RUBBER VINE

Rubber vine
(*Cryptostegia grandiflora*)
in Queensland

PEST STATUS REVIEW SERIES - LAND PROTECTION BRANCH

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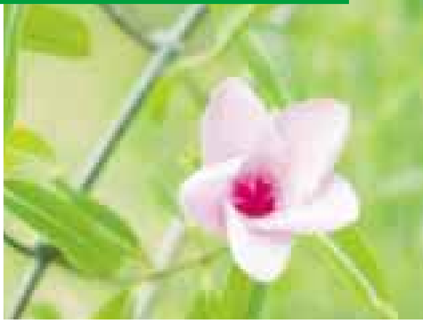

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Contents

1.0 Summary

Rubber vine (*Cryptostegia grandiflora*) originally a native of Madagascar, now densely covers more than 700,000 ha of tropical and subtropical Queensland between the 400 and 1400 mm isohyets and is particularly dense along waterways. Scattered infestations are found over most of the state. Bioclimatic modelling suggests that most of tropical northern Australia is highly suited to rubber vine. The spread of rubber vine in Queensland appears exponential and it is predicted that by 2000 the infestation will cover 2.0 million ha. Rubber vine invades pasture, impedes access of stock to water and hinders mustering. It is toxic to stock but few stock losses have been attributed to rubber vine. It is estimated that in 1995 rubber vine has cost the grazing industry $18.13 million. The environmental cost of rubber vine is immense but has not been estimated in monetary terms. Rubber vine is an aggressive invader of dry rainforests. It scrambles up trees, eventually smothering and killing them and shading out the ground cover. Rubber vine threatens many areas of high conservation value and has been implicated in the decline of several animal species. Rubber vine has the potential to completely destroy many unique ecosystems, including national parks and World Heritage areas.

The main agents for dispersing rubber vine are wind and water (both fresh and salt). Seed has a high viability and remains viable for up to 12 months. Germination and establishment is enhanced by the presence of mulch on the soil surface and high soil moisture. Soil type does not appear to be important. A plant can be reproductive at an age of 200 days.

Effective chemical control methods are available but due to the large areas that require treatment and the poor return from the land, are often uneconomic. Mechanical control methods are effective for dense infestations but their use is sometimes restricted as many dense infestations line the banks of waterways where mechanical methods may not be used. Two biocontrol agents are establishing on rubber vine but they debilitate (by defoliation) rather than kill the plant and their likely effectiveness is unknown. There is potential for these agents to conflict with the use of foliar sprays. There is little scope for the introduction of additional rubber vine biocontrol agents due to the limited suite of available organisms. Fire and grazing management have the potential for limiting seedling establishment and regular burning can act as a useful control.

The current control paradigm for rubber vine centres around a strategic control line which separates densely infested north-eastern Queensland from the more sparsely infested region south and west of this line. North of the line the spread of rubber vine is to be contained. South and west of this line rubber vine is to be eradicated. The effect of this strategy should be to restrict rubber vine to north-eastern Queensland and stop its spread to the Northern Territory and the rest of northern Australia.

2.0 Taxonomic Status

Rubber vine, *Cryptostegia grandiflora* R. Br. is a well defined species and a member of the Periplocoideae, of the family Asclepiadaceae. A detailed botanical and taxonomic description of *C. grandiflora* is given by Tomley (1995a). *Cryptostegia madagascariensis* Decne also occurs in Australia, as an ornamental or naturalised, in the Northern Territory (Marohasy and Forster 1991) Western Australia (McFadyen *et al.* 1991) and Queensland. In Queensland, the Periplocoideae is represented only by two native species, *Gymnanthera oblonga* (Burm. f.) P.S. Green which can be differentiated from rubber vine by its having interpetiolar or more or less axillary, rather than terminal inflorescences (Stanley and Ross 1986) and *Cryptolepis grayi* P.I. Forster, which is restricted to the Tolga scrub. The related *Gymnanthera fruticosa* Wilson is restricted to and area around Alice Springs. Putative hybrids between *C. grandiflora* and *C. madagascariensis* have been found in Madagascar but none have been recorded from Australia (Marohasy and Forster 1991).

3.0 History of Introduction and Spread

The exact date of the introduction of rubber vine into Australia is not known, but was certainly prior to, or around 1875 (Parsons and Cuthbertson 1992, Vitelli 1995). The first official record is for 1875 in the Queensland Botanic Gardens (Dale 1980). It was used as an ornamental in mining towns of North Queensland and quickly became naturalised so that by early 1917 there were major infestations around Charters Towers, Georgetown and Rockhampton (Caltabiano 1973). By 1975 these infestations had become more extensive and the infestations had spread to other centres (Fig.1). By 1987 the weed had spread further to the south and west and continues to spread. It was declared noxious in 1955.

4.0 Current and Predicted Distribution

Rubber vine originates from Madagascar where it is restricted in distribution to areas below 500 m elevation which receive 350-800 mm rainfall annually (McFadyen and Harvey 1990). Currently, in Australia, rubber vine is restricted to tropical and sub-tropical Queensland receiving 400-1400 mm summer dominant rainfall. The species does not occur in areas with more than 100 days frost per annum, with the zone between 50-100 days frost per annum being a less suitable habitat (Chippendale 1991). Dale (1980) states that it is the nature of the soil surface layer in relation to suitability for germination and establishment that is important in determining distribution within rubber vine's climatic envelope. The presence of a surface layer of organic matter and the absence of frequent fires are important in this respect.

Rubber vine densely infests over 700 000 ha of tropical and subtropical Queensland between the 400 and 1400 mm isohyets but is present across 34.6 million hectares, or twenty percent of Queensland (Chippendale 1991). It is found throughout the river systems of southern Cape York, the Queensland Gulf country, central Queensland and along the east coast to the Burnett River (inside back cover). Isolated infestations have been found as far south as Gatton and as far west as the Northern Territory border (Appendix 1). Chippendale (1990, 1991) found that in 1989, forty-two percent of properties in northern Queensland had rubber vine on them (Fig. 1).

Infestations have also been located at Mt. Isa, Longreach, Blackall and Charleville. Initial infestations generally occur along rivers and creeks until the river edge is completely choked. It then aggressively and progressively invades open pastures. Most of the infested areas away from watercourses have a high water table as in the Burdekin and Gilbert River deltas and the basalt areas of Mt. Surprise and Fletcher Creek (Dale 1980).

The potential distribution of rubber vine in Australia has been predicted using CLIMEX (Skaratt, Sutherst and Maywald 1995) and the ecoclimatic characteristics of the areas of Madagascar where rubber vine is currently growing. Most of tropical north Australia is sufficiently ecoclimatically suited to rubber vine (Fig. 2) to suggest that an extensive area is under threat of invasion from rubber vine. Chippendale (1991) used the 300, 400 and 1400 mm isohyets and the 50 and 100 frost days per annum isopleths to predict potential distribution (Fig. 3). The two predictions are in good agreement. These predicted distributions do not take into account soil type, but Dale (1980) suggests that rubber vine distribution is largely independent of this.

A simple model of the spread of rubber vine as a reasonably dense infestation (data from McFadyen, Chippendale and Tomley 1991 and Vitelli 1995) (Fig. 4) suggests that 2.0 million hectares of northern Queensland will be reasonably densely infested by the year 2000.

Figure 1. *The spread of rubber vine in Queensland, 1917-1987. (McFadyen and Harvey [unpublished]).*

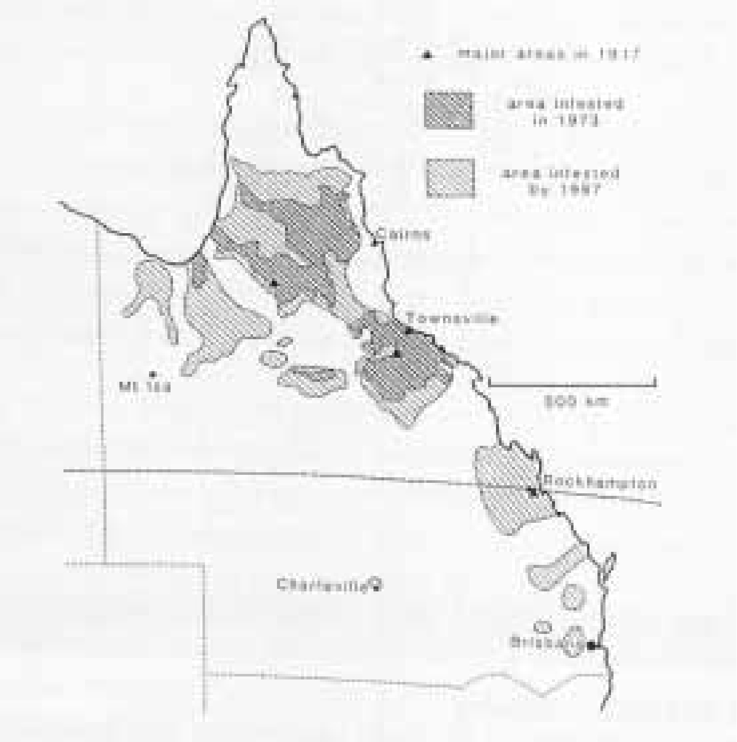


Figure 2. *The potential distribution of rubber vine in Australia based on ecoclimatic modelling (symbols represent values for an ecoclimatic index, the higher the value, the greater the suitability of the area for rubber vine).*

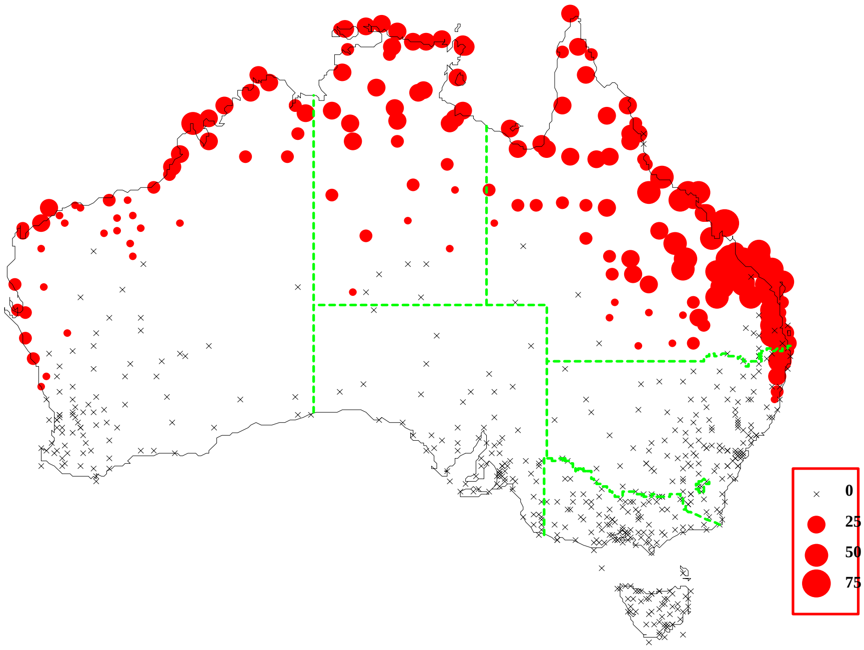
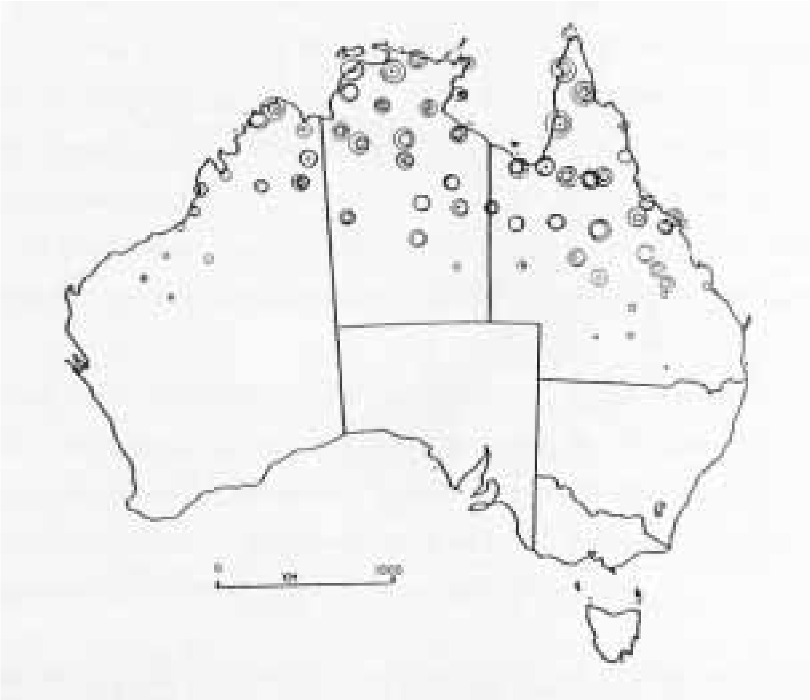


Figure 3. *The potential distribution of rubber vine in Australia based on rainfall and minimum temperature (Chippendale 1991).*

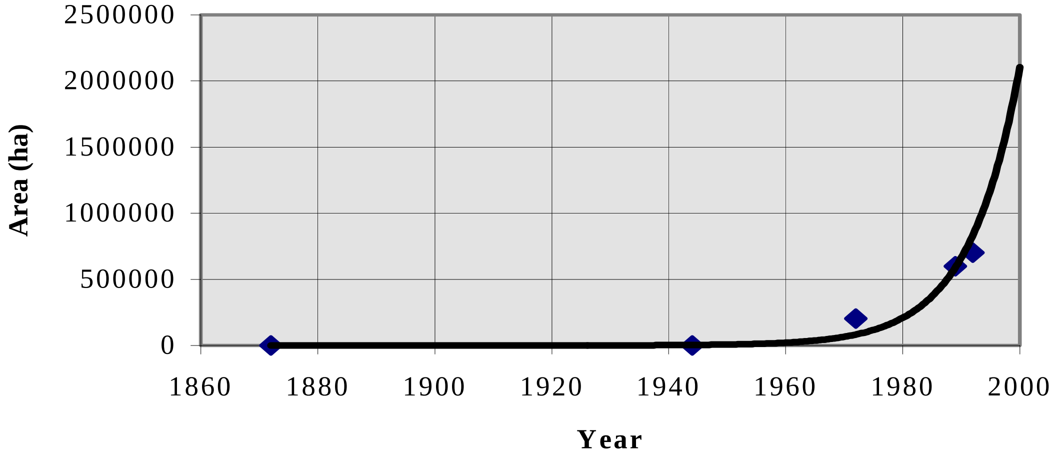


5.0 Estimates of Current and Potential Impact

5.1 Impact on Primary Industry

The major impact on primary industry is through the loss of cattle production from infested areas and subsequent control costs. As rubber vine invades open pasture, grass growth decreases as rubber vine cover increases (Vitelli 1995) and the weed utilises soil moisture and this translates directly into a loss of carrying capacity. Since rubber vine usually infests creeks and rivers and invades pasture from there, it is often the fertile and productive river flats that are primarily affected.

Figure 4. *The rate of spread of rubber vine in Queensland predicted to the year 2000.*



Dense infestations along watercourses impede access to water for cattle. They also make mustering more difficult and expensive (1985 figures from Chippendale 1991 show that mustering costs in infested country are 167% more than those in uninfested country).

Incomplete mustering means that missed cattle become aggressive and more difficult to muster subsequently. Herd improvement programmes are jeopardised by missing stock during mustering and the eradication of disease and the maintenance of herd quality is made more difficult (Chippendale 1991). Stock can also become entangled in rubber vine to such an extent that they die through lack of water, or they become so debilitated that they have to be destroyed. Rubber vine also provides a habitat for animals such as feral pigs and dingoes.

Feeding tests have shown the leaves of rubber vine to be toxic to cattle, horses, goats and sheep (McGavin 1969, Everist 1974). Horses are particularly susceptible; toxic effects follow after consumption of only 0.03-0.06% of their body weight (McGavin 1969, Cook *et al.* 1990). The leaves contain cardiac glycosides (Doskotch *et al.* 1972) but stock losses are few as rubber vine is seldom eaten by stock unless other feed is very scarce.

Estimated direct losses to primary industry due to rubber vine were $5.67 million per annum (Chippendale 1990, 1991) (Table 1) over an estimated infestation of 349,537 ha in 1989/90. Extrapolating these costs to the recorded 700,000 ha infestation present in 1992 (Vitelli 1995) gives a loss of $13.10 million (1995 dollars) and for the predicted 1995 infestation, $18.13 million (1995 dollars).

5.2 Control Costs

The majority of control costs are borne by landholders, many of who use fencing, stock management, herbicides and mechanical measures for the control of rubber vine. In a survey of nineteen shires in which rubber vine was perceived to be a problem, Chippendale (1991) estimated control costs to be about $2.27 million (Table 1) or $6.50 per hectare. For the 700,000 ha of rubber vine present in 1993 this would be $4.55 million and for the predicted 1995 infestation, $9.05 million (1995 $'s).

Table 1. *Per annum cost of rubber vine (1989/1990 dollars) to landholders in 19 infested shires (Chippendale 1990, 1991).*

Source	$
Spraying	746,322
Burning	182,000
Fencing	1,342,845
Loss of Carrying Capacity	3,645,328
Mustering	1,058,391
Cattle Destroyed	966,893
Total	**7,941,779**

There is a variety of control options available for rubber vine and the costs of herbicides are summarised in Table 2. Mechanical control costs vary from around 4-5¢ per plant for slashing scattered and medium infestations to 3¢ per plant for using a cutterbar or blade plough in dense infestations. Fire when used in dense infestations costs about 5¢ per plant (Vitelli 1995). Vitelli (1995) estimates that many of these treatments translate to costs of up to $300-400 per hectare.

The main reasons for undertaking rubber vine control are to regain pasture production and to improve access to water. In both cases, cost is a major concern. Even productive land returns less than $30-40 per hectare (Vitelli 1995) and with control costs of up to $300-400 per hectare, many years are needed to repay the price of control. In such an economic situation, it is not feasible that landholders can prevent rubber vine from spreading (Chippendale 1990).

5.3 Environmental Cost

Rubber vine is an extremely aggressive invader of gallery forest and dry rainforest ('vine thickets'). It is a vigorous climber and can scramble up trees to 30 m in height, eventually completely smothering and killing them and shading out the ground layer. In the northern rivers of the Gulf it can form impenetrable barriers up to 400 m wide on each bank (Chippendale 1991).

Vine thickets are floristically and structurally complex, each site usually having unique features. Many have been lost or are under threat, due to land management; many of the remainder are being lost to rubber vine before they have been described. Riparian zones provide a unique habitat and act as refuges for eucalypt woodland species that are essential to maintaining woodland populations. Rubber vine invasion of the gallery forest on Big Mitchell Creek, north of Mareeba, has apparently led to the decline of the white-browed robin (*Poecilodryas superciliosa*) and the disappearance of the rufous owl (*Ninox rufa*) and Bower's shrike thrush (*Colluricincla boweri*) (Humphries *et al*. 1991). The greater glider *(Petauroides volans*) and the squirrel glider (*Petraurus norfolicensis*) are also under threat (Chippendale 1991). Rubber vine has the potential to completely destroy all deciduous vine thickets in northern Queensland, leading to the complete loss of some unique ecosystems and the extinction of many plant and animal species. In north Queensland, 8,490 ha of national park are infested and a further 1.1 million ha is at risk (Chippendale 1991).

Any attempt to quantify the environmental costs associated with rubber vine in dollar terms would be suspect (Chippendale 1991) but there is no doubt that rubber vine is having a severe and deleterious impact on natural ecosystems throughout northern Queensland and is damaging the most important wildlife habitats and best recreation assets of the region. It has the potential to seriously degrade the World Heritage areas of northern Queensland and the Northern Territory and produce a significant depreciation of their tourism values.

Table 2. *Herbicide costs for the control of rubber vine (Vitelli 1995).*

Foliar			**Basal Bark**			**Cut Stump**		
Chemical	Cost($)[1]	$/plant[5]	Chemical	Cost ($)[5]	$/plant[5]	Chemical	Cost ($)[2]	$/plant[5]
Grazon DS	12.80	0.04	AF Rubber Vine Spray	0.75	0.13	AF Rubber Vine Spray	0.76	0.08
Dicamba	16.20	0.07	Access	1.35	0.15	Garlon 600	1.54	0.11
Tordon 75-D	29.80	0.10	Garlon 600	1.54	0.18	Access	1.35	0.09
Arsenal 250 A	29.80	0.08				Amicide 500	0.50	0.09
Brushoff	22.80	0.08						
AF Rubber Vine Spray	5.55	0.10						

Soil Application			**Aerial Application**		
Chemical	Cost($)[1]	$/plant[5]	Chemical	Cost ($)[5]	$/plant[5]
Velpar L		0.13-0.24	Grazon DS	110.00	0.17
Graslan	3.35	0.09-0.14	Graslan	164.00	0.13
			AF Rubber Vine Spray	55.50	10.05

[1] Cost / 100 L
[2] Cost /L mix
[3] cost/100 m^2
[4] Cost/ha not including application
[5] Cost per plant killed

5.4 Land Value

Chippendale (1991) reported that landholders perceived that property values in his survey area had dropped by a total of $35.3 million due to infestation by rubber vine. This equates to an average loss of approximately $30,300 per property or $0.88 per hectare. Whilst the price of land is not a good indicator of the total cost of land degradation (Chippendale 1991) it is indicative of the fact that landholders recognise that rubber vine is a serious enough problem to affect their capital investment.

6.0 Biology and Ecology of Weed Spread and Control

Where sufficient moisture is available, rubber vine develops an aggressive climbing and twining habit, producing extensive dense thickets that are difficult to access for control purposes. In the more moist parts of its range, it colonises open country, forming a rambling sub-shrub of 1.3-2 m height, with long trailing vines. Its root system penetrates to 12 m. In the drier parts of its range, it is confined to areas where it can access groundwater (Dale 1980, McFadyen *et al*. 1991, Parsons and Cuthbertson 1992).

Nath (1943) reported that the maximum and minimum temperatures and the relative humidity all influence the growth rate and development of field-grown plants in India. Best growth was recorded under moderate temperatures and high humidity, when seedlings 43 days old had roots twice as long as the corresponding shoot portion.

Rubber vine occurs on a wide variety of soil types (Polhamus *et al.* 1934, Hubble and Keogh 1942) but there is a dearth of information on the effect of soil type on growth rate. In coastal areas, rubber vine grows on sand dunes and salt flats and can withstand tidal inundation.

Although the species occurs naturally in arid regions, there is evidence that the water supply to the plant is a major factor influencing the growth rate. At Charters Towers the most vigorous growth occurred where the moisture supply to the plant was high irrespective of soil type (Hubble and Keogh 1942). They also observed plants with extensive root systems (>13 m) in mine shafts, capable of drawing food and moisture from a large area, thereby growing even under dry conditions.

In Haiti, plants have been shown to flower at 5 to 7 months of age, when supplied with continuous water and grown as a commercial rubber crop (Symontowne 1943). Curtis (1946) recorded plant flowering 3 months after transplanting grafts in Haiti. First flowering under Queensland conditions (Charters Towers) can be within 250 days of germination with good rain on a sandy alluvial or heavy clay loam soil (Fig. 5) but is more usually 400-450 days after germination irrespective of soil type (Fig. 5).

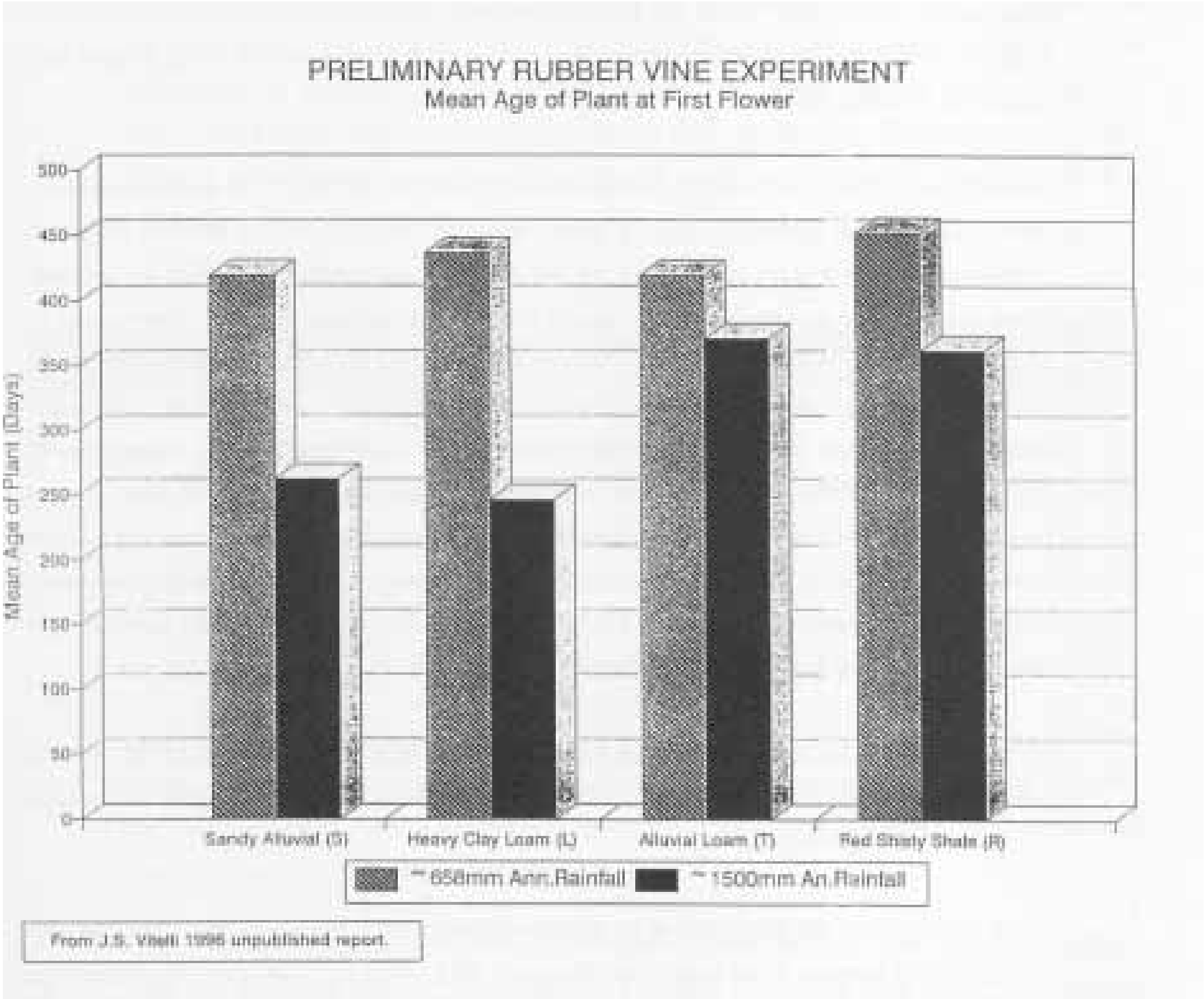
Other factors which may affect the age at which flowering commences are not known. Observations in Charters Towers are that the plant displays a very definite periodicity in regard to growth and foliage production and that leaves tend to drop off in winter. Very dry and cold conditions defoliate the plant.

Rubber vine is insect pollinated but flower structure restricts the suite of available pollinators and in Queensland pollination has not been observed, although viable seed is produced (Tomley 1995a). In a study of the flowering and fruiting characteristics of rubber vine in Haiti, Curtis (1946) found that the species produced flowers at all times of the year. The number of flowers was shown to vary greatly with the season, being highest in summer when conditions for vegetative growth were optimum. In this study, fruit production maxima did not correspond with maximum flower production and the best correlation of fruit set with an environmental factor was with rainfall. Fruiting maxima occurred 2 months after each rainfall peak. Flower production was independent of rainfall as the maximum flower production occurred at the same time each year despite differences in the distribution of rainfall. Curtis did not detect any effect of climate or soil type on fruit production. In Queensland however both rainfall and soil type affect the number of flowers produced per plant (Fig. 6).

Curtis (1946) also found the rubber vine density of 1100 plants per hectare produced 15 fruits per plant per annum, while densities of 12000-29000 plants per hectare produced an average of 1 fruit per plant per annum.

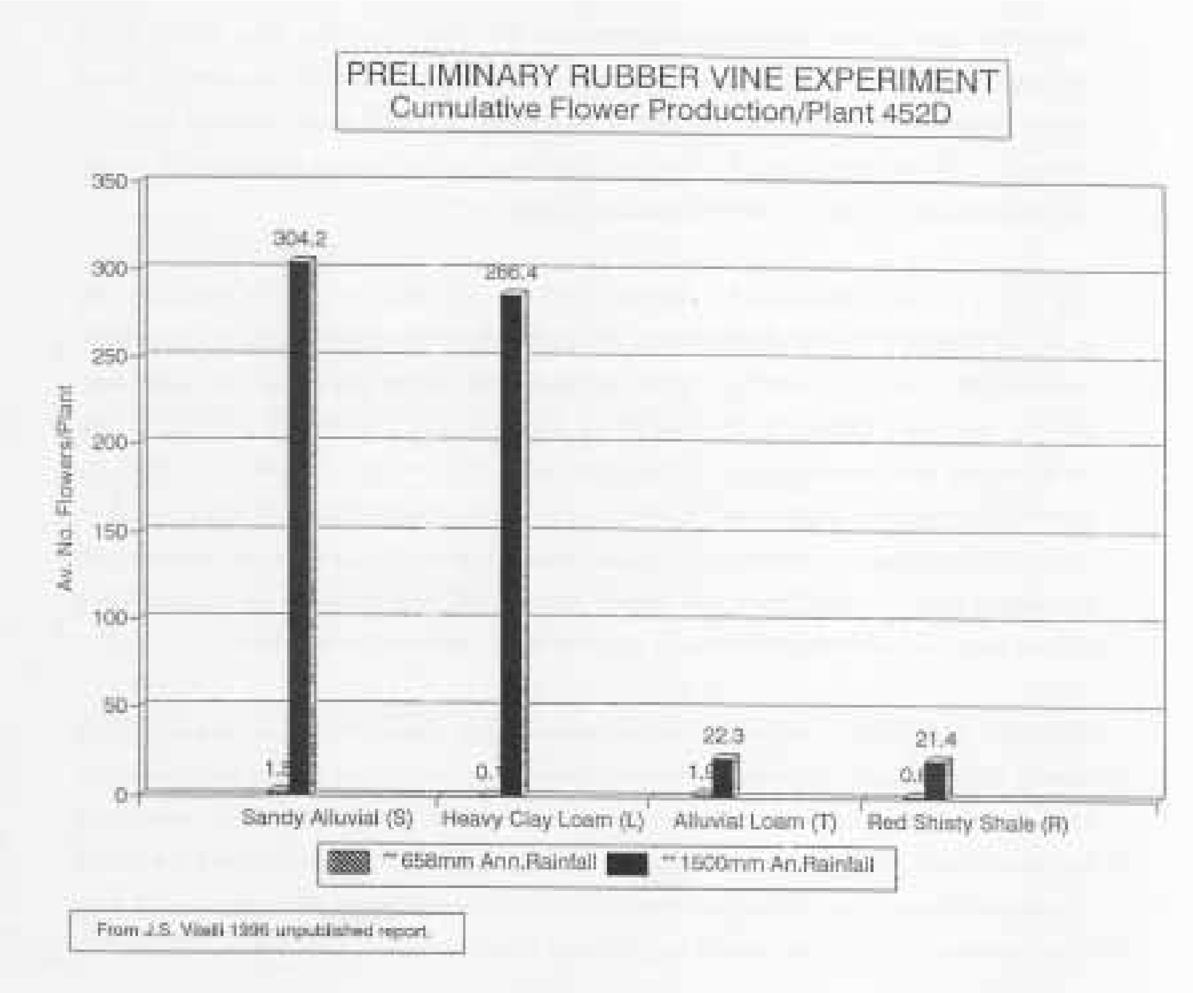
Curtis (1946) found the average time for fruit development from flowers to ripe open fruit was 173 days. The average seed weight was 9 mg with 668 seeds per fruit while 340-840 seeds per fruit have been recorded in Charters Towers (Vitelli 1987 unpublished report). A study in Haiti demonstrated that 3000 grafted *Cryptostegia grandiflora* plants per acre produced 8,061,000 flowers per acre per year and 182,700 fruit per acre per year (a flower to fruit ratio of 44:1) but in Queensland the flower to fruit ratio varies between around 6 to 150:1 depending on rainfall and soil type (Fig. 7).

Figure 5. *The relationship between rainfall, soil type and the age of first flowering for rubber vine.*



From J.S. Vitelli 1995 unpublished report.

Figure 6. *The relationship between rainfall, soil type and the number of flowers produced to age 452 days in rubber vine.*



From J.S. Vitelli 1996 unpublished report.

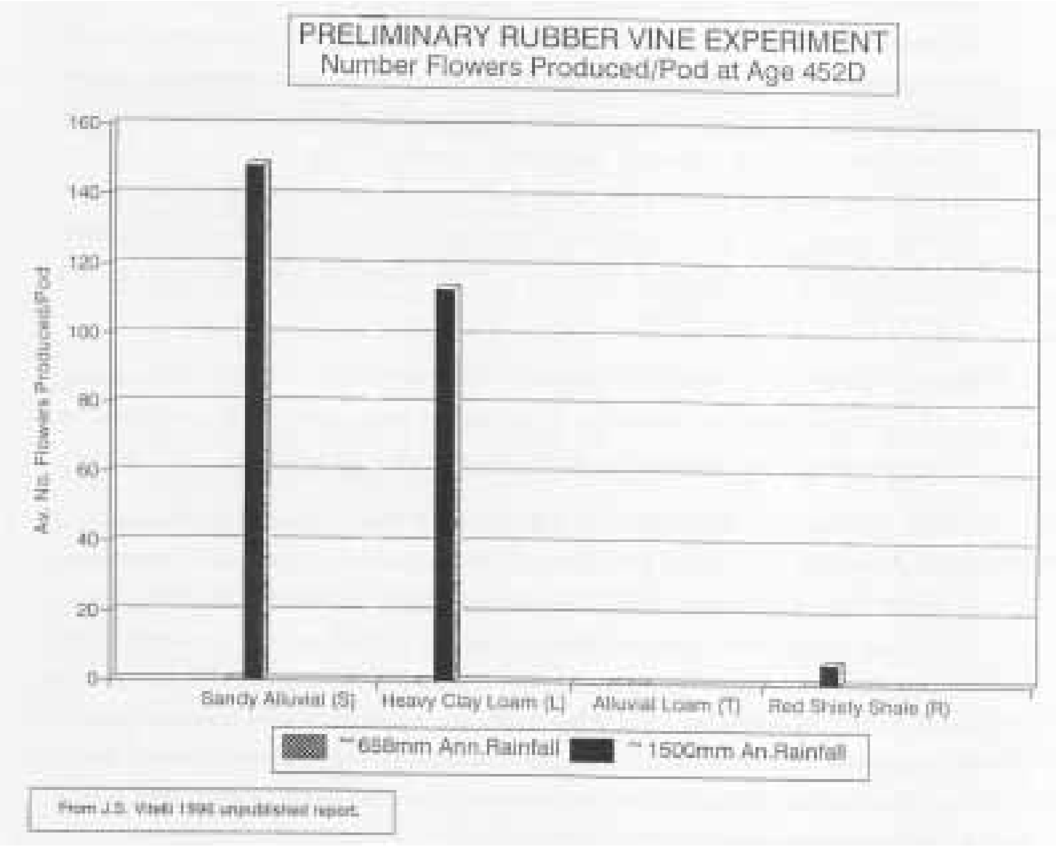
The flowers, including stigma and style, abscise within 24 hours of their opening and many of them within six hours; it follows that pollen germination and pollen tube growth must be sufficiently rapid to allow complete penetration into the ovary within that time. The pollen is capable of germinating 36 hours prior to anthesis and the stigma surface is receptive 24 hours before flowers open. The most efficient flowers were the ones, which opened first with efficiency falling off very rapidly for the later flower pairs at succeeding inflorescence levels. One fruit was set for every 44 flowers produced (Curtis 1946).

The fruit is a large greenish pod or follicle, 10-12 cm long and 3-4 cm wide, which can be produced within 6-8 months of germination with good rain. Fruits are produced as horizontally opposed pairs. As they mature they darken and when mature, they split along their upper face, allowing the seed plumes to be opened by the wind and carried off. Owing to the comparatively heavy seed (approx. 10 mg) dispersal distance would be limited (Sen 1968). No literature exists on the distance seeds fall from the parent plant or the effect strong winds or cyclones would have on seed dispersal. In Australia, a large number of seeds are observed on the ground near the parent plant after mature follicles split, with a small percentage of seed plumes remaining within the follicle cavity and later being dispersed by the wind.

Water may also play an important role as a dispersal vector. Seeds and follicles are capable of floating large distances. Flooding may cause seeds to be carried down stream and up stream, as well as spreading seeds outwards from the creek channel. Small, isolated and remote but well established rubber vine infestations along the east coastline of Queensland and the Gulf of Carpentaria, suggest that follicles and seeds may be dispersed by sea. Pods float for 40 days in seawater so currents may act as a long distance dispersal vector.

Rubber vine seed has a very high viability but is short lived (12 months) in field situations. Seed remains 80% viable after 14 days immersion in seawater. Siddiqui and Warisi (1945) found that seeds planted 5 to 10 mm deep in soil and covered in mulch began germination in 4 days and over 90% had germinated within 6 days. In Queensland, freshly collected rubber vine seeds planted in soil or potting mix in a glasshouse and held at 30°C maximum, 15°C minimum, exhibited germination levels in excess of 95% within 6 to 20 days (Dale 1980). Seeds surface sown in field nurseries with no mulch had 49% germination after 20 days, while adding mulch increased germination to 92% after 14 days when watered “suitably”
(Nath 1943). Dale (1980) investigated the germination of rubber vine on seven soil types with surface sown seeds and found wide variation from 22% (brown loamy sand to sandy loam) to 100% (cracking clay) germination. Water was applied daily, maintaining each soil type to a previously determined water content, though no mention of the water content value was made.

Figure 7. *The relationship between rainfall, soil type and the number of flowers produced per pod at age 452 days in rubber vine.*



From J.S. Vitelli 1996 unpublished report.

For buried seed or seed in a location where it is protected from desiccation, the seed would not be so dependant on continuous rainfall for germination. For seed lying on undisturbed soil in an open environment, the probability of the soil surface remaining moist long enough for germination to occur is much lower than for protected locations. Charters Towers has on average only 6.5 and 6.7 days receiving more than 5 mm rainfall in the wettest months (January and February respectively) (Dale 1980) and under these conditions an exposed soil surface would be unlikely to stay moist for long periods. Rubber vine seeds require approximately 5 days to commence germination; seedlings would therefore be unlikely to establish in unprotected environments under the normal climatic conditions experienced at Charters Towers. The highest densities of seedlings in the field are present in protected areas under shrubs, in the beds of streams and along stream banks where the soil surface remains moist for extended periods.

Seeds on the surface of the soil may experience temperatures high enough to reduce viability (>35^{o}C) whereas buried seed would have a more uniform temperature throughout the day. No information exists on germination under normal field environmental conditions.

Hubble and Keogh (1942) concluded that the major factor affecting germination and establishment was the degree of protection at the soil surface during germination. Disturbance of the soil surface by erosion, man or animals improves the establishment of rubber vine. Hubble and Keogh (1942) suggested that this was less a matter of direct protection of the seedling than of improved moisture status. Abundant germination of seed under parent vines and at the foot of creek banks points to the importance of a combination of protection (layer of leaf litter) and improved water supply. On self-mulching, cracking clay soils the plants established naturally, probably because of the protection of the seeds by the broken surface and the high moisture storage ability of the soil.

A pot trial using seven soil types was performed by Dale (1980) who showed wide variation in establishment (i.e. the number of individuals which grew into healthy plants) of rubber vine on the different soil types when the seeds were sown on the surface. The establishment varied from 9% to 75% of the seeds sown. Good establishment of rubber vine (84-100%) on the seven soil types with seeds buried at 1 cm depth indicates that soil type has little effect on establishment when the seed is buried (Dale 1980).

Seed burial would normally occur where the soil surface is disturbed by natural causes such as floods, erosion, animals or man. Burial by wild pigs could be significant in areas where large pig populations occur. Deeper burial (5 cm) reduced establishment (53-100%) in the heavier textured soils but good establishment still occurred on most soil types (Dale 1980). The clay content was the soil factor most closely related to the establishment of surface sown rubber vine seeds in pots and it appeared that water availability (content at field capacity) was the major factor in this relationship.

In the field where rainfall would not be as regular as pot trial watering, the effect of soil type may be more important. Cracking of the soil surface and partial burial of the seed would become more important as the amount of water reaching the soil surface decreased.

7.0 Efficacy of Current Control Methods

The control of rubber vine is a long-term problem. Mechanical and chemical control are essentially short term solutions but research at the Tropical Weeds Research Centre, Charters Towers is aimed at improving efficiency in the techniques. Biocontrol agents are generally looked to as long term solutions and ecological data on factors affecting seed germination, plant establishment, rates of growth and time frames on flower and fruit production are also being obtained. This information should enhance future control and management options.

From the point of view of the landholder, the control of dense rubber vine infestations is uneconomic and they have requested assistance through tax concessions, cheaper herbicides, access to heavy machinery and accredited weed control operators. Non-compliance by leaseholders to lease conditions regarding declared pest plants and the inability to effectively enforce the conditions, has contributed to the current level of infestations.

7.1 Prevention

Because rubber vine seed is most commonly spread by wind and water it is difficult to prevent seed dispersing onto uninfested land. The goal is thus to prevent rubber vine from establishing and forming dense infestations. Properties should be inspected regularly and particular attention should be given to creek and riverbanks, gullies and other moist areas. Any isolated plants that are found should be promptly controlled and follow-up visits should be made to ensure there is no re-establishment or regrowth.

7.2 Chemical Control

A number of chemical control procedures are available:

- <u>Foliar spraying</u>: Several herbicides can be used (Table 2) but in all cases, a wetting agent such as BS 100 must be used. Plants must be sprayed to the point of run-off and all leaves should be covered. The plant must be actively growing and not water stressed or bearing pods, so the optimum time of year is March to May. Foliar spraying is most effective on plants less than 2 m high; large plants with a stem diameter of more than 8 cm are not killed. If the sprayed areas are densely infested, a follow-up spraying when leaves begin to develop normally is required, or preferably, the stand should be fired although this requires the exclusion of stock to allow adequate fuel build up. With foliar sprays mortalities of 55-95% can be expected.

- <u>Cut Stump</u>: There are several available herbicides (Table 2) and this is the most successful method of chemical control but it is labour intensive and therefore only suitable for scattered infestations.

- <u>Basal Barking</u>: There are several available herbicides (Table 2) and the method can give a high level of control, with 80-95% mortality although it is less effective on multi-stemmed plants and on stems greater than 28 cm diameter. Best results are obtained when the plant is actively growing.

- Root Application: Graslan and Velpar can be used, but these chemicals are not specific, and their activity and therefore effectiveness will vary with soil type and environmental conditions (50-80 mm rainfall is needed to ensure up take by the plant). Graslan should not be used along waterways, where the most dense rubber vine infestations often are as it is ineffective and environmentally unacceptable.

- Aerial Application: Three herbicides are recommended for aerial spraying (Table 2) and this control technique is most cost effective on large dense infestations. Best results (65-90% mortality Grazon DS and 10-20% AF Rubber Vine Spray) are obtained when plants are actively growing. Graslan should not be applied along waterways and AF Rubber Vine Spray requires repeated applications.

The availability of a cheap herbicide would substantially aid control efforts at the property level and the use of adjuvants as an aid to reducing costs and improving the efficacy of current herbicides needs investigation.

7.3 Mechanical Control

The use of slashing, cutterbars, ploughing and discing are effective to reduce dense infestations, particularly along creek flats. Optimum control is affected in June to September. Kill rates greater than 90% can be achieved with a blade plough/cutter bar, although slashing usually only achieves about a 50% kill rate. Bulldozing only kills approximately 10% of the infestation and creates a good rubber vine seedbed so is not an effective control treatment.

As of yet there is no really effective method for the control of rubber vine in its core habitat area of creeks and gullies. New tree clearing guidelines preclude the use of mechanical control methods in these areas although the Preliminary Tree Clearing Policy recognises the problem of rubber vine along watercourses and special consideration will be given to these areas. Under the Land Act (1994) a tree clearing permit is not needed for noxious plants unless mechanical means are to be used in a critical area.

Under the Ancillary Provisions to the Land Act (1962) one type of critical area is an area of high conservation value that can be (Land Regulations 1988):

- Land within 40 m of a watercourse or lake
- Land within 400 m of the highest astronomical tide reaches on a river, creek or stream
- Wetlands
- Land within 1 km of high water mark at the coastline.

Ground surface cover (including leaf litter) is important in reducing run-off and sheet erosion. However, riparian areas receive most run-off from surrounding areas and are more susceptible to rill erosion. Rubber vine roots help in reducing rill erosion in these areas and large scale removal of rubber vine from along the banks of waterways, particularly by mechanical means, may cause erosion problems as large scale infestations will have destroyed any other vegetation which may have helped in maintaining bank stability.

7.4 Fire

Dale (1980) made a major study of the distribution and ecology of rubber vine in Queensland in relation to the frequency of fires. He concluded that the first requirement for rubber vine to develop into a dense stand was for the area to be free from regular burning. Within the areas where fires seldom occurred, rubber vine was restricted in distribution by factors affecting seedling establishment.

Dale (1980) found that the reduction in density of rubber vine plants over four years in an area burnt each year ranged from 19-73%, with seedlings being more susceptible to fire than mature plants. Plants growing in alluvial soil along a watercourse were least affected by fire; the highest mortality occurred in scattered stands of rubber vine on the slopes. The major effects of annual fires is to prevent seeding by killing the plants back to the base each year. Fires also prevent seedling establishment. No mention of fuel load was made in this study except that the area was lightly stocked at one beast per 15 ha.

Land management practice may have affected the distribution of rubber vine. Heavy grazing and drought reduced the amount of available fuel, and so reduced the frequency and intensity of fires. Absence of fires has also led to an increase in the density of shrubs, thus further assisting the establishment of rubber vine. Because of the continuing trend towards greater utilisation of pasture and reduced fire frequency, the control of rubber vine by fire has become less effective and less practiced.

Where there is sufficient dry fuel load to produce a fire hot enough to ignite green rubber vine fire will kill 30-70% of plants, reduce the bulk of rubber vine present and can control seedling establishment and regrowth. A fuel load of 1000 kg ha^{-1} will kill exposed seeds but mortality drops to 20% if seeds are even slightly buried. In many instances areas will have to be closed off from stock for 12-18 months in order for a sufficiently high fuel load to accumulate.
Periodic drought and subsequent grazing pressure can render fire an ineffective control option. It is still being evaluated but once a major infestation has been removed a judicious use of fire and pasture management may be sufficient to avoid reinfestation by rubber vine.

All of the above control methods require follow-up treatments to ensure that remaining plants and establishing seedlings do not grow back and become a problem.

7.5 Biological Control

In the extensively infested north-eastern part of Queensland biocontrol is the only feasible method for slowing down the invasion of rubber vine

A number of potential insect natural enemies of rubber vine have been tested as biological control agents, but most were insufficiently host specific and could not be released
(Tomley 1995b). There is genuine concern that biological control may not be a control option because of the limited insect fauna specifically associated with rubber vine and that the available suite may have been exhausted. However the rubber vine moth, *Euclasta whalleyi* (Pyralidae) was found to be restricted to plants in the sub-family Periplocoideae. There are two native species of *Gymnanthera, G. oblonga* and G. *fruticosa*, in the Periplocoideae

that occupy similar habitats to rubber vine but no important crop or ornamental plants. On the basis that the threat of extinction of *G. oblonga* was far greater from rubber vine than from *E. whalleyi* and that because of its location (restricted to an area near Alice Springs) *G. fruticosa* was at minimal risk from *E. whalleyi*, permission was given in 1987 for release of the moth in the field (Tomley 1995b).

Despite large numbers of insects being released, it appeared that the moth had failed to establish, but in the winter months in 1995 it was found to be causing heavy defoliation to rubber vine in the Charters Towers, Hughenden, Georgetown, Greenvale area. The moth was more active in the drier open areas than the more moist gullies. It is possible that the dry, drought conditions prevailing at the time favoured the population build up of this insect.

A rust, *Maravalia cryptostegiae*, was also considered to be a potential biocontrol agent for rubber vine. Host testing showed it to be highly specific to the genus *Cryptostegia* with only weak infection of the Australian Periplocoidid *Cryptolepis grayi*. Permission was given to release the rust in the field in early 1993. This isolate did not appear to result in permanent establishment, but another isolate was released in 1994/95 with apparent good results - the rust appears to be spreading and causing large-scale defoliation.

Neither the rust nor the moth appears to kill the plant. At the best their effect will be to weaken the host so that it is less invasive. Since both the rust and moth can affect the flowers, it is possible that seed production may be reduced but in view of the low ratio of fruit to flower set, possible compensation by the plant makes this unlikely.

With both control agents it is too early to make any predictions about what level of control might eventuate. The presence of both of them has little bearing on control methods and management practices for the near future although one concern is that both biocontrol agents are defoliators and this may interfere with control strategies based on the use of foliar herbicide sprays. Information on the rate of spread and the activity and population dynamics of the two species is required for their effectiveness to be established.

7.6 Commercial Exploitation

Opportunistic commercial exploitation of a weed can complement weed control if there are economic benefits to be gained and if commercialisation does not jeopardise control objectives.

Rubber vine produces a rubber of fair quality and has been used in Madagascar and India for this purpose (Caltabiano 1973). Caltabiano (1973) has reviewed investigations of the plant as a commercial source of rubber. During World War II in particular, it was considered as a commercial source of rubber in Queensland. Although the rubber is of good quality, yields were low (8 lb per ton of harvested material) and this precluded an economic exploitation. It is unlikely that rubber vine will be commercialised in the future.

8.0 Management and Control Practices

8.1 Legislative Status In Queensland

Rubber vine is a declared plant under the provisions of the Rural Lands Protection Act. Currently it is declared as category P3 in the local government areas of Calliope, Barcaldine, Banana, Duaringa, Bauhinia, Jericho, Ilfracombe, Longreach, Winton, Boulia, and all local government areas to the north of the line formed by the areas specified. All P3 infestations are to be reduced in area. It is declared as category P2 for the remainder of the State and the plant must be destroyed.

8.2 Containment Strategies in Queensland

Rubber vine is largely confined to northern Queensland. A proposal for a National Rubber Vine Buffer Zone aimed at restricting further spread throughout Queensland and into the Northern Territory and Western Australia has been accepted into the National Weeds Strategy however the National Weeds Strategy is yet to be adopted. The proposition of establishing a buffer zone is accepted as a working principle by the Department of Natural Resources in carrying out its routine control programmes.

The action plan aims to:

- Establish a buffer zone within Queensland to prevent spread of rubber vine into the Northern Territory consisting of:
    - An eradication zone, approximately 105 km wide, extending from the Gulf of Carpentaria to latitude 21° S (inside back cover). All rubber vine plants found within this zone are to be destroyed.
    - An active control zone, immediately east of the eradication zone (inside back cover). All infestations in this zone are to be mapped. Control work will be carried out on isolated infestations and by a system of catchment management, commencing control activities at the heads of catchments and working progressively downstream.
    - Eradicate the current scattered infestations in the:
        - Lake Eyre, Bulloo and Murray-Darling catchments
        - Coastal catchments from the Boyne River southwards
        - Upper Fitzroy catchments
        - Belyando River catchments

      and establish a monitoring programme to prevent reinfestation.
- Prevent northern spread on Cape York by monitoring the Holroyd River catchment and further north.

Many of the minor infestations south and west of the strategic control line (inside back cover) have been eradicated or are in the process of being controlled. Several shires within the strategic control zone have very little rubber vine, yet. The expansion of rubber vine into these shires must be guarded against. The infestations in the Burke and Mornington shires are of strategic importance since their presence presents a high risk of the plant spreading to the Northern Territory.

8.3 Eradication Strategies in Queensland

Any control programme, whether regional or local, will be sensitive to economic disruption. From the point of view of the landholder, the control of dense rubber vine infestations is uneconomic. Failure of landholders to spend money on control in financially lean years may put an entire control objective at risk. Within north-eastern Queensland, rubber vine infestations are extensive and over much of the region economic returns from the land are poor. Consequently, it is impractical and uneconomic for landholders to undertake large-scale control programmes. In this region an incremental, small scale approach is required. The region contains World Heritage areas, many important national parks and several shires that are relatively uninfested, and control efforts should target these areas.

Control objectives for the north-east are:

1. Eradicate rubber vine in the Herbert River catchment.
2. Ensure adequate and continuing control in national parks and other critical conservation areas, in cooperation with the Department of Environment and Heritage.
3. Isolated areas should be covered by property management plans that centre on fencing creeks, a gradual clearing of open areas and an incremental attack on heavy creek bank infestations using annual fires as the control option.

Eradication objectives south and west of the control line are:

1. To bring the infestations in the Burke and Mornington shires fully under control.
2. Monitor the northern limit of distribution of rubber vine in Cape York, around the Holroyd River region, to ensure no further northward invasion of Cape York.
3. Ensure eradication of rubber vine in Belyando shire around Clermont.
4. Ensure eradication of rubber vine in Emerald shire.

It is imperative that once control of infestations south and west of the control line has been achieved, regular monitoring and follow-up treatments are carried out to restrict the distribution of rubber vine to within north-eastern Queensland.

8.4 Property Management Strategies

Management practices are a most important aspect of controlling rubber vine on a property. The property should be divided up according to rubber vine densities (scattered, medium and dense) mapped from aerial photographs and the resulting areas should be prioritised for control and treated with appropriate control methods (Table 3). As rubber vine can be spread by flooding, water flows over the property in relation to possible source areas for infestation, should be worked out and control should be carried out in liaison with neighbouring properties. If possible, heavily infested areas, including creeks, should be fenced to exclude stock and allow grass to grow to provide fuel for burning. Control should be initiated on scattered infestations.

Whilst regular burning can be an effective management tool its efficacy can depend on prevailing environmental conditions. In drought, it may take several years for sufficient fuel to accumulate for a hot burn and then the fuel may be more valuable as stock feed than for burning. In moist areas, such as along creeks, burns may be patchy and the kill rate low because of insufficient heat in the fire. Such areas may have to be burnt for 2 or 3 years running and then a follow-up up treatment of herbicide applied for control to be effected.

Table 3. *Suggested chemical control options for different levels of rubber vine infestation (Vitelli 1995)*

Infestation Level	Treatment	Herbicide	Ratio	Carrier
Scattered: 1-1000 plants ha-1	Basal Barking Cut Stump Brush Cutter	AF Rubber Vine Spray® AF Rubber Vine Spray® Brushoff®	1:40 1:40 1g L^{-1}	Diesel Diesel Water & Wetter
Medium: 1000-2000 plants ha-1	Foliar spraying Soil (granular) Fire	Grazon DS® Graslan® - -	1:300 7.5-10 g^{-2} - -	Water & Wetter - - - -
Dense: > 2000 plants ha-1	Aerial spraying Soil (granular) Blade plough	Grazon DS® Graslan® - -	3L ha^{-1} 15 kg ha^{-1} - -	Water & Wetter - - - -

An integrated pest management approach should be implemented for rubber vine that is both effective and economically feasible. Depending on rubber vine density, herbicides (ground and aerial), biological control agents, mechanical control (bulldozing, cutterbar, blade plough and slashing) and burning should be used in combination. Biological control agents and fire are the cheapest options for controlling large, dense infestations.

However, development of suitable fire and mechanical control procedures and widespread establishment of biological control agents remain to be achieved. Rubber vine is relatively easy to kill and effective chemical control methods are available, though costly, ranging from
$600-2000 for herbicide and labour costs (depending on the herbicide) to ground treat a dense infestation (3000-5000 plants ha^{-1}) of rubber vine. The poor economics of chemical control are further compounded by the availability of the few effective weed control contractors operating in the region.

All control efforts require monitoring and follow-up treatments. The follow-up treatment should be carried out when plants reach 1-1.5 m high. As seed is wind borne the entire property has to be monitored for seedling establishment. Where possible, the use of annual fires will prevent seedling establishment.

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