REVIEWS

Distribution and biological control of cactus species in eastern Australia

J. R. Hosking
New South Wales Department of Agriculture, Agricultural Research Centre, R.M.B. 944, Tamworth, N.S.W. 2340

R. E. McFadyen
Queensland Department of Lands, The Alan Fletcher Research Station, P.O. Box 36, Sherwood, Queensland 4075

N. D. Murray
Department of Genetics and Human Variation, La Trobe University, Bundoora, Victoria 3083

Summary

Maps are presented detailing present distributions of cactus species in eastern mainland Australia. Also included are the areas of origin, common names, plant features and the first recorded Australian occurrence for each species. Biological control agents for each cactus are listed along with information on whether these agents are established in Australia and the degree of control achieved by them.

Introduction

Dodd (1940) published a distribution map for *Opuntia stricta* (Haw.) Haw. varieties and since then the only detailed cactus distribution maps to be published were for *Eriocereus martinii* (Labouret) Riccob. in Queensland (Mann 1970, Johnston and Lloyd 1982, McFadyen 1986) and *Opuntia aurantiaca* Lindley in New South Wales (Hosking and Deighton 1979). This paper updates the earlier maps and describes more species than are mentioned in previous publications. Superficial maps for most species were provided by I. Telford, with assistance from the authors, for 'Flora of Australia: Volume 4' (Telford 1984). The maps will be of interest to those working on biological control of weeds and weed control in general. Dried specimens of each of the cactus species discussed here are stored in the herbarium of the Canberra Botanic Gardens.

Biological control agents for each cactus species are listed along with comments on whether they are established in Australia and the degree of control achieved by them. These insects, mites and pathogens are often best suited to certain habitats. Such data, where known, are included here. Reviews such as those of Dodd 1940, Mann 1969, 1970, Moran and Zimmermann 1984 and Julien 1987 should be consulted for further information on biological control of cactus.

Materials and methods

Nomenclature of cactus species used in this publication corresponds to that used by Telford (1984). Most of the species are described in Telford (1984) and those species not covered by him are described in Britton and Rose (1919–1923) and Benson (1982).

The maps were compiled from information on files and from officers of the Prickly-Pear Destruction Commission of New South Wales and the Department of Lands in Queensland, museum specimens and from the personal observations of the authors.

New information on biological control agents has been gathered from personal observations and unpublished experiments.

Distribution of cactus species and their biological control agents

The cactus species are listed in alphabetical order with information on areas of origin, common names, first records in Australia, present distribution and biological control agents. Some plant features are included, particularly those relating to presence or absence of spines, clump-forming ability and whether plants are dispersed by seed or vegetatively.

1. Acanthocereus pentagonus *(L.) Britton & Rose*

A. pentagonus, sword pear, is native to southern Texas, peninsular Florida, the Keys and thence south to northern South America (Benson 1982). It has spiny stems upright to 2–3 m and then arching over to form dense clumps. The large white flowers open at night and ripe fruit is eaten by birds and mammals.

The means of introduction to Australia is unknown; the earliest record is from Springsure, Qld, in 1926. The species now occurs in wooded country over a large area north and south of Gogango in Central Queensland and in several small patches between Charters Towers and Jandowae (Figure 1). The mealybug *Hypogeococcus festerianus* (Lizer y Trelles) (Hemiptera: Pseudococcidae), introduced for the biological control of harrisia cactus, *E. martinii*, is established at Gogango and provides reasonable control. No other insects are recorded from this cactus.

2. Echinopsis multiplex *(Pfeiffer & Otto) Zucc.*

E. multiplex is native to Brazil (Mann 1970). Commonly cultivated in gardens for its delicate trumpet-shaped pink flowers, it forms dense clumps and has occasionally become naturalized from garden escapes. Only one infestation, near Clermont in Central Queensland, is known to exist at present (Figure 2).

No biological control of this cactus has been attempted and there are no records of insects feeding on it in Australia.

3. Eriocereus ?bonplandii *(Parm. ex Pfeiffer) Riccob.*

Mann (1970) lists *Eriocereus regelii* Weng as naturalized north of Jandowae, Qld. In 1982 an area of several hectares of an *Eriocereus* sp. with spineless fruit was discovered at Springton near Duaringa in Central Queensland (Figure 3). These plants, reaching over 3 m tall when supported by trees, appeared identical to *E. bonplandii*, a common species in the eastern Chaco of Argentina (McFadyen 1986). When the plants at Jandowae were subsequently re-examined, they appeared to be the same species. However, no authoritative identification has yet been obtained (Telford 1984).

The mealybug *H. festerianus* has been released on *E. ?bonplandii* at Jandowae and Springton, resulting in satisfactory control in both areas.

4. Eriocereus martinii *(Labouret) Riccob.*

E. martinii, harrisia cactus, is a native of the Chaco of Argentina and Paraguay (McFadyen 1979). Harrisia is the name Britton and Rose adopted for the genus *Eriocereus* (Britton and Rose 1919–23). *E. martinii* grows as a rambling tangled mass with 1 or 2 central spines (10–35 mm long) and 5 to 7 radial spines (1–6 mm long) per areole. This species has large

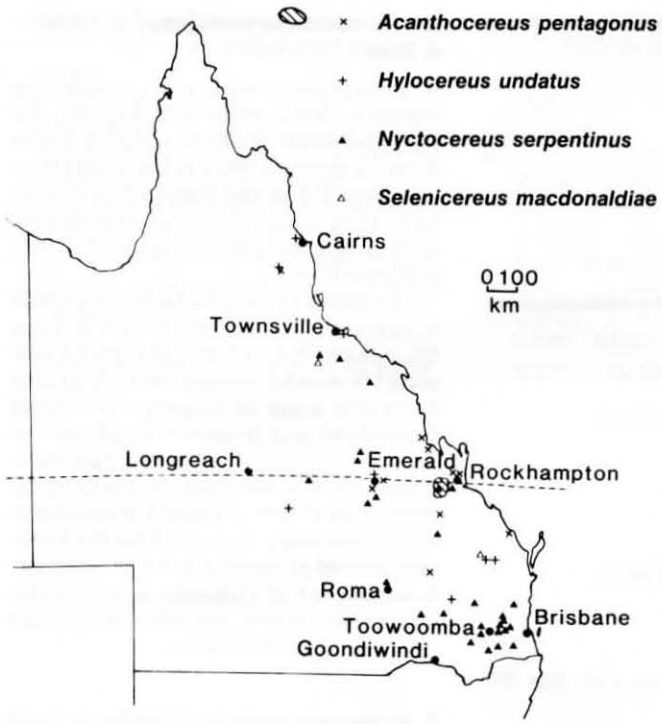

Figure 1 (above) Distribution of *Acanthocereus pentagonus, Hylocereus undatus, Nyctocereus serpentinus* and *Selenicereus macdonaldiae*. Shaded areas are over 100 ha, other areas are less than 100 ha.

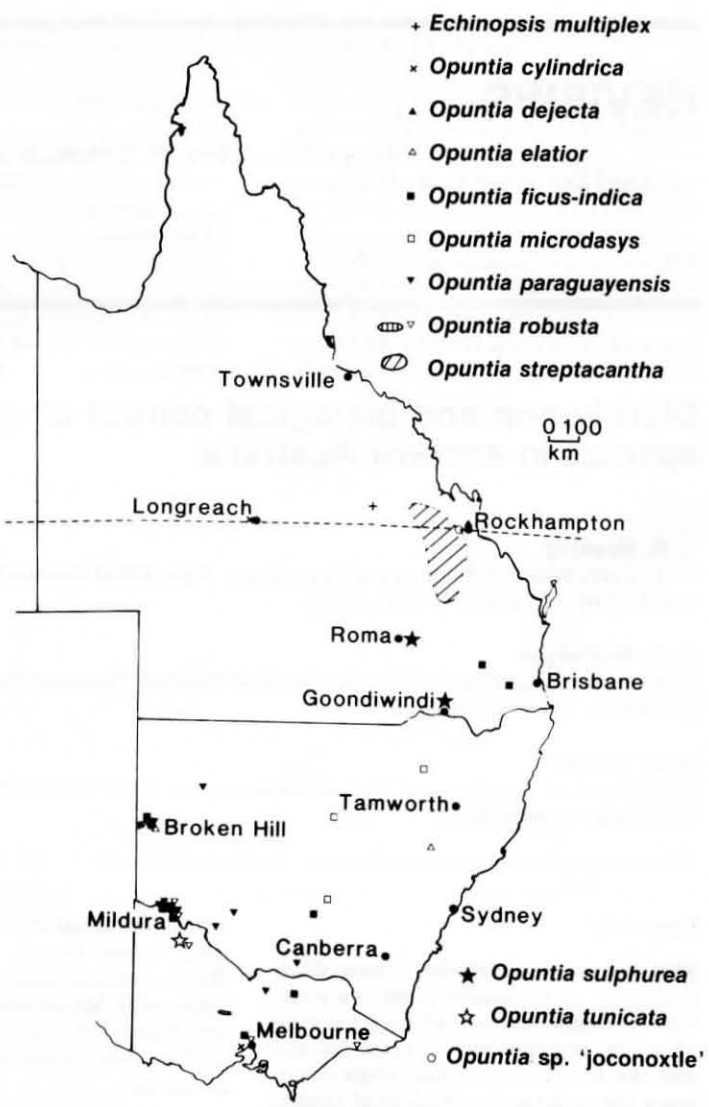

Figure 2 (right) Distribution of *Echinopsis multiplex, Opuntia cylindrica, O. dejecta, O. elatior, O. ficus-indica, O. microdasys, O. paraguayensis, O. robusta, O. streptacantha, O. sulphurea, O. tunicata* and *O.* sp. 'joconoxtle'. Shaded areas are over 100 ha, other areas are less than 100 ha.

white flowers which open at night. *E. martinii* is mainly spread by seed, fruits being eaten by both birds and mammals.

The earliest record of introduction of *E. martinii* is as a pot plant brought to Gatton in about 1886 (Mann 1967). *E. martinii* was first recorded as a weed in Queensland in 1935 (McFadyen and Tomley 1981). This species now occurs in discontinuous areas from the Collinsville district in central Queensland to northern New South Wales south of Goondiwindi (Figure 3).

E. martinii has been the object of a biological control program conducted for the Queensland Department of Lands by the Commonwealth Institute of Biological Control. Insects on *E. martinii* were studied and tested in Argentina. Following these tests, insects specific to *E. martinii* and related genera were sent to Queensland and released by the Department of Lands in Queensland. The most successful biological control agent introduced was *H. festerianus*. Queensland now relies on this insect for control of *E. martinii*. *H. festerianus* is still being hand distributed to spread this insect throughout *E. martinii* infestations (McFadyen and Tomley 1981). Two beetles, *Alcidion cereicola* Fisher (Coleoptera: Cerambycidae) and *Eriocereophaga humeridens* O'Brien (Coleoptera: Curculionidae), also became established (McFadyen and Tomley 1981) but the latter has since died out (McFadyen 1986). *Cactoblastis* new sp. (Lepidoptera: Pyralidae) (McFadyen 1980) was released but has not become established on *E. martinii*. Other insects found feeding on *E. martinii* are listed in Table 1.

5. Eriocereus tortuosus *(James Forbes ex Otto & A. Dietr.) Riccob.*

E. tortuosus is a native of Argentina (Telford 1984). This cactus is also known as harrisia cactus in Australia. *E. tortuosus* grows as a rambling tangled mass with 6 to 10 radial spines (1–3 cm long) and 1 to 3 central spines (2.5–6 cm long) per areole. The flowers are white.

E. tortuosus was planted in a garden at Western Creek Homestead, Millmerran, Qld, in about 1888 (Mann 1970). The largest infestation of *E. tortuosus* now occurs in this area, although some plants have escaped from gardens in the Hunter Valley, New South Wales (Figure 3).

H. festerianus causes severe damage to *E. tortuosus* in Queensland (McFadyen 1979) and is now relied on for control of this cactus. *Cactoblastis* new sp. introduced from Argentina for the control of *E. martinii* has possibly established on *E. tortuosus* but causes little damage. *A. cereicola* was released but did not establish. No other insects have been recorded on *E. tortuosus* in Australia.

6. Hylocereus undatus *(Haw.) Britton & Rose*

H. undatus, moonlight cactus, is a native of tropical America (Telford 1984). It is a common epiphyte in gardens throughout Queensland, growing up to 30 m high on trees, particularly ironbarks. Aerial roots attach the stems closely to the bark. During the summer there is profuse blooming of large white flowers opening at night, but the large red fruit rarely form.

Small patches of *H. undatus* are naturalized in and near towns from Cairns to Brisbane (Figure 1). Individual infestations increase quite rapidly but as fruit are rare, spread is minimal and *H. undatus* has never become a problem.

No biological control has been attempted against this cactus and no insects are recorded feeding on it.

7. Nyctocereus serpentinus *(Lagasca & Rodrigues) Britton & Rose*

N. serpentinus, snake cactus, is native to Mexico (Telford 1984). It has stems covered

Table 1 Summary of published information on biological control agents of minor importance not otherwise dealt with in the text

Cactus species	Biological control agent	Reference
Eriocereus martinii	*Chelinidea tabulata* (Burmeister) (Hemiptera: Coreidae)	Mann 1970
	Diplacaspis echinocacti (Bouché) (Hemiptera: Diaspididae)	Mann 1970
	Tucumania tapiacola Dyar (Lepidoptera: Pyralidae)	Mann 1970
Opuntia aurantiaca	*Moneilema ulkei* Horn (Coleoptera: Cerambycidae)	Mann 1969
	D. echinocacti	Mann 1969
	Mimorista pulchellalis Dyar (Lepidoptera: Pyralidae)	Moran 1981
Opuntia ficus-indica	*Archlagocheirus funestrus* Thompson (Coleoptera: Cerambycidae)	Annecke and Moran 1978
	Metamasius spinolae (Gyllenhal) (Coleoptera: Curculionidae)	Annecke and Moran 1978
Opuntia imbricata	*C. tabulata*	Anon. 1925
	T. tapiacola	Hoffman and Moran 1977
Opuntia streptacantha	*M. ulkei*	Mann 1970
	Olycella junctolineella (Hulst) (Lepidoptera: Pyralidae)	Mann 1970
Opuntia stricta	*Eriophyes* Von Siebold sp. (Acarina: Eriophyidae)	Mann 1970
	Tetranychus opuntiae Banks (Acarina: Tetranchidae)	Mann 1970
	M. spinolae (Gyllenhal)	Mann 1970
	M. ulkei Horn	Mann 1970
	Moneilema variolare Thomsom (Coleoptera: Cerambycidae)	Mann 1970
	Aphis armoraciae Cowen (Hemiptera: Aphididae)	Eastop 1966
	C. tabulata	Mann 1970
	Chelinidea vittiger Uhler (Hemiptera: Coreidae)	Mann 1970
	Dactylopius confusus (Cockerell) (Hemiptera: Dactylopiidae)	Mann 1970
	D. echinocacti	Mann 1970
	Melitara prodenialis Walker (Lepidoptera: Pyralidae)	Mann 1970
	O. juntiolineella	Mann 1970
	T. tapiacola	Mann 1970
Opuntia tomentosa	*T. opuntiae*	Mann 1970
	D. echinocacti	Mann 1970

with soft spines. The night-blooming flowers are large and white and the ripe fruit are red. It is frequently cultivated and has become naturalized outside towns throughout Queensland from Townsville to the New South Wales border (Figure 1). Occasional large infestations have developed but it is not considered a problem.

No biological control has been attempted againt *N. serpentinus* but the mealybug *H. festerianus* attacks this species and could be used for biological control.

8. Opuntia aurantiaca *Lindley*

O. aurantiaca is a native of Uruguay and the Entre Rios region of Argentina (Moran and Annecke 1979). This species is known as tiger pear in Australia and jointed cactus in South Africa. *O. aurantiaca* is the major cactus pest in New South Wales and South Africa. *O. aurantiaca* is also common in south-eastern Queensland where it is not now regarded as a serious problem (Mann 1970). *O. aurantiaca* grows as a low shrub rarely exceeding 40 cm in height, except where supported by other vegetation. Areoles have 3 to 7 spines up to 4 cm long. This cactus is mainly spread by floodwaters. The flowers are yellow, not orange as the species name suggests. Although fruit are common, seeds of *O. aurantiaca* are not viable (Moran and Annecke 1979).

The means of introduction of *O. aurantiaca* to Australia is not known. The pest potential of *O. aurantiaca* in Australia was recognized as early as 1911 (Maiden 1911*a*). *O. aurantiaca* is now common along watercourses in north-eastern New South Wales and south-eastern Queensland (Figure 4).

In 1933 *Dactylopius austrinus* De Lotto (Hemiptera: Dactylopiidae), under the name *D.* sp. nr. *confusus* (Cockerell), was released for control of *O. aurantiaca* (Mann 1970). This insect causes a lot of damage particularly in hot dry conditions (Hosking and Deighton 1981, Hosking 1984). *D. austrinus* controls *O. aurantiaca* in Queensland, although some manual redistribution of this insect is occasionally necessary. *D. austrinus* is assuming an increasingly important role in control of *O. aurantiaca* in New South Wales. Two moths, *Cactoblastis cactorum* (Berg) and *Tucumania tapiacola* Dyar (Lepidoptera: Pyralidae), also damage *O. aurantiaca* in Australia. *T. tapiacola* was specifically released for control of *O. aurantiaca* in 1935, while *C. cactorum* was released, largely for control of *O. stricta* varieties, in 1926 (Mann 1970). *C. cactorum* may cause considerable damage to clumps of *O. aurantiaca* but usually fails to kill all joints within clumps. *T. tapiacola* mostly causes minor damage to joints around the base of plants. *Aphis armoraciae* Cowen (Hemiptera: Aphididae) has been found on roots of *O. aurantiaca* (unpubl. data) but the degree of damage caused by this aphid is unknown. In recent years *Heliothis punctigera* Wallengren (Lepidoptera: Noctuidae), a native insect, has been recorded feeding on flowers and young joints but damage is minimal. Other insects which feed on *O. aurantiaca* are listed in Table 1. Two plant pathogens, *Colletotrichum* sp. close to *C. capsici* (Syd.) Butl. & Bisby (Coelomycetes) and *Phoma* close to *P. exigua* Desm. (Coelomycetes), cause minor damage to *O. aurantiaca*. This damage appears to be greatest in wet cool areas from late winter to early summer (unpubl. data).

9. Opuntia cylindrica *(Lam.) DC.*

O. cylindrica is native to Peru and Ecuador (Telford 1984), and is recorded by Telford (1984) as occasionally naturalized in New South Wales and Victoria as a garden escape. This species has been recorded from alongside the Werribee River in Victoria. A cactus which may be this species occurs naturalized in a small area near Longreach, Qld (Figure 2).

10. Opuntia dejecta *Salm-Dyck*

O. dejecta is probably native to Panama (Mann 1970). It has long narrow pads with long spines and grows as a much-branched, slightly drooping shrub. It is not known when it was introduced into Australia but a few plants are now naturalized just north of Rockhampton (Figure 2).

O. dejecta is attacked by *C. cactorum* and by the cochineal *Dactylopius oppuntiae* Cockerell (Hemiptera: Dactylopiidae).

11. Opuntia elatior *Miller*

O. elatior is a native of Panama and northern South America (Telford 1984). This

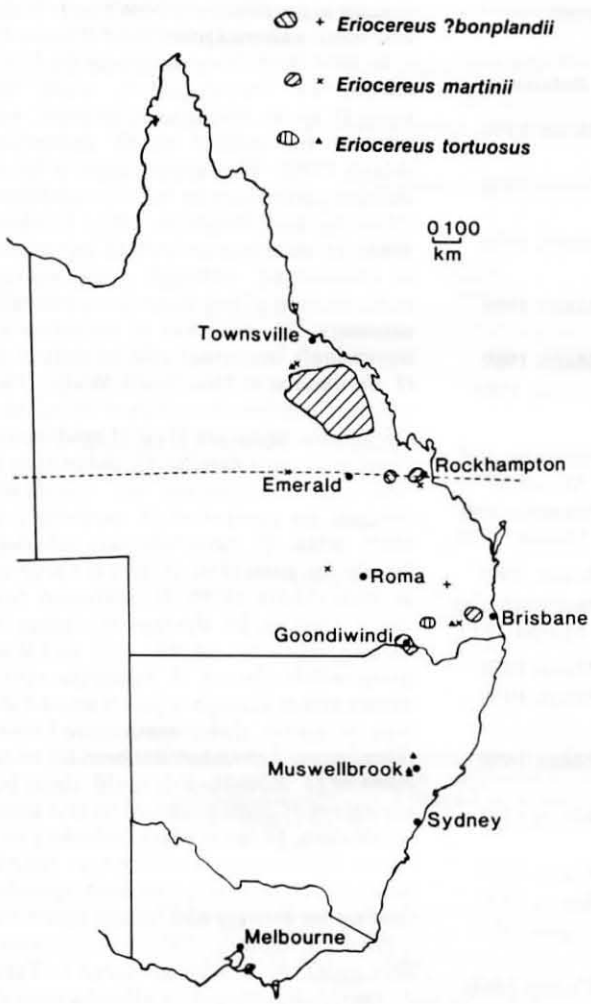

Figure 3 Distribution of *Eriocereus ?bonplandii, E. martinii* and *E. tortuosus*. Shaded areas are over 100 ha, other areas are less than 100 ha.

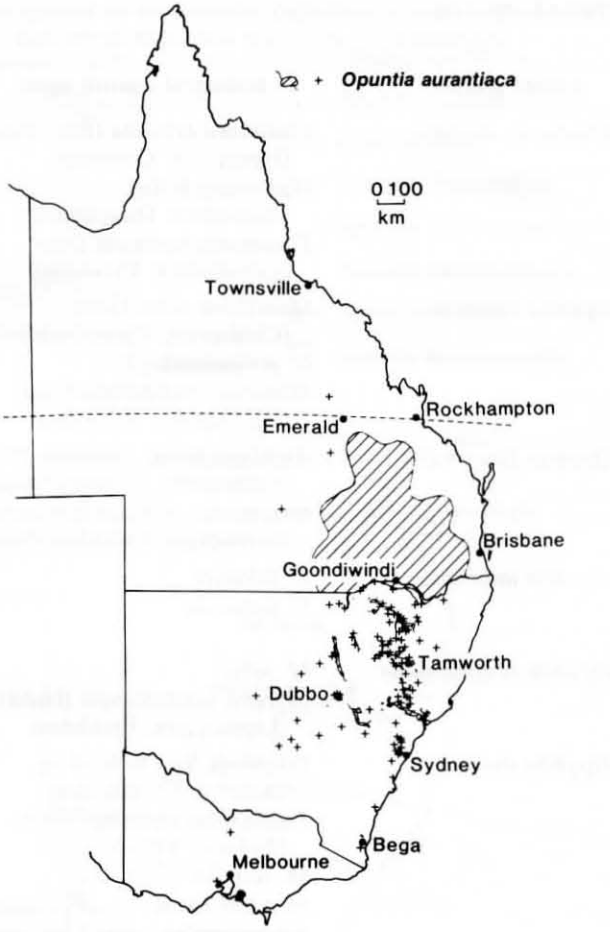

Figure 4 Distribution of *Opuntia aurantiaca*. Shaded areas are over 100 ha, other areas are less than 100 ha. The shaded area for Queensland is the approximate distribution. As for New South Wales, *O. aurantiaca* probably follows floodplains with other isolated areas resulting from movement of joints by animals and vehicles.

plant is not common in Australia (Figure 2). *O. elatior* grows as a shrub or tree to 5 m with 2 to 6 spines (rarely 1) up to 4 cm long per areole. The flowers are orange-pink.

Early records show that *O. elatior* was established at Liverpool, Scone, Camden and Muswellbrook in New South Wales in 1887 (Mann 1970). Maiden (1912*a*) said that this plant, recorded as *Opuntia nigricans* Haworth, was common at Gungal by 1912 and plants can still be found in this locality. The plant is not common now and those that have been seen were being fed on by *C. cactorum* and *D. opuntiae*. Both these insects appear to cause considerable damage. Dodd (1940) also records that *D. opuntiae* was particularly effective against *O. elatior* and was used for control of this species in Sri Lanka (formerly Ceylon) and India.

12. Opuntia ficus-indica *(L.) Miller*

O. ficus-indica, Indian fig, is probably native to Mexico where there are numerous cultivars and many hybrids with other species (Benson 1982). There are two types of plants common in cultivation, one spineless and the other spiny (formerly known as *O. megacantha* Salm-Dyck), both variable in form. Fruit, particularly of the spineless form, has been used as a food since prehistoric times (Benson 1982). Trade has probably resulted in the current wide distribution of *O. ficus-indica* in tropical America. Plants grow to 7 m tall. Joints are largely spineless in the varieties present in Australia. Flowers are yellow.

O. ficus-indica is grown throughout Australia for its fruit. Spineless varieties of *O. ficus-indica* are also grown in plantations for drought fodder in South Africa and the U.S.A. There have been some escapes from cultivation in Australia (Figure 2) but these seem to be mainly spineless varieties. The spiny form of *O. ficus-indica* was the major cactus pest in South Africa and Hawaii prior to biological control of this species (Annecke and Moran 1978, Holloway 1964).

Many species of insects have been recorded feeding on *O. ficus-indica* in South Africa (Annecke and Moran 1978). *D. opuntiae*, aided by hand-felling of plants, contributed most to the biological control of *O. ficus-indica* in that country. *C. cactorum* damages small plants or scattered, succulent, terminal joints of lower branches of large plants. In Hawaii *D. opuntiae* and *C. cactorum* were responsible for control of this cactus (Holloway 1964). Other insects which feed on *O. ficus-indica* are listed in Table 1.

This cactus should not become a major problem in Australia as the biological control agents which keep it in check in other countries are also present in Australia.

13. Opuntia humifusa *(Raf.) Raf.*

O. humifusa is a native of the eastern half of the U.S.A. (Telford 1984). This species is known as creeping pear in Australia and eastern prickly pear in the U.S.A. In the U.S.A. this species has a wide distribution and grows under a wide range of climates varying from hot (humid to dry) summers to severe winters (Benson 1982). *O. humifusa* is a low clump or mat-forming cactus. Areoles are generally spineless, although some may have single spines up to 5 cm long. The flowers are yellow. *O. humifusa* hybridizes with *O. stricta* varieties in the U.S.A. and apparent hybrids occur in the Hunter Valley (Telford 1984).

O. humifusa, recorded as *O. opuntia* (Linnaeus) Britton and Rose, was said to be established in scattered quantity near Singleton by 1940 (Dodd 1940). Today *O. humifusa* occurs in the same area

and has not been reported elsewhere in Australia (Figure 5).

There are no published reports of insects feeding on *O. humifusa* in Australia. Both *C. cactorum* and *T. tapiacola* have been found feeding on *O. humifusa* in the Hunter Valley. *C. cactorum* appears to cause the most damage and may be responsible for reducing *O. humifusa* to scattered clumps which now occur over its range in the Hunter Valley.

Hot dry summers appear to cause death, through desiccation, of many young joints.

14. Opuntia imbricata *(Haw.) DC.*

O. imbricata is a native of the U.S.A. and Mexico, occurring between central Colorado and central Mexico (Benson 1982). This species is known as devil's rope or rope pear in Australia, tree cholla or coyonostole in the U.S.A. and imbricate cactus in South Africa. *O. imbricata* grows to 3 m high as a small tree or thicket-forming shrub. Two to 30 spines up to 3 cm long arise from areoles and these spines are covered by a detachable sheath. The flowers are purple and fruit vary from green to yellow. American Indians used this cactus for food, protection of villages and ceremonial purposes (Benson 1982).

The earliest record of *O. imbricata* in Australia was published in 1911 (Maiden 1911*b*). At this time *O. imbricata* was grown in gardens in New South Wales and was growing wild at a number of places in the Hunter Valley and north of Bathurst along the Turon River. Today the largest concentrations of rope pear are around old mining towns such as Broken Hill, Cobar and Nymagee. Scattered plants also occur along a number of watercourses inland from the Great Dividing Range to the south of Mt Isa, Qld (Figure 6).

Dactylopius tomentosus (Lamark) is the insect which causes the most damage to *O. imbricata* in Australia. Other insects and mites also feed on *O. imbricata,* some are of minor importance in biological control (Table 1) but most of these have not been released, or failed to become established, in Australia (Mann 1969).

D. tomentosus, recorded as *D. newsteadi* Cockerell, was introduced to Australia in 1924 and released in 1925 (Dodd 1940). Initially most of the smaller *O. imbricata* plants were killed and the larger plants reduced to a few woody stems (Dodd 1940). After initial successes insect numbers decreased following death of smaller plants and spraying was reintroduced in an attempt to eradicate this cactus. *D. tomentosus* was released in many areas within New South Wales and Queensland prior to spraying and still persists in many of these areas. *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) sometimes prevents population build-up of *D. tomentosus*. Experiments conducted by Zimmermann (pers. comm.) in South Africa have shown that felling of large plants, once *D. tomentosus* is established, improves the level of control achieved by this insect. Small plants are more susceptible to *D. tomentosus* and these do not need to be cut down. This control technique has also been successfully applied in New South Wales over recent years. Cutting down of old plants was found to be unnecessary in more arid areas of New South Wales such as Broken Hill and Cobar.

15. Opuntia microdasys *(Lehm.) Pfeiffer*

O. microdasys, golden bristle, is a native of northern Mexico (Mann 1970). This plant is popular with growers of succulents.

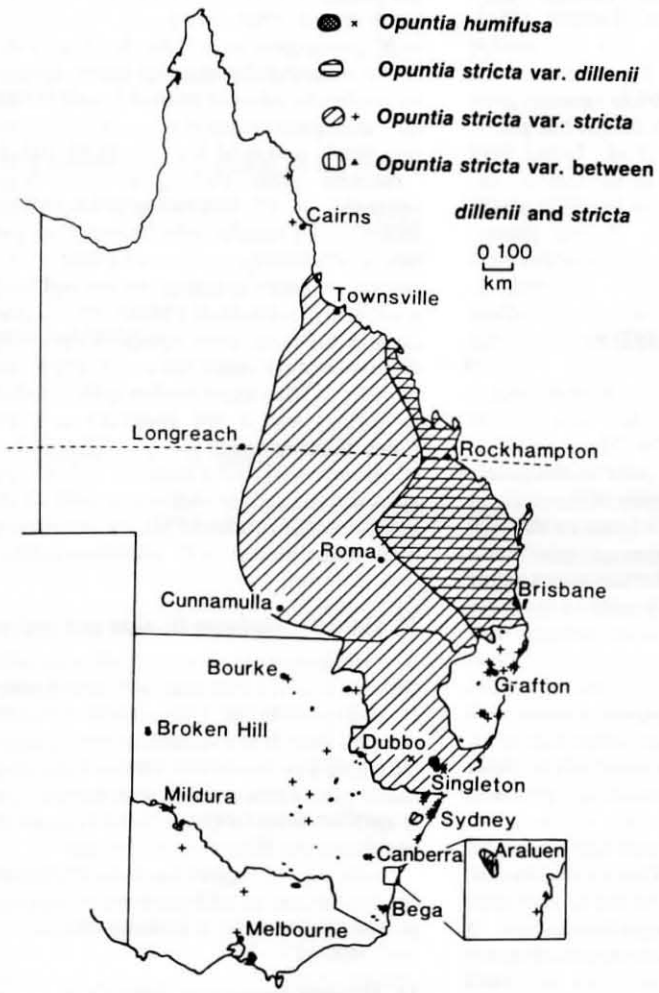

Figure 5 Distribution of *Opuntia humifusa, O. stricta* var. *dillenii, O. stricta* var. *stricta* and *O. stricta* var. between *dillenii* and *stricta*. Shaded areas are over 100 ha, other areas are less than 100 ha. All small areas of *O. stricta* are var. *stricta* with the exception of areas near Singleton, which are *O. humifusa*, and south-east of Canberra which are *O. stricta* var. between *dillenii* and *stricta*.

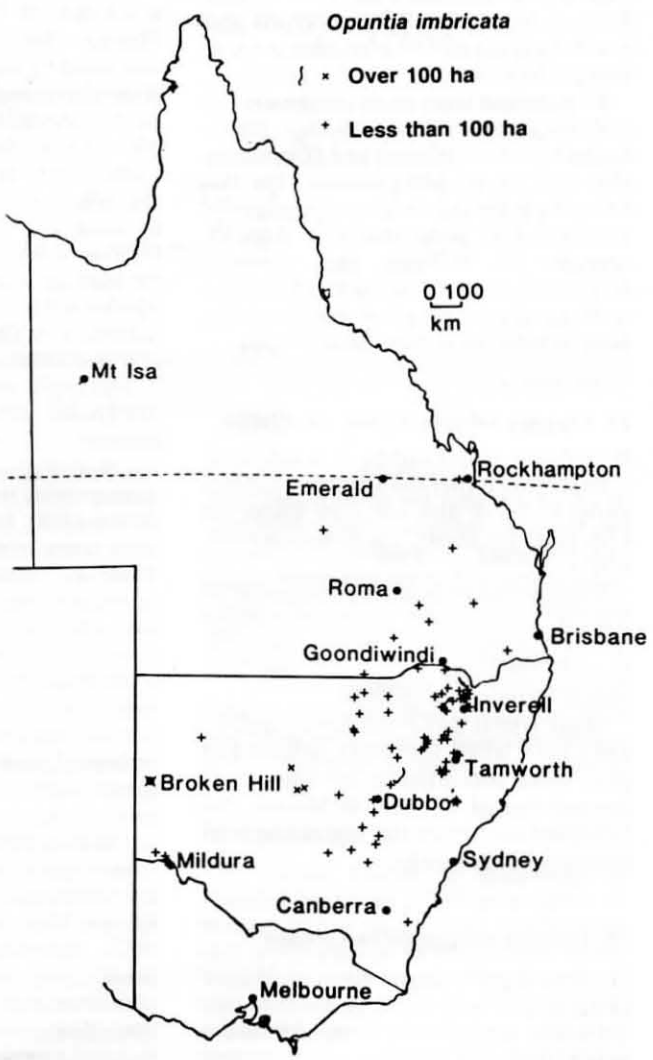

Figure 6 Distribution of *Opuntia imbricata*. All lines other than State boundaries are areas along watercourses where *O. imbricata* may be found.

O. microdasys grows as a spreading shrub up to 60 cm high. The plant is without spines but has large numbers of glochids at each areole. The flowers are yellow to pink.

The earliest record is for a clump in the Pilliga Scrub in 1910 (Maiden 1914). This species does not appear to spread rapidly and all known naturalizations are for small areas (Figure 2). Mann (1969) lists *Olycella junctolineella* (Hulst) (Lepidoptera: Pyralidae) and *D. opuntiae* as insects which feed on *O. microdasys* but did not indicate the amount of damage caused by them.

16. Opuntia paraguayensis *K.Schum.*

O. paraguayensis is a native of Paraguay and Argentina (Britton and Rose 1919–1923). This species is known as Riverina pear in New South Wales, after the area in which it occurs. *O. paraguayensis* grows to 2 m high and is largely spineless, although single spines sometimes occur at areoles. These spines are up to 4 cm long. The flowers are orange–apricot with green stigmas.

There are no records of *O. paraguayensis* introduction to Australia and this species was not mentioned in early Commonwealth Prickly Pear Board bulletins. *O. paraguayensis* is now established along the Murray River in New South Wales, Victoria and South Australia as well as in other areas of western New South Wales (Figure 2).

C. cactorum feeds on *O. paraguayensis* and can cause considerable damage. *Dactylopius ceylonicus* (Green) and *D. opuntiae* also feed on *O. paraguayensis*. On this host, *D. ceylonicus* develops more rapidly with less first instar mortality than *D. opuntiae* (P. Sullivan, pers. comm.). *D. ceylonicus* has caused a lot of damage to *O. paraguayensis* where this insect has been introduced in New South Wales.

17. Opuntia robusta *Wendl. ex Pfeiffer*

O. robusta, wheel cactus, is a native of central Mexico (Benson 1982). *O. robusta* grows to 3.5 m and has 1–10 spines (to 4 cm long) per areole. The flowers are pale yellow.

There are no records of introduction of this plant to Australia. In 1961 *O. robusta* was proclaimed as a noxious plant for Victoria (Parsons 1973) to which it is mainly restricted (Figure 2).

Mann (1969) lists a number of insects, and a mite, which feed on *O. robusta* and gives some indication of the amount of damage caused by them in Mexico. No biological control of this cactus has been attempted in Australia.

18. Opuntia streptacantha *Lemaire*

O. streptacantha is a native of Mexico (Telford 1984). It grows to 3–3.5 m tall, branching from the base and forming a strong trunk. The segments have numerous 20–25 mm long spines at the areoles. The flowers are yellow and the ripe fruit dark red or purple.

O. streptacantha was first planted at Gracemere near Rockhampton about 1880 and is now known in Queensland as Westwood or Gracemere pear. It is found in wooded country over that part of Central Queensland east of the Dawson range, from the Mackenzie river north of Dingo to near Wandoan, and to Gracemere and Biloela in the east (Figure 2). Its range appears to be increasing but it is not considered a problem.

O. streptacantha is attacked by *C. cactorum* (Mann 1970) but damage to mature plants is minor. *D. opuntiae* is more damaging and occurs widely on *O. streptacantha* (Mann 1970).

19. Opuntia stricta *(Haw.) Haw. varieties*

O. stricta is native to south-eastern U.S.A., east coast of Mexico, northern South America, West Indies, Cuba, Bahamas and Bermuda (Benson 1982). The two major varieties are *O. stricta* var. *stricta* (= *O. inermis* DC.) which is known as common pest pear, common prickly pear or common pear, and *O. stricta* var. *dillenii* (Ker Gawler) L. Benson (= *O. stricta*) spiny pest pear. Plants intermediate in form between *O. stricta* var. *stricta* and *O. stricta* var. *dillenii* are known to occur in the U.S.A. (Benson 1982) and in the Araluen Valley south-east of Canberra (Telford 1984). Murray (1982) details the taxonomic confusion relating to *O. stricta* in the Australian context. *O. stricta* varieties grow as erect shrubs to 2 m in height but generally only reaching 1–1.5 m. Joints vary from mainly spineless in *O. stricta* var. *stricta* to 11 spines (1–6 cm long) per areole in some *O. stricta* var. *dillenii* plants. Flowers of both varieties and intermediates between varieties are yellow. *O. stricta* is also known to hybridize with *O. humifusa* in the U.S.A. (Benson 1982) and Australia (Telford 1984).

The origin of *O. stricta* in Australia is not known, although a plant in a pot was brought to Scone in 1839 (Mann 1970). It has been suggested that prior to this plants were growing in cultivation in Parramatta (Mann 1970). From here joints or cuttings were taken to many areas of New South Wales and Queensland for use as pot plants or hedges. By 1926, 24 million hectares were affected by *O. stricta* varieties with about half this area being unproductive as a result of *O. stricta* infestations (Dodd 1940). Although *O. stricta* varieties are now present over a much larger area (Figure 5), biological control has resulted in these plants only rarely reaching problem proportions.

The first detailed search for biological control agents for *O. stricta* varieties followed the appointment of the Queensland Prickly Pear Travelling Commission in 1912. This Commission spent 2 years investigating natural enemies of cacti (Johnston and Tryon 1914). The insects that they brought back to Australia included a species of *Cactoblastis* (probably not *C. cactorum*) which failed to survive (McFadyen 1985). In 1919 the Australian Government constituted 'The Commonwealth Prickly Pear Board' to control all problem cacti in Australia. Most of the Board's work was directed toward control of *O. stricta* varieties by insects.

C. cactorum was released for control of *O. stricta* varieties in 1926 and is still the major insect keeping these varieties under control (Monro 1967, Myers *et al.* 1981). In areas where *C. cactorum* cannot complete two generations per year there is poor control of *O. stricta*. At present these areas in New South Wales are mainly treated with herbicides. There are also occasional problems with *O. stricta* control in sandy coastal areas where *O. stricta* plants are tough and dry and survival of *C. cactorum* larvae is poor (White 1981). *D. opuntiae* may be suitable for these areas. *D. opuntiae* was released in 1921 for control of *O. stricta* (Mann 1970). Early reports indicate that this insect provided control in some areas; dispersal of *C. cactorum* was so rapid, however, that *D. opuntiae* was only a minor factor in initial control (Dodd 1940). *D. opuntiae* is a successful biological agent in hot dry areas and has caused considerable damage in some cooler areas.

Many other insect species have been released for control of *O. stricta* varieties, while further species known to feed on these cacti were not introduced as they were not sufficiently host specific (Table 1, Dodd 1940, Mann 1969, 1970).

H. punctigera causes the death of some flower buds and flowers, and minor damage to joints. At one site in New South Wales *H. punctigera* caused the loss of 21.0% of one year's potential fruit (unpubl. data).

Several plant pathogens have been recorded on *O. stricta* varieties (Mann 1970). In Australia *Phylosticta concava* Seaver (Coelomycetes) often damages *O. stricta* varieties growing in central and northern Queensland (Mann 1970) and coastal areas in New South Wales. The disease occurs each year between the months of May and October (late autumn to spring) and is not apparent at other times. *Gloeosporium lunatum* Ell. and Ev. (Coelomycetes) and a bacterial soft rot are also widespread in Australia and cause some damage (Mann 1970). *G. lunatum* is often associated with *C. cactorum* larvae.

20. Opuntia sulphurea *G. Don ex Loudon*

O. sulphurea is native to Argentina and Chile (Telford 1984) and was first grown at Wallumbilla in Queensland in 1889 (Mann 1970). It is a spreading shrub reaching a height of 30–40 cm. One to eight long spines arise from areoles. It is naturalized at two localities in Queensland (Figure 2) but shows no tendency to spread.

No biological control has been attempted against this cactus and there are no records of insects attacking it in Queensland.

21. Opuntia tomentosa *Salm-Dyck*

O. tomentosa is a native of central Mexico (Telford 1984). This cactus is known as velvet tree pear or velvety tree pear in Australia. Plants grow up to 8 m tall. Joints are tomentose and largely spineless,

although rarely 1 or 2 spines (3–25 mm long) occur at areoles. The flowers are orange.

O. tomentosa was recorded as common in Queensland and present in South Australia by 1912 (Maiden 1912*b*). At this time plants were found near Goondiwindi and Warwick and these areas are probably the source of present infestations in north-eastern New South Wales. Today *O. tomentosa* is common from just south of Townsville to north-eastern New South Wales (Figure 7). The area affected in Queensland has increased considerably and this is now the commonest cactus in Queensland, occasionally reaching pest proportions under trees on brigalow soils.

Many species of insects and mites have been recorded as feeding on *O. tomentosa* (Mann 1969). In Australia *D. opuntiae* causes the most damage to *O. tomentosa*. In areas where *D. opuntiae* does not cause sufficient damage, felling of large plants increases the level of control achieved by this insect (Anon. 1984). *C. cactorum* destroys many seedlings and smaller plants but causes only minor damage to large plants. *Archlagocheirus funestus* Thompson has been reported to cause considerable damage to *O. tomentosa*, particularly following initial releases in Queensland during 1936 (Mann 1970). This beetle has become less common in recent times (Mann 1970) and is now nearly extinct. Other insects causing minor damage to *O. tomentosa* in Australia are listed in Table 1.

22. Opuntia tunicata *(Lehm.) Link & Otto*

O. tunicata is native to the U.S.A., Mexico, Cuba, Ecuador, Peru and Chile (Benson 1982). It grows as a bush or is mat-forming. Six to 10 spines up to 5 cm long arise from areoles and these spines are covered by a detachable sheath. The flowers are yellow. This species has been recorded from 5 km west of Mittyack in Victoria.

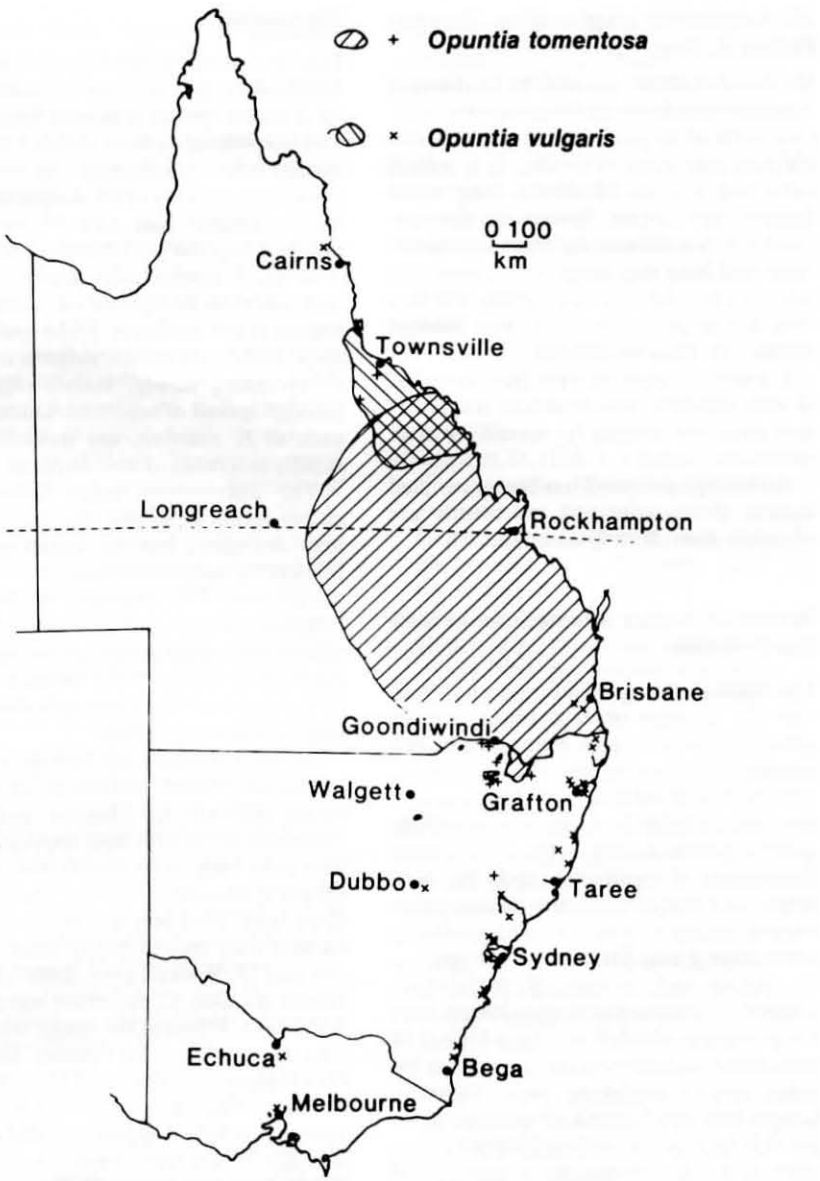

Figure 7 Distribution of *Opuntia tomentosa* and *O. vulgaris*. Shaded areas are over 100 ha, other areas are less than 100 ha. All lines other than State boundaries are areas along watercourses where *O. vulgaris* may be found.

23. Opuntia vulgaris *Miller*

O. vulgaris is a native of Brazil, Paraguay, Uruguay and Argentina (Mann 1970). Common names used for this cactus in Australia include drooping tree pear and smooth tree pear. For a long time this species has been known under the synonym, *O. monocantha* (Willd.) Haw. *O. vulgaris* normally grows as erect plants up to 2 m high but can reach greater heights when growing amongst other tall vegetation. One or two spines occur per areole on joints but up to 12 per areole on the main trunk; spines can reach 10 cm in length. The flowers are yellow with red markings on the outer petaloids.

Captain Arthur Phillip was probably responsible for the first introduction of this plant to Australia in 1788. The first fleet picked up some cochineal infested plants, thought to be *O. vulgaris*, from Rio de Janeiro in 1787 and brought them to Australia where Captain Phillip hoped to establish a cochineal dye industry (Mann 1970). No records are available on the subsequent destination of either this cactus or the cochineal insects (Anon. 1925). Later imports of *O. vulgaris* were made during the 1800s (Anon. 1925). *O. vulgaris* was reportedly in every State of Australia by 1913 (Maiden 1913). Today this cactus is mainly distributed along coastal areas of Australia but also occurs in gardens and as garden escapes elsewhere (Figure 7).

D. ceylonicus, a native of Brazil, Uruguay and Argentina (Mann 1970), is the main biological control agent for *O. vulgaris* and has been successfully used to control this species in South Africa (Pettey 1948), India and Ceylon (Johnston and Tryon 1914, Anon. 1925) as well as Australia (Dodd 1940). This insect is possibly the one introduced by Captain Phillip to Australia. The Queensland Travelling Commission sent *D. ceylonicus* from Ceylon in 1912 and again in 1913. These insects were successfully reared on *O. vulgaris* at Dulacca, Qld, and subsequently released. By 1925 *O. vulgaris* was reported to occur as rare plants in Queensland, largely as a result of *D. ceylonicus* (Alexander 1925).

D. opuntiae reportedly feeds on *O. vulgaris* (Mann 1970) but tests conducted at Tamworth failed to establish this cochineal species on *O. vulgaris*. *C. cactorum* also causes minor damage to this cactus. Other insects feed on *O. vulgaris* (Mann 1969) but these have not been released, or have failed to become established, in Australia.

Two plant pathogens, *P. concava* and *Colletotrichum crassipes* (Speg.) Arx, have been observed causing considerable damage to *O. vulgaris* (P. Sullivan, pers. comm.).

24. Opuntia *sp.*

This cactus, known as joconoxtle, is recorded by Mann (1970) as a native of Mexico. Plants were grown at Glenmore near Rockhampton in 1857 (Mann 1970). It is a moderately large cactus, 50–100 cm high, with nearly round pads bearing short spines. The flowers are yellow and fruit pink.

This species is naturalized near Rockhampton but has shown no tendency to spread (Figure 2).

25. Selenicereus macdonaldiae *(Hooker) Britton & Rose*

S. macdonaldiae is native to Central America or possibly to Uruguay and adjacent parts of Argentina in South America (Britton and Rose 1919–23). It is widely cultivated for its 30–40 cm long white flowers, the largest flowers in the subfamily. It is a clambering plant with aerial roots and long thin stems with prominent tubercles bearing very short spines. The ripe fruit are large and reddish, and bearing clusters of hairs or bristles.

S. macdonaldiae has only been recorded as naturalized at two localities (Figure 1) and does not appear to spread or fruit profusely.

No biological control has been attempted against this cactus and no insects are recorded from it in Queensland.

Survey of cactus infestations in New South Wales

The maps in this publication do not indicate the amount of each cactus species present in each locality. Some idea of this amount, in New South Wales, can be obtained from estimates of the areas that they infest (Table 2). These figures include only properties on files of the Prickly-Pear Destruction Commission and the area where seed-borne cacti occur include entire shaded areas on maps – and probably some other areas. The area of one species, *O. stricta* var. *stricta*, is particularly underestimated as files are no longer kept for properties which have a long history of only minor quantities of cactus. Figures for other species would be more accurate. Queensland and Victoria do not have comparable figures for cactus infestations as control is carried out by a number of groups of government and semi-government bodies as well as individuals. In Queensland, biological control is now relied on for the control of most cactus species and chemical sprays are rarely used.

Table 2 Areas infested by cactus species in New South Wales (1988)

Species	Area of infestation (ha)
Eriocereus martinii	2003
E. tortuosus	31
Opuntia aurantiaca	199568
O. elatior	2
O. ficus-indica	1
O. humifusa	3484
O. imbricata	6182
O. microdasys	1.5
O. paraguayensis	459
O. robusta	0.5
O. stricta var. *stricta*	881534
O. stricta var. between *stricta* and *dillenii*	1143
O. tomentosa	45530
O. vulgaris	1759

Discussion

Distribution maps shown here cover known infestations to the time of publication. Most cactus species in eastern Australia are now considered to be controlled by insects though most are still extending their range. Long-term surveys of *O. aurantiaca* distribution suggest that rate of spread has declined over the past 20 years (Auld *et al.* 1982/83). Unfortunately, detailed information on rate of spread of other cactus species is not available. Some species such as *O. imbricata* and *O. vulgaris* appear to be spreading slowly, mainly vegetatively through spread of segments. Other species, such as *E. martinii*, are spreading more rapidly as a result of seed dispersal by birds.

The distribution maps indicate that cactus occurs in suitable country within the area delimited, but the actual area now infested by each cactus may be only a small proportion. For example much of the brigalow country of Queensland previously affected by cactus is now under cultivation (McFadyen 1984) and the cactus is confined to the narrow treed strips left along roads and between properties.

Insects were the main biological control agents introduced, pathogens, at the time, being difficult to identify and hence problems arose with host specificity tests. The only pathogens mentioned are from *Opuntia* species; very few specimens of these fungi have been examined in Australia and their exact identity remains to be clarified (J. Walker, pers. comm.). Of the insects released, *C. cactorum* was the most important, bringing the major cactus species, *O. stricta,* under control. Cochineal (*Dactylopius* species) were also important in controlling many of the other *Opuntia* species. Cochineal appear to cause the most damage in hot dry conditions (Hosking 1984). In recent times, *H. festerianus* has been important in the control of *E. martinii* and other related cacti in Queensland.

A number of insects not previously mentioned have been found in rotting cactus. There is no information on whether these insects assist in the spread of rot in plants. Two species of *Camptodes* (Coleoptera: Nitidulidae) have been found in rotting segments of *O. aurantiaca, O. streptacantha, O. stricta* and *O. tomentosa.* These were identified as *C. scutellatus* Sturm and *C. ornatus* Lacordaire, although they may represent two colour forms of the same species as both usually occur together. *Drosophila aldrichi* Patterson & Crow and *Drosophila buzzatii* Patterson & Wheeler (Diptera: Drosophilidae) are also found in rotting tissue of many *Opuntia* species (Barker 1982). *Drosophila* mainly develop in rots which occur after damage caused by *C. cactorum* or *Dactylopius* species.

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