Parthenium weed in the Americas

A report on the ecology of *Parthenium hysterophorus* in South, Central and North America.

I. J. Dale
Queensland Department of Lands, Townsville, Queensland 4810

Summary

***Parthenium hysterophorus* L. is an annual weed of American origin which is now present in many tropical and subtropical regions and has become the dominant vegetation over large areas of grazing land in Queensland. The plant was studied in South, Central and North America to determine the soil, climatic and management conditions which favour its growth.**

The plant currently identified as *P. hysterophorus* in much of South America shows significant differences from Queensland material in flower colour and morphological characters. In Mexico and the United States, the distribution of *P. hysterophorus* is dependent on soil type and disturbance within the broad climatic region where it occurs. Some comparison is made with the Queensland situation and the most probable areas of expansion of the plant are considered.

Introduction

Parthenium weed *(Parthenium hysterophorus* L.) is a relatively recent introduction to Australia and has invaded extensive areas of grazing land in central Queensland (Haseler, 1976). The plant has been regarded as native to the countries around the Gulf of Mexico, the West Indies and possibly to central Argentina (Rollins, 1950). In Queensland, the plant is continuing to appear in new locations and large sums of money are being spent to reduce this spread.

The study of *P. hysterophorus* in its areas of origin was designed to determine the climatic conditions and other environmental factors required for growth and distribution. Countries which were visited during the study included the United States of America, Mexico, Bolivia, Brazil and Argentina. These cover the regions regarded as the possible sites of origin of the plant and include most of the situations where it is now present in the Americas.

Due to uncertainty regarding the taxonomy of the species in parts of South America, the characteristics of these plants will be described separately from those present in Mexico and the United States of America. Plants grown from seed collected in Argentina, Bolivia and Corumba, Brazil, showed differences in morphology (Johnson, pers. comm.), pollen colour, capitula size, development of axillary branches, size of disc flowers and petal size from *P. hysterophorus* collected in Australia. The plants from South America also showed variation in these characteristics between samples collected from different areas. The dominant South American form has cream to yellow flowers while the North American type has a white flower. The sesquiterpene lactone, hymenin, which is present in plants from Argentina and Bolivia is different from the lactone, parthenin, identified from most samples collected in India and North and Central America (Towers *et al.*, 1977). One population from southern Texas showed differences in lactone chemistry from other North American populations. Rodrigues (pers. comm.) considers a sample from the Australian population to be identical in the sesquiterpene lactone chemistry of the parthenin race from India, Mexico, the West Indies and the United States of America.

The cream- to yellow-flowered South American group

The distribution of this group of plants (which has been included in *P. hysterophorus* in all published literature) is shown in Figure 1. The plants occur as urban weeds on vacant allotments, as weeds of cultivation, as colonizers of road verges and in native pastures grazed by cattle. The annual rainfall where the plants grow varies from 200 to 1400 mm. The plant grows on soils ranging from sandy alluviums to dark cracking clays but the main occurrences are on clay loams. It occurs at altitudes ranging from 100 to 1600 m (Wild, pers. comm.) to 2500 m (Paniagua, pers. comm.). The plant is present at latitudes from 17°S to 34°S but published reports of the plant from Bahia Blanca (39°S) could not be verified (Wild, pers. comm.).

BOLIVIA

In Bolivia, *Parthenium* plants which have been identified as *P. hysterophorus* have cream- to yellow-coloured flowers and these, together with all cream-flowered plants from South America, will be identified as *Parthenium* sp. in this report. The plant was most common around Santa Cruz but has been reported to the south west as far as Samaipata (Wild, pers. comm.) with a specimen further west from Cochabamba province (Towers *et al.*, 1977). Santa Cruz has a hot sub-humid climate with a reliable summer dominant rainfall

Figure 1 Places at which *Parthenium* sp. and *P. hysterophorus* were observed in South America

and substantial winter rains (see Appendix). Samaipata has an estimated annual rainfall of 1400 mm (Paniagua, pers. comm.). The driest location where the plant was observed in Bolivia receives an annual rainfall of approximately 700 mm.

The climate allows the plant to grow at most times of the year, and young plants and seedlings were present in Santa Cruz during winter. Most of the *Parthenium* sp. in the areas of Bolivia visited occurred within 40 km of Santa Cruz on sandy alluviums with an annual rainfall of about 1100 mm. The most common locations were on roadsides, around houses in villages, in cultivation and on footpaths and vacant allotments in Santa Cruz. On roadsides, a dense mat of short continuous grass was present and *Parthenium* sp. occurred only in areas of recent roadworks.

South of Santa Cruz *Parthenium* sp. was very scattered and was restricted to areas surrounding houses and occasionally to disturbed roadsides. The soils were a heavy clay with the driest area receiving an annual rainfall of about 700 mm. In the town of Santa Cruz, *Parthenium* sp. was present as dense stands on vacant lots on soil types ranging from sandy loams to clay loams, but the main characteristic of these soils was the extreme disturbance of the surface and removal of all vegetation by mechanical means. The main locations of the plant in the city were on vacant lots, footpaths and areas of recent construction activity such as new roadworks and buildings.

To the north and east of Santa Cruz, the soils are very sandy with much of the area devoted to cropping. *Parthenium* sp. occurred in some cotton and soybeans but this was attributed to the use of trifluralin which does not control *Parthenium* sp. Local research workers did not consider that crop yield was being reduced but some problems were encountered at harvesting when the *Parthenium* sp. was still green. *Parthenium* sp. was also present around habitations north and east of Santa Cruz and was very common on roadsides, particularly in the drier areas to the east. For short distances these roadside infestations grew as pure stands with densities of adult plants reaching similar levels to those recorded in Australian populations.

In summary, *Parthenium* sp. in Bolivia was normally present in wet areas and on sandy soils. The plant was restricted to regularly-disturbed situations in the wetter areas but in drier regions it became more prominent on roadsides and around cultivation. The drier areas do not produce the dense canopy of competing vegetation present in wetter areas and the replacement of the pioneer species by later successional stages would be slower. Occasional clearing of all vegetation is sufficient to allow *Parthenium* sp. to retain its position as a major component of the vegetation in disturbed areas in the drier locations. Although the plant was common around Santa Cruz and was sometimes dense it rarely presented any problems to agricultural production.

ARGENTINA

Parthenium sp. occurs over much of the northern part of the country under a very wide range of climatic conditions. The rainfall in the areas where the plant has been located is 200 to 1000 mm, but most of the extensive areas occur where the annual rainfall exceeds 700 mm. The rainfall pattern in all of these areas shows a definite summer maximum with a dry winter period of several months. The plant extends to at least 34°S which, combined with the high altitude, is an area of cold winters where the plant grows each summer. Climatic data for some of the areas in Argentina where the plant occurs are listed in the Appendix.

In the cool dry areas at the southern limit of the plant's distribution, such as Mendoza, *Parthenium* sp. was restricted to the road verges and irrigation channels where extra water was available (Wild, pers. comm.). To the east at San Luis and Cordoba and north to La Rioja and Catamarca, the annual rainfall and temperatures are higher at all times of the year, and under these conditions *Parthenium* sp. occurred largely on vacant lots in towns, around dwellings and as dense stands along roadsides. Further north in the area around Tucuman, the rainfall is higher again, with the areas south and east of the city (where most *Parthenium* sp. was present) receiving 700 to 1000 mm a year. The most extensive stands of the plant in Argentina were present in this area, with many paddocks containing infestations covering many hectares. These paddocks were cultivated regularly for summer crops, and the dense stands of *Parthenium* sp. developed during the fallow period or when the crop was not planted. During the cropping phase, *Parthenium* sp. rarely became a problem because of control by cultivation and the application of chemicals.

The southern limit of the plant appears to be determined by a combination of low rainfall and a short growing season due to the cold winters. The *Parthenium* sp. plants in this region were normally less than 50 cm tall (Wild, pers. comm.). Further south most rainfall occurs during the winter months and *Parthenium* sp. does not appear to grow under this rainfall regime. In warm wet areas the plant germinates and grows over a longer period, and living plants may be present during winter. In the cooler areas, even in irrigation ditches where water is not limiting, the plant does not grow as large and senesces earlier, suggesting that senescence may be due to the onset of cold weather as much as to the start of the dry period of the year.

The plant has been recorded as a component of pastures of the Chaco in north-eastern Argentina by Morello and Saravia (1959a). This area of grazing land is used in its native state but prolonged overgrazing has caused extensive degradation. Bragadin (1959) recorded *Parthenium* sp. in a degraded pasture near Serrezuela, and Morello and Saravia (1959b) considered the plant as an indicator of the highest degree of destruction of the natural pasture when no grasses were left. *Parthenium* sp. was also reported in native pastures in Santiago del Estero province but always in the most degraded pasture situations (Morello and Saravia, 1959a). *Parthenium* sp. also occurred in native pastures in the east near Presidencia Roque Saenz Pena, again in very disturbed areas, but was eaten by livestock to a limited extent (Borden, pers. comm.).

Parthenium sp. in Argentina requires adequate rainfall or some source of supplementary water during the summer period when temperatures are high enough for good plant growth. In the wet areas in the east, however, the plant was not found perhaps due to competition from the good grass cover. *Parthenium* sp. was recorded from soils with a wide range of properties including texture, pH and nutrient levels. The major feature of the areas where *Parthenium* sp. was present was the regular disturbance. In the wetter areas *Parthenium* sp. has the potential to form dense stands covering many hectares, but regular destruction of the other vegetation is required for the plant to maintain its dominance. In drier areas the plant

has fewer areas suitable for growth, but does not require such regular or extensive disturbance of the other vegetation.

BRAZIL

The distribution of the yellow-flowered plant in Brazil was limited to the city of Corumba and the roads and railways leading out of the city. To the east, the plant extended only as far as the river Paraguay. Roadsides, around dwellings, old cultivations and recently-cleared areas were the main habitats of the plant. The largest areas of *Parthenium* sp. on cleared and fallow areas were on clay soils ranging from black and self-mulching through brown clays of hard blocky structure to red sandy clays. One area of the plant in a recently-planted *Panicum* pasture contained clumps of *Parthenium* sp. covering up to 300 m^2. The pasture was very dense and vigorous overall, but contained significant areas where no *Panicum* was present and pure stands of *Parthenium* sp. occurred.

Several paddocks which were in fallow or in the very early stages of pasture development contained scattered *Parthenium* sp. over many hectares but always at low densities. Overgrazed pastures contained *Parthenium* sp. at several locations at low densities but the grass component in these areas was always very sparse. In the city of Corumba, *Parthenium* sp. was very common on vacant allotments and disturbed areas around dwellings and on the outskirts.

The temperature and rainfall in Corumba (see Appendix) are higher than for the areas studied in Argentina but similar to Santa Cruz, Bolivia. The plant had a similar distribution to those in the other South American countries in the dense stands present on the vacant lots in the city, along roadsides and around dwellings, but at Corumba it was also present in planted pastures, overgrazed pastures and fallowed cultivations. The soils on which the plant was present at Corumba varied from cracking clay soils to a very stony loam on which the soil surface was completely covered by stone. All *Parthenium* sp. occurred in disturbed areas but in some locations the plant had continued to survive without repeated disturbances. The role of the grazing animal in removing other vegetation appeared as significant in this area as disturbance of the soil surface and removal of vegetation by man.

The white-flowered *Parthenium* group

This plant is the type which is present in Mexico, the United States of America, Australia and Brazil and, on the basis of similarities in the sesquiterpene lactone chemistry, probably also in India and the countries around the Caribbean Sea (Subba Rao *et al.*, 1978; Towers *et al.*, 1977). This plant conforms with the description of *Parthenium hysterophorus* as listed by Rollins (1950) and subsequent authors and will be identified as *P. hysterophorus* in this report.

BRAZIL

The white-flowered form occurred in southern Brazil in Parana and Sao Paulo States where it was largely restricted to the towns. The plant was common in Londrina and Maringa and occurred as far north as Ribeirao Preto (Wild, pers. comm.). The favoured locations were vacant allotments and disturbed areas such as building sites and median strips on major roads. The plant was seen very occasionally on roadsides between towns, in coffee cultivation and in a fallowed soybean cultivation. The soil over Parana State is an acid, red clay loam to light clay which originally supported rainforest. The rainforest has been cleared over the past 30 years for cropping but *P. hysterophorus* remains very restricted although spread over a large area.

In comparison with other countries where this plant is common (Mexico, the United States of America and Australia), the soil type is very acidic. Levels of pH from areas of *P. hysterophorus* were as low as 5.2 when tested. The rainfall for Londrina (see Appendix) is higher than for the other regions where *P. hysterophorus* was studied. The distribution of the plant in Brazil suggests either a very recent introduction or a plant which has only very limited habitats suitable for its growth.

Some *P. hysterophorus* also occurred in western Brazil along the railway line from Campo Grande to Corumba, but mainly on the eastern side of the river Paraguay. One small area was present south of Corumba — on the western side of the river Paraguay on the roadside in an area where the yellow-flowered form was dominant. The area of white-flowered plants was very restricted and clearly defined, although there was some mixing with yellow-flowered plants.

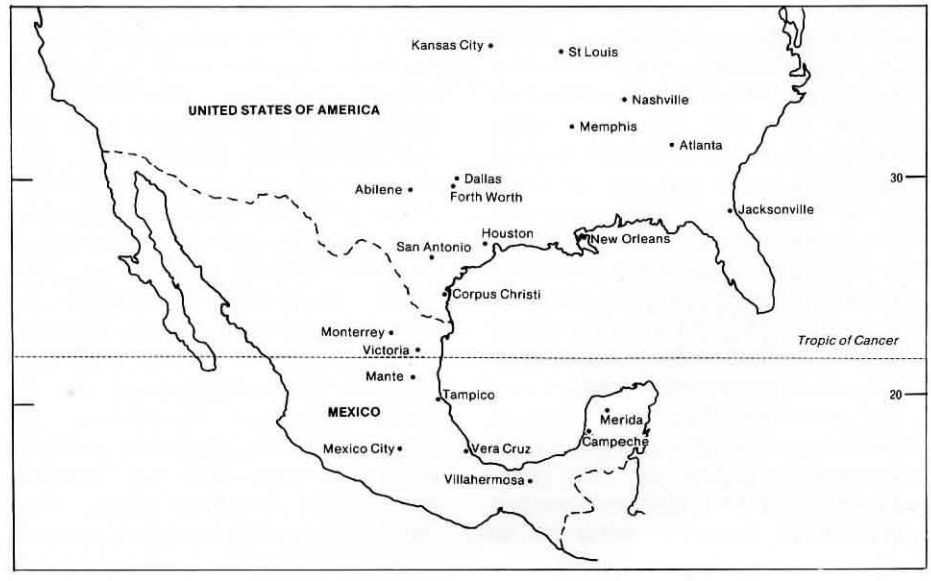
MEXICO

Parthenium hysterophorus has been collected from most parts of the country except the very dry far north west (Rollins, 1950). Although the plant has been recorded from most parts of Mexico, many of the records are from small isolated areas, particularly in urban situations.

In the west coast and central part of the country, *P. hysterophorus* has been reported as a weed in cultivated crops (McClay, pers. comm.) but the extent of the problem is unknown. The plant was also common on roadsides and in wetter pastures in the States of Nayarit, Calisco, Colima and Michoacan.

The plant grew in towns all over the country on vacant lots and disturbed areas, but in many regions it did not

Figure 2 Places at which *Parthenium hysterophorus* was observed in North America



extend to any other habitats. This may have been related to regular disturbance and to water runoff from buildings and streets. *P. hysterophorus* was also present on roadsides in widely scattered parts of the country, but often only for short distances around towns and habitations and where significant infestations occurred in fallowed paddocks and on the edge of cultivation. In some very dry areas, with annual rainfall of 300 to 450 mm, *P. hysterophorus* occurred as a narrow roadside strip up to 50 cm wide on the edge of the bitumen.

The plant occupied the widest range of habitats in only two regions of Mexico that were visited — a part of Vera Cruz State and the area between Tampico and Monterrey. At its most extensive, the plant occurred for long distances on roadsides, in fallowed paddocks, in cultivation and on the margins of cultivated paddocks and pastures. *P. hysterophorus* occurred west of Vera Cruz on roadsides, around farm buildings, in cultivation and occasionally in pastures. The soils were brown to black clays, mainly used for grazing and coffee.

The largest areas of *P. hysterophorus* in Mexico occurred between Monterrey and Tampico, with many fallowed paddocks containing dense infestations. The soil was predominantly a shallow, black, self-mulching, cracking clay. Most areas of *P. hysterophorus* that were examined had been cropped over the previous summer and had been cultivated since the crop was harvested. Several areas which had not been cultivated from some years and were being used for grazing also carried dense stands of the plant, especially around watering points, but other infestations covered many hectares in an apparently uniform stand over the whole paddock. The grass component of these pastures was extremely sparse. *P. hysterophorus* was occasionally observed around cattle watering facilities in other localities where disturbance and heavy grazing allowed the plant to establish.

Temperature does not prevent the growth of *P. hysterophorus* in any parts of Mexico except possibly at the highest altitudes. Restricted rainfall may exclude the plant from the driest parts and from the winter rainfall areas, but the presence of the plant in towns over most of the country indicated that it can find environments suitable for growth under most climatic conditions occurring in Mexico. *P. hysterophorus* does not grow in winter rainfall areas, probably due to the low temperatures during the period when soil water is not limiting. The very slow growth rate at low temperatures would reduce the probability of survival in competition with other species.

The soil type appeared to be the major factor determining the development of extensive stands of *P. hysterophorus* spread over many kilometres. The two regions in Mexico where this occurred both had predominantly dark, alkaline, self-mulching, cracking clay soils. Most of the extensive areas of *P. hysterophorus* occurred in areas receiving 600 to 800 mm annual rainfall although some had rainfalls up to 1500 mm.

UNITED STATES OF AMERICA

Although *P. hysterophorus* has been recorded from many eastern and central States of the U.S.A. (Rollins, 1950), the plant was common and dense only in parts of Texas and Oklahoma. In other States the plant occurred only in towns, usually in waste areas and vacant allotments, and probably grew only at irregular intervals. The northern towns where the plant has been collected have very cold winters, but during the summer the temperatures reach levels similar to areas further south where the plant was more abundant.

The two regions in Texas where *P. hysterophorus* was common, with some dense stands out of the towns, were around Corpus Christi and from San Antonio to Dallas. The heaviest concentration was seen within 70 km of Corpus Christi with plants present on roadsides, in cultivation and in grazing land. The infestations in grazing land were normally confined to small areas of several hectares where horses were confined in small paddocks. One large area extended for 3 km along the highway where the vegetation had been mechanically cleared but no cultivation had occurred. The original shrub vegetation had been very open and the disturbance allowed a dense stand of *P. hysterophorus* to cover hundreds of hectares of grazing land. Within the same paddock was an area developed to buffel grass *(Cenchrus ciliaris)* which contained no *P. hysterophorus*. Surrounding the densest area was a zone where the plant was present occasionally on roadsides, around farm buildings and in pastures and cultivation. This area extended north-eastward as far as Houston but only about 80 km west and 50 km south of Corpus Christi. This region has a black, self-mulching, cracking, clay soil of high fertility which is mainly devoted to cultivation.

In the area from San Antonio to Dallas and north to the State border, *P. hysterophorus* was present on a narrow strip several kilometres wide as occasional dense stands around farm buildings and in some paddocks used for grazing, especially when overgrazed. The obvious effect of grazing management was shown by sharp boundaries at fence lines. The soils in this region are black cracking clays which are used for both grazing and cropping.

Comparison of *Parthenium hysterophorus* in North America and Australia

The major feature of *P. hysterophorus* in North America was its limited distribution as a weed of towns, roadsides and very disturbed areas. The plant has been recorded in a range of crops including sugar cane, maize, cotton, sorghum, onions, citrus and pecan orchards. Although occasionally dense, production has not normally been affected by the presence of the plant. Dense stands of *P. hysterophorus* occurred only when a full control programme was not carried out. The plant is present in some crops in Australia, but its occurrence is restricted to small dense areas and larger areas of widely scattered plants, and it has not yet become a major problem in cropping areas.

Parthenium hysterophorus forms extensive dense stands along roadsides in Queensland in the absence of a chemical control programme, but in North America the plant did not reach the same density in this situation. The plant also occurred on roadsides in some parts of Mexico and Texas but was normally very scattered and present in limited areas only. The major difference in management between the roadsides in Queensland and in North America is the routine disturbance and grading of road verges that occurs in Queensland. With gravel and narrow bitumen roads regular maintenance of verges is required, but in North America the surfaced road section is sufficiently wide for regular

reworking of the verges not to be necessary for road safety. Some very limited areas of dense *P. hysterophorus* occurred where there had been extensive disturbance. In the absence of repeated disturbance, other vegetation replaced the *P. hysterophorus* which grew as the first colonizer after the disturbance. Where the roadsides were mown *P. hysterophorus* was uncommon and only grew as very scattered plants.

Parthenium hysterophorus rarely occurred as extensive stands in grazing lands in North America and normally occurred only in small, overgrazed paddocks. Only two large areas of *P. hysterophorus* were studied in purely grazing situations, but both of these paddocks had been mechanically cleared of tree vegetation during the previous few years, and in both cases the grass component was very sparse. In southern Texas and northern Mexico there was some clearing of scrub for pasture but this involved much more intensive land preparation prior to sowing and carefully controlled planting operations. The areas cleared were normally restricted to a few hectares, and subsequent management of the developing pasture stand could be carefully controlled. The main grass used was buffel grass and soils were mainly sandy loams. The combination of a soil type which does not normally favour *P. hysterophorus* and the intensive management of the pastures during development has resulted in no significant problems in pasture development in Mexico and Texas.

The situation in which the density of *P. hysterophorus* reached similar levels to the pulled scrub areas in Queensland was the fallow period between summer crops. In Mexico, dense stands grew in the early part of the summer before the crops were sown, with no obvious attempts to control weed growth by cultivation.

The restriction of extensive stands of *P. hysterophorus* to alkaline clay soils is similar in North America and Queensland. In both regions the plant will grow on other soils but is much more restricted in distribution and usually requires more severe soil disturbance for the plant to establish. Several other *Parthenium* species are restricted to soils with a high pH (Mears, 1973), and this appears to be a major factor in the distribution of *P. hysterophorus* in North America.

A comparison of climatic conditions in the areas where *P. hysterophorus* is most common in North America and Queensland — Monterrey and Twin Hills — shows the same general pattern. In Queensland, the daily temperature range is greater at all times of the year but the mean daily temperatures would be very similar in the two regions. Rainfall total for these two regions are similar, although in Mexico the plant extends into higher rainfall areas receiving up to 1000 mm annual rainfall.

The climatic data from areas in Texas where the plant was very common indicate that the plant will produce dense stands in areas with very low winter temperatures. The summer maximum temperatures for areas such as Dallas, however, are higher than for Monterrey so that during the growing period the plant would not be exposed to the low temperatures. The high latitude zone represented by Kansas City has a very short summer period of higher temperatures and this would appear to be the major factor limiting the northern spread as the rainfall distribution and total do not change. Comparison with climatic data from Roma, Queensland, indicates a climate fairly similar to San Antonio, Texas. The plant extends further north than San Antonio with some dense infestations as far north as Dallas, and this suggests that the plant could survive well south of the Queensland border purely on consideration of latitude and temperature.

The rainfall in most areas where *P. hysterophorus* occurred in North America is higher than for the presently-infested areas in Queensland, suggesting that the most probable direction of expansion by the plant in Queensland would be to higher rainfall areas. In North America the plant was very restricted in any areas receiving less than 600 mm annual rainfall, but soil factors may be a major complicating factor. In North America, where the rainfall is low, the stony shallow soils do not favour *P. hysterophorus*. In Queensland, where deep heavy clays occur under low rainfall conditions, the extra water storage in the soil may allow the plant to grow under lower rainfall regimes than in North America. The distribution of the rainfall during the year appears to be as important as the total because the plant grows rapidly only during periods of high temperatures which would restrict it to areas receiving good summer rainfall. A dry season lasting for several months would also benefit an annual species such as *P. hysterophorus* because competing perennial grass species would not be able to maintain active growth for the whole year.

Comparison with the South American race

Because the South American plant is different from that in Australia, the characteristics of *Parthenium* sp. may not indicate the probable behaviour of *P. hysterophorus* in Australia. In general, however, *Parthenium* sp. in South America occupies similar habitats to those favoured by *P. hysterophorus* in North America. The overall climatic conditions are similar similar but in South America the plant appeared to extend more commonly into the cool dry areas. *Parthenium* sp. did not show the marked preference for alkaline clay soils exhibited by *P. hysterophorus* in North America but soils of this type are very uncommon in this part of South America. Most *Parthenium* sp. in South America occurred on loams.

Conclusions

The distribution of *P. hysterophorus* in Queensland is controlled by factors similar to those limiting the plant in its areas of origin, but because of differences in land management, soils and climate the plant covers much greater areas and is a far more significant problem. The clearing of very large areas of *Acacia* scrubs which originally contained very little grass, and poor subsequent management of introduced pastures resulted in large areas of bare ground with negligible grass cover. The combination of neutral to alkaline clays and absence of competing vegetation provided ideal conditions for development of large stands of *P. hysterophorus*. The one feature of the plant in Queensland which is not seen in North America is that pure stands remain dominant for at least 15 years in the absence of further disturbance.

The plant is more common on roadsides in Queensland than in North America, but this can be attributed to more regular disturbance. In natural grasslands the situation is similar in the two areas with *P. hysterophorus* becoming dominant only in the most overgrazed situations. The plant appeared more prominent in cultivated areas in North America, particularly during the fallow period, but in neither area does it significantly affect crop production. In both regions the

densest stands produce a complete ground cover with no other species present.

From the distribution of *P. hysterophorus* in North America, the plant appears to have the potential to spread to many parts of Queensland and to survive in most parts of the State. The favoured area would be the heavy clay soils which extend through the brigalow belt of Queensland south into New South Wales. Rainfall through this area is within the range in which *P. hysterophorus* normally occurs and temperatures would be unlikely to limit the plant in Queensland. The area of infestation in this region would depend on the number of suitable habitats for the plant within the broad climatic region.

Although unlikely to become a major weed problem on the coast because of soil factors and the density of the natural grasses, the plant would be capable of growing and maintaining itself on disturbed roadsides and in towns. Restricted patches around yards and watering points in the coastal region could also be expected.

The possible extension of the plant into areas with less than 500 mm annual rainfall is difficult to assess. Roadsides, where there are both disturbance and extra water due to runoff, would provide conditions suitable for growth in the dry environments. Although the soils in western Queensland are similar to some of the most-favoured soil types overseas, *P. hysterophorus* would probably be restricted to wetter areas where water accumulates. In all areas, the spread of the plant into large areas of grazing land will depend on large-scale clearing or severe overgrazing of natural pastures to provide suitable conditions for growth of *P. hysterophorus*.

References

Bragadin, E. A. (1959). Las pasturas en la region de Los Llanos. *Revista Agronomica Del Noroeste Argentino.* pp. 289–335.

Haseler, W. H. (1976). *Parthenium hysterophorus* L. in Australia. *PANS* **22**:515–7.

Mears, J. A. (1973). Systematics of *Parthenium* section Bolophytum (Compositae, Heliantheae): A correlation of morphological, biochemical and habitat data. *Proceedings of the Academy of Natural Sciences of Philadelphia* **125**(7):121–35.

Morello, J. H. and Saravia, T. C. (1959a). El bosque chaqueno. I. Paisaje promitivo, paisaje natural y paisaje cultural en el oriente de Salta. *Revista Agronomica Del Noroeste Argentino.* pp. 5–81.

Morello, J. H. and Saravia, T. C. (1959b). El bosque chaqueno, II. La ganaderia y el bosque en el oriente de Salta. *Revista Agronomica Del Noroeste Argentino.* pp. 209–59.

Rollins, R. C. (1950). *The Guayule Rubber Plant and Its Relatives.* Contributions of the Gray Herbarium No. 172. Harvard University.

Subba Rao, P. V., Mangala, A., Towers, G.H.N. and Rodriguez, E. (1978). Immunological activity of parthenin and its diasterioisomer in persons sensitized by *Parthenium hysterophorus* L. *Contact Dermatitis* **4**:199–203.

Towers, G. H. N., Mitchell, T. C., Rodriguez, E., Bennett, F. D. and Subba Rao, P. V. (1977). Biology and chemistry of *Parthenium hysterophorus* L.: A problem weed in India. *J. Sci. Ind. Res.* **36**:672–84.

Appendix: Climatic variables for areas in South, Central and North America and Queensland where *Parthenium* grows.

	Average for the months of											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Bolivia: *Santa Cruz* (17°47′S, 63°11′W, alt. 437 m)												
Mean min (°C)	21.1	21.3	20.4	18.8	17.1	15.7	15.0	16.4	18.5	19.8	20.4	20.6
Mean max (°C)	30.5	30.0	30.1	28.2	25.8	23.7	24.4	27.7	30.0	30.2	31.1	31.1
Mean precip (mm)	179	128	107	103	71	72	43	30	63	98	108	139
Mean total (mm)												1141
Argentina: *Mendoza* (32°53′S, 48°50′W, alt. 769 m)												
Mean min (°C)	17.8	16.9	14.7	10.3	6.3	3.0	2.2	4.4	8.1.	10.8	14.5	16.8
Mean max (°C)	29.5	28.2	25.7	21.0	16.8	13.2	13.0	16.1	19.7	22.6	26.3	28.7
Mean precip (mm)	28	21	22	10	11	8	7	10	14	23	20	23
Mean total (mm)												197
Argentina: *San Luis* (33°16′S, 66°21′W, alt. 716 m)												
Mean min (°C)	16.6	15.5	13.3	8.7	5.5	2.6	1.7	3.4	6.8	9.8	13.1	15.8
Mean max (°C)	31.5	30.6	27.1	23.0	19.0	15.9	15.9	18.0	21.1	24.4	27.9	30.7
Mean precip (mm)	90	74	60	33	14	13	10	6	17	53	67	105
Mean total (mm)												542
Argentina: *Catamarca* (28°26′S, 65°46′W, alt. 547 m)												
Mean min (°C)	20.9	19.5	17.3	12.5	8.1	4.5	3.3	6.1	10.9	15.1	18.0	20.3
Mean max (°C)	34.6	32.6	30.7	26.7	22.7	18.7	19.6	22.9	26.4	29.5	31.8	34.2
Mean precip (mm)	66	82	49	20	11	6	4	4	7	29	41	51
Mean total (mm)												370
Argentina: *Presidencia Roque Saenz Pena* (26°49′S, 60°27′W, alt. 92 m)												
Mean min (°C)	20.0	19.4	17.5	13.7	11.8	10.0	8.5	9.9	12.0	14.8	16.9	18.9
Mean max (°C)	34.6	33.3	30.6	26.6	24.0	21.6	22.0	24.5	26.9	29.4	31.5	34.1
Mean precip (mm)	136	125	133	97	49	35	23	23	44	101	113	111
Mean total (mm)												990
Argentina: *Tucuman* (26°48′S, 65°12′W, alt. 481 m)												
Mean min (°C)	18.3	18.0	16.5	12.8	9.8	6.6	5.4	6.1	9.2	12.9	15.7	18.0
Mean max (°C)	30.8	29.5	27.5	23.9	21.0	18.0	19.9	21.9	25.1	27.6	29.4	31.2
Mean precip (mm)	183	159	162	59	29	19	10	8	12	77	108	150
Mean total (mm)												976
Brazil: *Corumba* (19°00′S, 57°39′W, alt. 138 m)												
Mean min (°C)	21.3	21.1	20.7	19.0	17.2	16.0	15.2	17.1	18.8	19.7	20.6	21.2
Mean max (°C)	32.1	32.0	31.6	29.6	28.0	26.5	26.9	29.2	30.9	31.8	32.6	32.5
Mean precip (mm)	178	147	119	83	67	32	18	24	66	103	122	163
Mean total (mm)												1121
Mexico: *Merida* (20°58′N, 89°38′W, alt. 22 m)												
Mean min (°C)	18.1	18.4	19.8	21.3	22.4	22.8	22.5	22.8	22.7	21.8	19.8	18.5
Mean max (°C)	28.0	29.3	31.4	33.0	33.3	32.6	32.1	32.1	31.5	30.1	28.6	27.6
Mean precip (mm)	31	24	17	21	83	134	130	148	180	91	35	34
Mean total (mm)												929
Mexico: *Monterrey* (25°40′N, 100°18′W, alt. 534 m)												
Mean min (°C)	10.0	11.3	14.0	17.5	20.4	22.2	22.4	22.4	20.8	17.6	12.9	10.2
Mean max (°C)	20.9	22.8	26.6	29.3	31.5	33.4	33.9	33.6	30.4	27.4	23.0	21.0
Mean precip (mm)	19	17	13	26	36	63	61	111	156	91	23	18
Mean total (mm)												634
Mexico: *Tampico* (22°12′N, 97°51′W, alt. 73 m)												
Mean min (°C)	15.4	16.6	18.3	21.0	23.5	24.6	24.5	24.7	23.6	21.9	18.2	16.2
Mean max (°C)	23.0	24.2	25.8	28.2	30.2	31.4	31.6	31.8	30.8	29.4	25.9	23.6
Mean precip (mm)	43	16	12	23	47	121	153	135	281	132	46	26
Mean total (mm)												1035

Appendix: Climatic variables for areas in South, Central and North America and Queensland where *Parthenium* grows.

	Average for the months of											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
U.S.A.: ***Houston, Texas*** (29°46′N, 95°22′W, alt. 12 m)												
Mean min (°C)	8.2	9.4	12.2	16.1	20.0	23.3	24.3	24.3	21.9	17.3	11.5	9.1
Mean max (°C)	17.1	18.4	21.7	25.3	29.2	32.5	33.3	33.6	31.4	27.6	21.3	18.1
Mean precip (mm)	94	82	61	87	113	97	131	90	97	91	103	104
Mean total (mm)												1150
Australia: ***Clermont, Queensland*** (22°49′S, 147°38′E, alt. 267 m)												
Mean min (°C)	21.6	21.2	19.7	15.9	11.8	8.4	6.5	9.2	12.4	16.3	19.3	20.6
Mean max (°C)	34.3	33.1	31.5	29.5	25.8	23.1	22.6	25.3	28.4	31.6	34.1	34.0
Mean precip (mm)	125	115	77	39	34	38	27	18	21	34	52	90
Mean total (mm)												670
Australia: ***Twin Hills, Queensland*** (21°57′S, 146°59′E, alt. 195 m)												
Mean min (°C)	21.9	21.7	19.7	15.7	11.3	8.6	7.0	10.1	12.3	16.8	19.5	20.8
Mean max (°C)	35.5	33.4	32.7	31.0	27.3	24.7	24.2	27.2	29.9	33.7	35.6	35.2
Mean precip (mm)	120	118	72	36	25	36	21	16	20	29	50	75
Mean total (mm)												618
Australia: ***Roma, Queensland*** (26°35′S, 148°48′E, alt. 300 m)												
Mean min (°C)	20.5	20.4	18.2	13.9	8.7	6.0	4.4	6.2	9.6	14.3	17.2	19.2
Mean max (°C)	34.1	33.9	31.6	28.7	23.8	21.0	20.2	22.3	26.1	30.1	33.0	34.0
Mean precip (mm)	81	76	65	31	34	36	38	26	34	49	55	68
Mean total (mm)												593