

The introduction and spread of capeweed, *Arctotheca calendula* (L.) Levyns (Asteraceae) in Australia

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Summary

Specimens of capeweed (*Arctotheca calendula* (L.) Levyns) from major Australian herbaria were examined in a study of the history of introduction and spread of capeweed in Australia. Capeweed was introduced to Australia from South Africa, probably on repeated occasions, as a contaminant of stock fodder and packing straw. The earliest record of its presence dates from 1834 (King George Sound, WA).

Sites with early records of capeweed (Albany, Fremantle, Adelaide) have climates closely resembling that of Capetown, while capeweed took several decades to establish in climatically less similar regions (e.g. Sydney). The rapid spread of capeweed into the interior of the continent was aided by human transport; this trend commenced during the expansion of agriculture in the 1800s and has continued unabated since then. While capeweed is a weed of considerable economic impact, it is regarded as a useful component of pastures in low-rainfall areas. The evidence suggests that capeweed's range in Australia is still expanding.

Introduction

Despite the best efforts of a competent quarantine service (Groves 1986b), exotic plant species continue to enter Australia undetected and to establish and naturalize at an estimated rate of at least four species per year (Specht 1981). Only a fraction of these plants are likely to create weed problems (Groves 1986a), but methods for predicting which of the spectrum of invaders is a potential weed remain elusive. Climatic parameters may be useful for predicting which weeds in other countries would present similar problems in Australia (Medd and Smith 1978, Panetta and Mitchell 1991), and investigations of factors such as geographical origin (Forcella and Wood 1984, Fox 1987, Kloot 1987), pattern and speed of spread (Auld 1987, Forcella 1985) and various biological traits (Baker 1965, Newsome and Noble 1986, Panetta 1987, Groves 1992) have attempted to identify an 'invasive' syndrome. However, it has not yet proved possible to predict the weed potential of species which are not known to be weedy in other parts of the world.

One aspect of plant invasions which has received little attention is the history of introduction of plant species which are

ultimately recognized as weeds in the new environment (Groves 1986b). This information could be useful in a number of respects; for example, by highlighting the methods which particular species use for long-distance dispersal and allowing quarantine procedures to be improved in countries where the species have not yet established. Studies of successful invasions may also indicate where control measures could have been improved and assist in preventing a repetition of past mistakes when new species arrive.

Species for which information of this type is known, such as subterranean clover (*Trifolium subterranean*) and *Echium* species (Piggin 1977, Gladstones and Collins 1983), have complex introduction histories involving broad native ranges, repeated introductions (both deliberate and accidental), the likelihood of secondary introductions and genetically variable parent populations, and in the case of *Echium* a degree of taxonomic confusion and some differences of opinion about the pattern of spread within Australia (Piggin 1977, Kloot 1982). These complicating factors make it difficult to draw any conclusions about the relative importance of different introduction routes or mechanisms of spread, or to make comparisons between the species.

This paper describes the history of introduction and the pattern of spread of capeweed (*Arctotheca calendula*) in Australia. This species has a limited native range being confined almost exclusively to the Cape Province of South Africa (Scott and Way 1990). Capeweed is a common but relatively minor component of the flora in its native range (Harvey and Sonder 1894, Adamson and Salter 1950), but is a widespread and successful coloniser in southern Australia and is responsible for significant economic losses in both cropping and pastoral industries (Shovelton 1982, Scott and Delfosse 1992). The restricted native range and the likelihood that capeweed was introduced directly from South Africa to Australia suggest that the introduction history of capeweed should be less fraught with complications than the examples mentioned above.

Methods

Capeweed specimens from the following herbaria were examined: the State Herbarium of South Australia, Adelaide

(AD); the Queensland Herbarium, Brisbane (BRI); the Australian National Herbarium, Canberra (CANB); the Tasmanian Herbarium, Hobart (HO); the National Herbarium, Melbourne (MEL); the National Herbarium, Sydney (NSW) and the Western Australian Herbarium, Perth (PERTH). All specimens collected in Australia prior to 1985 were included; a full listing of specimens is available from the author on request. Of the 332 specimens examined a small number were discovered to be misclassified (identified by Mr. M. Gray as *Arctotis* sp. and *Cymbonotus* sp.) and some specimens in different herbaria were clearly duplicates, reducing the effective number of specimens. On the other hand some sheets contained more than one plant (or parts of more than one plant), on occasions collected at different times from a variety of locations, and where possible these were considered as separate specimens in this analysis. For each specimen, the date of collection and collector's comments (if any) were recorded if available: flowering status and leaf form were also recorded for a separate study (Wood 1993). The collection locations of specimens were identified wherever possible and plotted in cells of 1° latitude by 1° longitude on a map.

Results

History of introduction

The earliest dated specimen in this study (MEL105452) was collected in South Australia (Gawler Plain north of Adelaide) in 1848. However, capeweed arrived in Western Australia at least fourteen years earlier, having been recorded from King George Sound (probably the vicinity of Albany) in 1834 (Endlicher 1837) and Fremantle in 1839 (Lehmann 1844); there is also anecdotal evidence that the 1848 specimen from Gawler postdates the arrival of capeweed in South Australia by about ten years (Agricultural Bureau of South Australia Report: Mount Gambier 1899). Introduction to Victoria and Tasmania probably occurred before 1860 even though no specimens were collected from these States until 1886 and 1929 respectively, since Hooker (1860) reported that capeweed was abundant at Perth (Tasmania) and Hayter (1865) described capeweed as common around Melbourne in 1861. Herbarium records thus provide an incomplete picture of the pattern of introduction and spread of capeweed in Australia, especially in the early years of European settlement. Despite the value of herbarium specimens in providing tangible evidence of the presence and spread of introduced plants (Forcella and Harvey 1983), such records must be supplemented with information from other sources when investigating patterns of introduction and spread (Mack 1991).

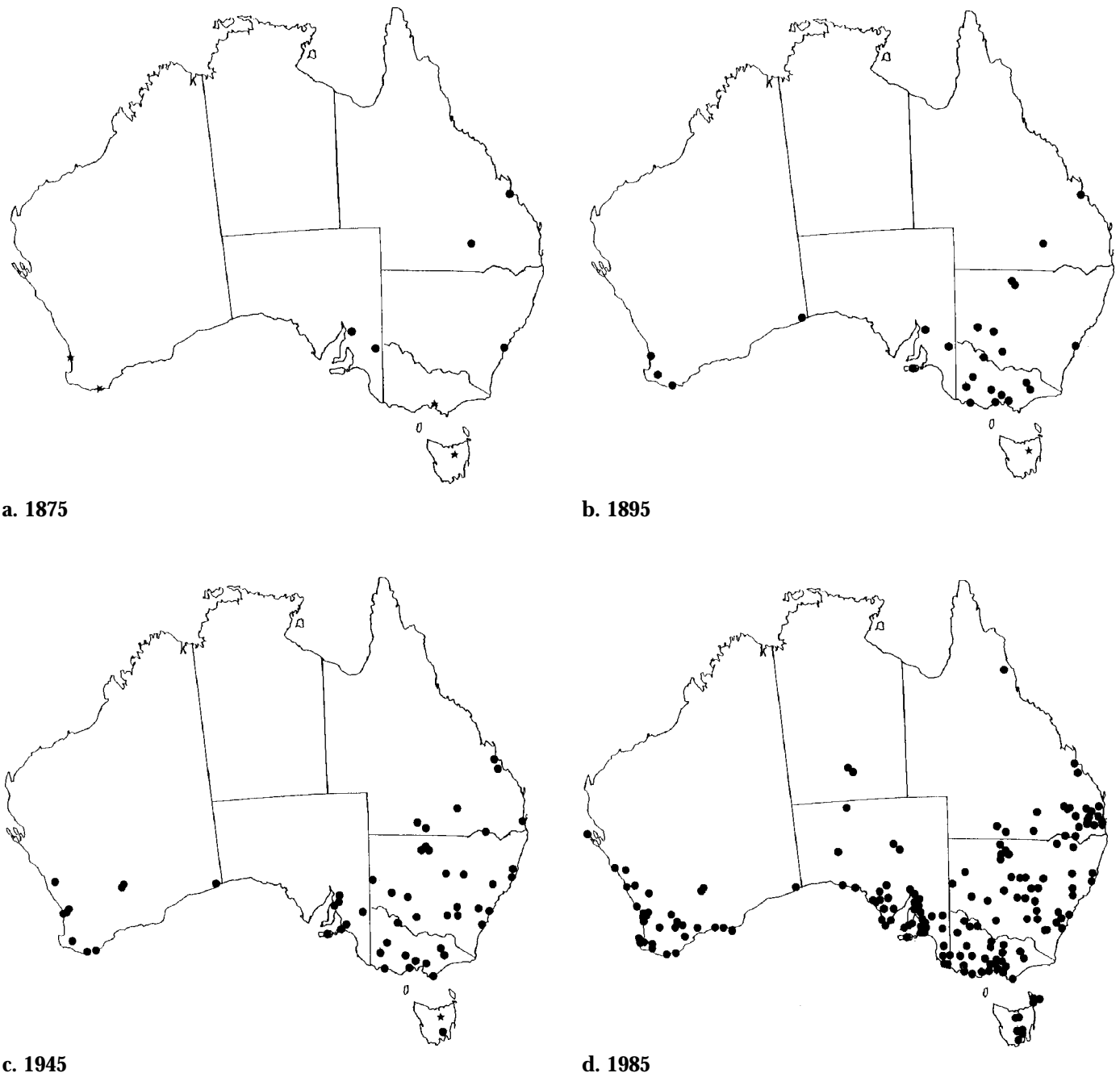


Figure 1. Distribution of capeweed in Australia. Dots represent collection locations of herbarium specimens, stars represent locations based on other sources.

Capeweed was collected in New South Wales (Port Jackson) in 1865 (MEL-105466). This is probably an accurate indication of the introduction date, since there is no suggestion in the literature of its presence earlier than this date (Maiden 1916b) and an annotation by the collector indicates that it was a newly arrived species. Capeweed was reported as spreading in the neighbourhood of Sydney in 1867 (Woolls 1867). Plants were collected in Rockhampton in 1866, but it would appear that permanent populations have failed to establish there; Bailey (1880) reported noticing the species in Queensland about 1870, and by 1880 it was well established along the Brisbane River (Bailey and Tenison-Woods 1880).

Pattern of spread

Capeweed was introduced initially along the southern coast and as a consequence its subsequent spread has followed three general trends (Figure 1). The first of these was an inland spread from the coast away from the sites of introduction (Turner 1891). There was also a west-to-east spread from South Australia into Victoria (Adcock 1915, Maiden 1916c) and a south-to-north spread from Victoria to southern New South Wales and from New South Wales into southern Queensland (Bailey 1883, Agricultural Bureau of NSW Report: Temora 1915, Maiden 1916c). Western Australian populations have been largely isolated from those in the eastern States, but the same trends are evident.

Within a matter of years after introduction several colonies developed at considerable distances from the nearest established coastal population (Figure 1a, b): specimens were collected from the Murray River (NSW-Victoria border) in 1868, near Roma (Queensland) in 1871, Lake Bonney (SA) in 1874 and Eucla (WA) and Omeo (Victoria) in 1882. This saltatory form of spread coincided with the rapid expansion of the pastoral industry into the interior of the continent after about 1850, in the wake of explorers such as Leichhardt, Sturt and Mitchell (Taylor 1990).

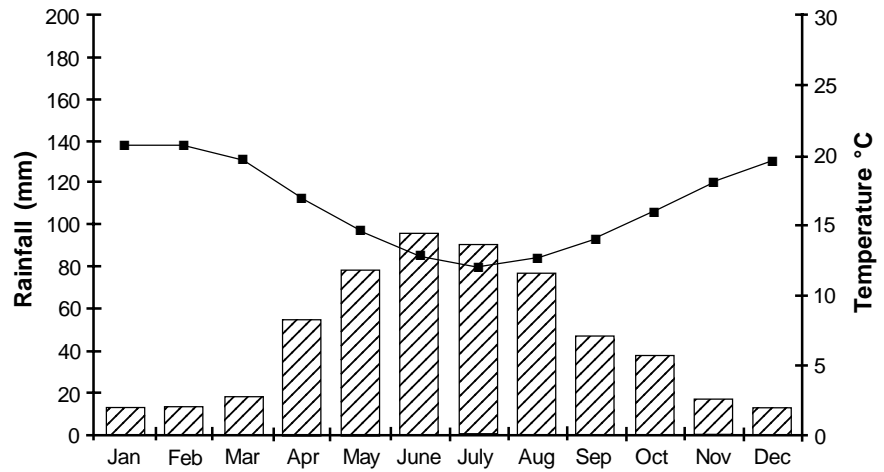
The two decades between 1875 and 1895 saw a substantial increase in collections of capeweed (Figure 1b). This may

be a result of the efforts of Baron von Mueller and his collectors or may be a reflection of a sudden increase in capeweed abundance or distribution. In either case, by the turn of the century capeweed was well established throughout most of Victoria, in the southern parts of Western and South Australia and in western and coastal regions of New South Wales.

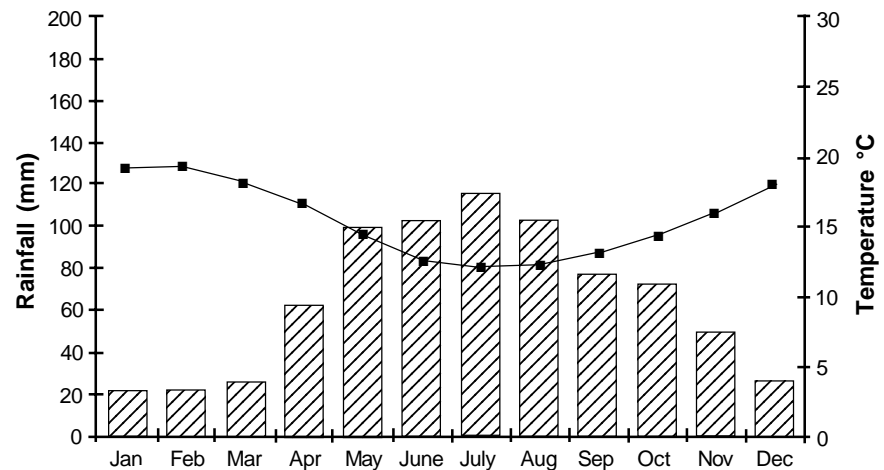
Present distribution

As evidenced by herbarium collections, capeweed is distributed widely through southern Australia (Figure 1c, d). In Western Australia it is found throughout the sheep-wheat areas of the south-west and extends northwards along the coast as far as Shark Bay. Although initially confined to Adelaide and environs in South Australia, capeweed was first collected from the Eyre Peninsula in the early 1960s and has subsequently spread northwards into the interior of the State. Apart from the north-east corner, capeweed is found throughout Victoria. The previously disjunct distribution in New South Wales now covers most of the State and extends into south-eastern Queensland. It has been recorded from Alice Springs in the Northern Territory and Atherton in far north Queensland. In Tasmania capeweed has not been collected from the south-west but is present in more settled areas.

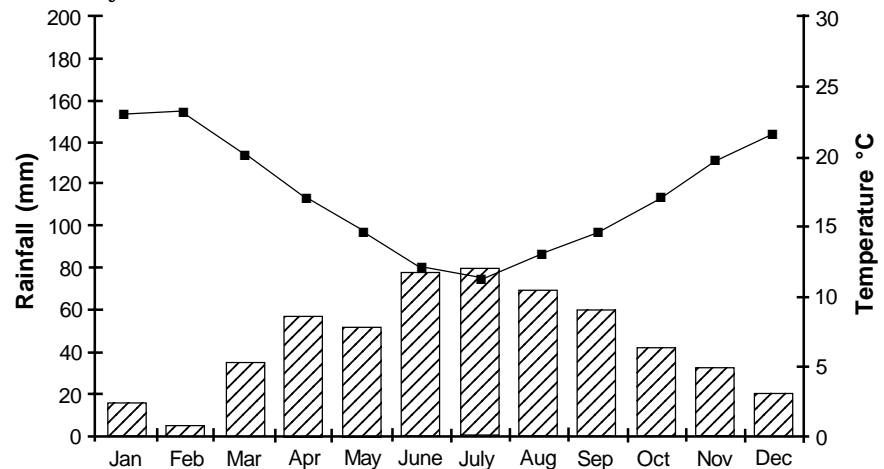
Although capeweed now generally occupies regions in Australia with similar climatic patterns to those of its native range in South Africa (Michael 1981), specimens have been collected from locations which could be considered marginal at best. Early collections from Rockhampton in 1865 (AD 97943575, MEL 105455, MEL 105456, MEL 105472, MEL 105477, MEL 105479, NSW 1377) and 1868 (MEL 105467) and from Atherton in 1947 (BRI 309502) have not been repeated subsequently. Capeweed plants collected near Alice Springs in 1962 (AD 96243306, AD 96349054, CANB 126906, NSW NT9323, NSW NT9299) are clearly adventive (Chippendale 1972); of the two recorded locations, one is adjacent to cattle trucking yards and the other is a mown (and presumably watered) lawn. Similarly all but one of the six South Australian specimens collected north of 30°S (AD 96317102, AD 96519153, AD 97933330, AD 97934311, AD 97934346, AD 97934369) were located at sources of water (bore, spring, creek) or at stockyards or railway sidings. It is probable that collections from tropical Queensland and the arid interior represent incidental and short-lived introductions; comparisons of the respective climates with that of capeweed's native range (Figure 2) suggest that the species is unlikely to survive in either environment in the long term.



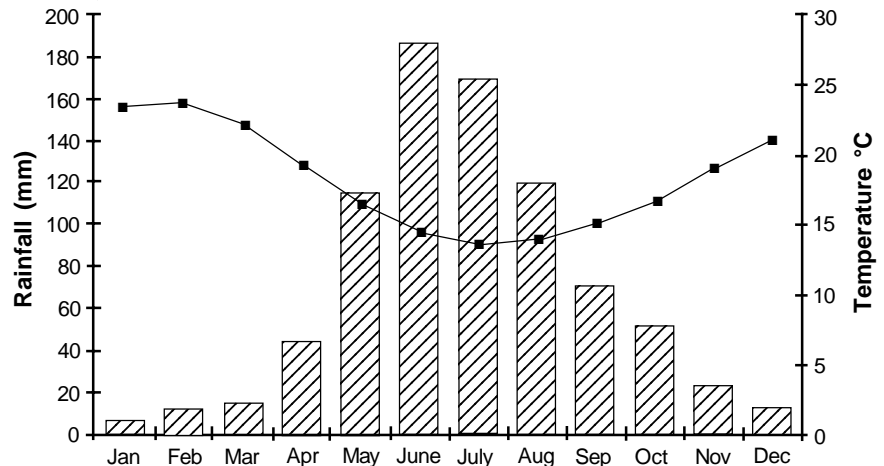
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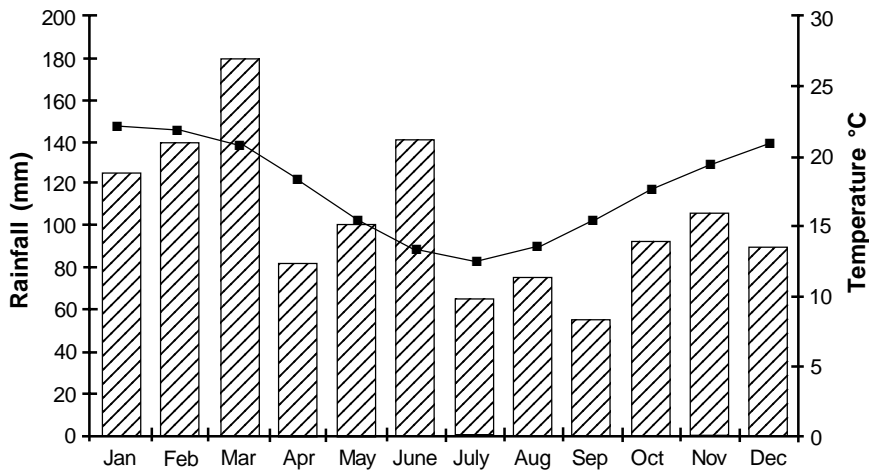
b. Albany, Western Australia



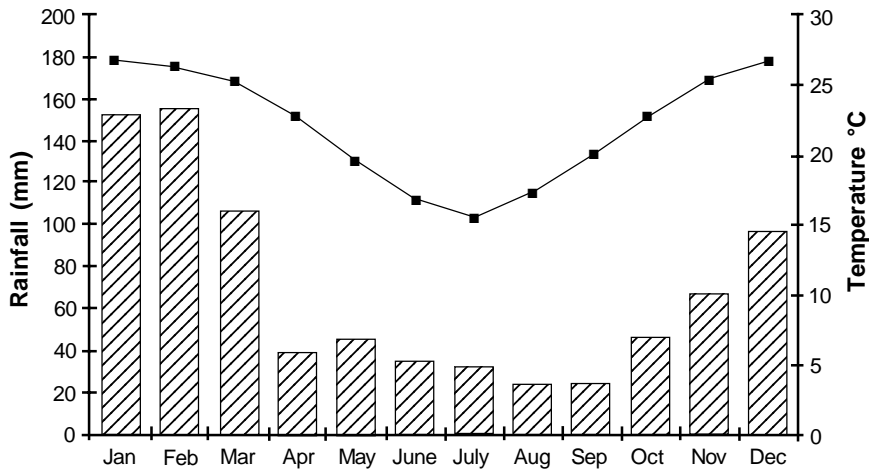
c. Perth, Western Australia



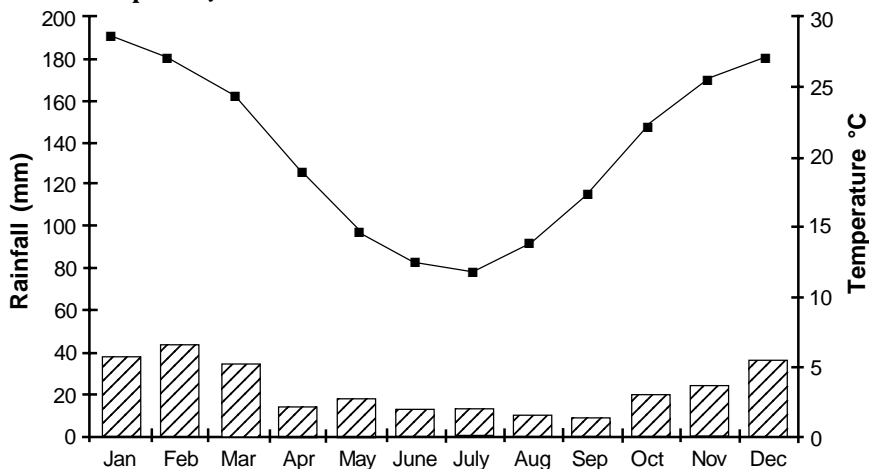
d. Adelaide, South Australia



e. Sydney, New South Wales



f. Rockhampton, Queensland



g. Alice Springs, Northern Territory

Figure 2. Climatic data for selected capeweed collection sites. Bars represent mean monthly rainfall, lines represent mean monthly temperature. Data for Capetown is from Takahashi (1986) and for Australian sites from Australian Bureau of Meteorology.

Discussion

Sources of capeweed

During the early European colonization of Australia there were abundant opportunities for introductions from South Africa. Capeweed is a very common plant of roadsides and waste ground in its native habitat (Adamson and Salter 1950, Harvey and Sonder 1894) and virtually every ship bound for Australia from England made a victualling stop at Capetown

and took on board cargo which provided a vehicle for seed transport. For example, Captain Phillip obtained provisions as well as a variety of plants, seeds, livestock and fodder in Capetown when the First Fleet put in there in 1787 (Clark 1962), and seven of the 21 ships entering Port Jackson in the first nine months of 1801 arrived from the Cape of Good Hope (Aplin and Parsons 1988) while a further six from London probably also stopped at Capetown on the way to Australia.

There is a possibility that capeweed was introduced from populations established elsewhere, rather than direct from South Africa. Since the evidence indicates that capeweed did not become naturalized in Europe until this century (Caballo 1940, Tutin *et al.* 1976), secondary introductions from Europe could only have been as garden specimens; therefore the balance of probabilities favours the overwhelming bulk of capeweed seeds introduced into Australia having arrived as primary introductions from South Africa.

Routes of introduction

Anderson (1934) listed five possible introduction routes for weeds into Australia: deliberate introductions, seed impurities, stock fodder, contamination in packing around goods and the ballast of ships. The relative importance of each route varies depending on the particular life history characteristics of the species in question. In the case of capeweed all five routes are possible, although some are considerably more likely than others.

The most probable routes of introduction are as seed contaminants in stock fodder and in packing material. The likelihood is high that capeweed seeds were present in hay loaded in Capetown to feed livestock en route to Australia (Tench 1789). Fragile goods such as crockery, glassware and wine were transported in crates packed with straw, and this is also a probable source of capeweed seeds (Roach 1900, Maiden 1916c, Aplin and Parsons 1988).

Other routes of introduction were less important. Capeweed was unlikely to have been brought into the country in ballast initially since ships bound for Australia were fully laden with cargo; however after the 1850s when Australia became a net exporter of agricultural produce (Taylor 1990) seed in ballast may have contributed to the subsequent acceleration of spread. It is possible that capeweed was deliberately introduced for ornamental purposes, having been in garden cultivation in England since 1752 (Loudon 1880); Woolls (1867) suggested that capeweed was introduced into the Botanical Gardens at Melbourne, presumably as an ornamental species. This was probably of minor importance since plants growing along roadsides in Australia were viewed as novelties rather than as familiar garden escapes (Turner 1891). There is a suggestion that capeweed may have been introduced as a potential fodder species (Anon 1880, cited in Kloot and Burry 1982/83) and introduction as an impurity in seed for agricultural crops is also possible.

Establishment and climate

A military garrison was founded at Albany in 1826 and settlers arrived in

1831 when the garrison was disbanded (Jose 1930, Clark 1973), so capeweed was successfully introduced into King George Sound within eight years of European occupation and three years of civilian settlement. This surprisingly rapid establishment probably reflects the similarity between the climatic patterns of Capetown and Albany (Figure 2a, b) and the next two sites where capeweed was recorded (Fremantle, near Perth, and Gawler, near Adelaide) also have climates resembling that of its native range (Figure 2c, d).

By contrast, colonization of Sydney dates from 1788 and there were ample opportunities for capeweed to be transported there, yet the earliest specimen from the Sydney region (MEL 105466) dates from 1865, some 77 years later. The climate of Sydney (Figure 2e) has an absence of the marked summer drought characteristic of Capetown and a higher overall rainfall, and this difference in climate may have hindered capeweed's establishment on the eastern seaboard despite repeated opportunities for introduction. Commenting on the absence of capeweed from coastal New South Wales, Tenison-Woods (1887) speculated that capeweed may require dry windy weather during summer to ensure dispersal and encourage autumn germination; summer rainfall was suggested as a limiting factor to this establishment.

Morphological variation among capeweed herbarium specimens indicates that populations in New South Wales may be genetically different from their counterparts in other States as a reflection of separate introductions (Wood 1993). Alternatively, it is possible that the capeweed biotypes which eventually established in Sydney were secondary introductions derived from an Australian population in which ecotypic adaptation was occurring (Wood and Degabriele 1985); after 1850 Albany was the first landfall for ships bound for the eastern ports (Appleyard 1981), so it is possible that some establishments after this date involved capeweed derived from Albany (or some other Australian source) rather than directly from Capetown. Capeweed was among a collection of 60 plant species obtained from King George Sound during a three-hour stay (Anon 1890), indicating its proximity to an effective means of eastward migration.

Methods of spread

Rapid spread over long distances is typical of species in which seed dispersal is mediated by human activity (Panetta 1987), and transportation of stock fodder is a likely route (Thomas *et al.* 1984). Maiden (1916c) stated that the appearance of capeweed in the New England district of New South Wales after the drought of 1902 was attributed to the importation of

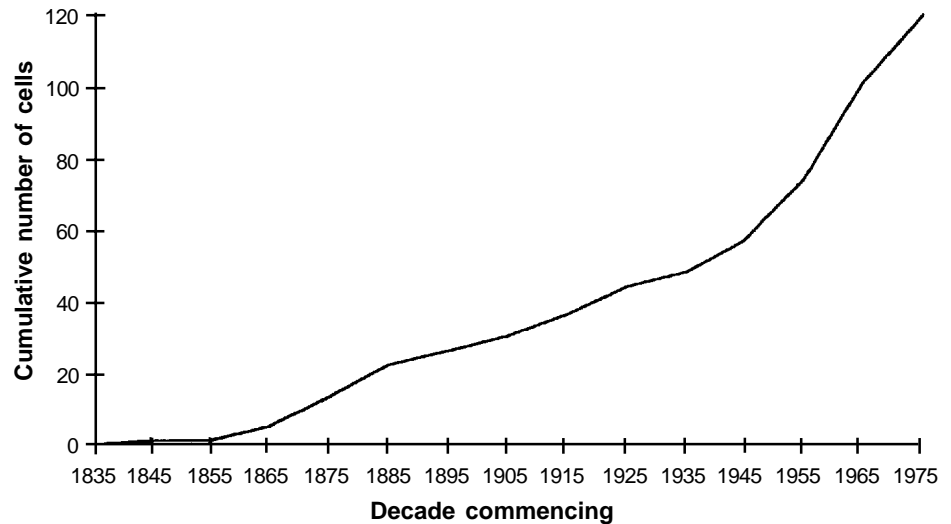


Figure 3. Spread of capeweed over time. Cells are 1° latitude by 1° longitude

“dirty chaff”, and contaminated fodder was the seed source for new infestations most often mentioned by collectors in this study. Other effective long-distance dispersal routes included horses, sheep's wool and packing material (Agricultural Bureau of NSW Report: Temora 1915, Maiden 1916c).

The pattern of spread after introduction to a new area was more reminiscent of an advancing front, suggesting that different dispersal methods were more important for local spread. These include wind dispersal, contaminated lawn turf and the transplantation of roadside plants into gardens (Turner 1891, Maiden 1916a, c). Roadsides and waste ground were implicated as important sources of infestation, with capeweed reported as spreading along roadsides (Ewart 1913, Maiden 1916c, Carne 1926).

Is capeweed a weed?

Although capeweed has been identified as a serious weed in both crop and pasture situations (Shovelton 1982, Velthuis and Amor 1982), an ambivalence towards its weed status is evident (Scott and Way 1990). In New South Wales its weed potential was recognized as early as 1890 (Turner 1890, 1892); by 1915 capeweed was rated seventh in a list of the 20 worst weeds in the State and had been declared noxious in 37 shires and municipalities (Maiden 1915). The number of declarations had increased to 47 by 1934 (Anderson 1934). Similarly, in Victoria capeweed was first proclaimed in 1901 (Ewart and Tovey 1907) and within 15 years was one of the commonest weeds in the valley of the Upper Murray (Ewart 1913). In a statewide survey of Victoria in 1978 capeweed was rated as the most important weed of lucerne and pasture in Victoria (Shovelton 1982).

Opinions about capeweed appear to be more equivocal in South Australia and Western Australia. Its detrimental effects

in cereal crops are recognized (Agricultural Bureau of South Australia Report: Kanmantoo 1898, Agricultural Bureau of South Australia Report: Boothby 1901, Carne 1926) and tainting of milk is also reported (Agricultural Bureau of South Australia Report: Mount Gambier 1899, Pierce 1970), but it is also perceived as “often more beneficial than injurious” (Agricultural Bureau of South Australia Report: Murray Bridge 1898, Carne 1926). Apiarists value capeweed as a pollen source for honeybees (Clemson 1985) and it even seems to have been deliberately sown to provide fodder for sheep and pigs (Agricultural Bureau of South Australia Report: Mount Gambier 1899).

The dichotomy of opinion regarding capeweed's value is related to land use and climate. It is regarded as a weed in crops generally and in pastures in higher-rainfall regions, while in drier areas it is considered to make a valuable contribution to pastures (Carne 1926, Scott and Way 1990).

Future prospects for control

The relatively short lag phase after introduction and the high initial rate of spread displayed by capeweed (Figure 3) are typical of weeds which have a wide final distribution (Forcella 1985). Migration rates of many introduced plant species are best described by a sigmoid curve (Auld *et al.* 1982/83, Forcella 1985) and the curve for capeweed continues to rise steeply so it is probable that this species has not yet reached the limits of its distribution in Australia; the apparent rapidity of its spread through the Eyre Peninsula in the 1960s is a case in point. The potential distribution of capeweed in Australia could be predicted by homocline analysis (Panetta and Mitchell 1991) and uninfested areas thus identified should be carefully monitored in future. The potential for biological control by phytophagous insects is currently under

investigation (Scott and Way 1990, Scott and Delfosse 1992). However, the history of failed efforts to eradicate, or even control, introduced weeds (Medd 1987, Streibig 1992) leads to the conclusion that capeweed will continue to spread in Australia.

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