase productivity, production efficiency and product quality

Post-harvest technology development

- Promote quick-cooling after harvest and pre-transport storage in a cool room.
- Promote cool-chain integrity at all stages from storage to market.
- Monitor cool-chain performance for selected vegetable loads.

Agronomic practices

- Study the validity of sap monitoring and use it as a research tool to refine the nutrition program for a range of vegetables.
- Develop a commercial growing system for bush tomatoes in Central Australia.

Variety/cultivar evaluation

- Conduct cultivar trials of the major vegetable varieties every two to three years.

Develop and maintain markets? See drivers above

Strengthen business adaptability

Extension

- Engage growers and determine their information needs.
- Engage industries that support the extension effort, including input suppliers, transport providers and wholesalers, and determine their information needs.

Enhance sustainability and natural resource management

Entomology

- Encourage adoption of IPM.
- Develop an IPM system for *Spodoptera litura.*

Plant pathology

- Screen major vegetable varieties, especially snake beans, for resistance to *Fusarium* sp.
- Continue breeding snake beans for resistance to *Fusarium* sp.
- Investigate the use of organic amendments and crop rotation as methods to control soil-borne diseases and nematodes.
- Conduct extension activities to explain hygiene and insect management as a way of managing cucurbit viruses.

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