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THE WEED SOCIETY OF NEW SOUTH WALES

FORMATION AND OBJECTS

The Society was formed at an inaugural meeting in Sydney on 17th February 1966, and as part of its constitution established its objects to be:

(*a*) To promote wider interest in weeds and their control.

(*b*) To provide opportunities for those interested in weeds and their control, to exchange information and ideas based on research and practice.

(*c*) To encourage the investigation of all aspects of weeds and weed control.

(*d*) To co-operate and, where appropriate, affiliate with other organizations engaged in related activities in Australia and overseas.

(*e*) To encourage the study of weed science and the dissemination of its findings.

(*f*) To produce and publish such material as may be considered desirable.

(*g*) To foster the development of an Australia-wide weeds organization.

MEMBERSHIP

(*a*) Membership is of three classes, "ordinary", "honorary" and "corporate body", and is open to all those individuals and corporate bodies respectively who are interested in weeds.

(*b*) Honorary members are elected from persons who, in the opinion of the Executive Committee, have made major contributions to the objects of the Society and have the same rights as ordinary members.

(*c*) Corporate body members may nominate one representative to the Society who has the same rights as an ordinary member.

Membership fees are: private members $4 annual subscription, corporate body members $10 joining fee and $10 annual subscription. Fees are payable on the first day of March in each year.

PROCEEDINGS

This fifth volume of proceedings, edited by Mr. B. A. Auld, Mr. A. D. Mears and Dr. P. W. Michael, includes the papers presented at the Symposium on the History of Weed Research in Australia, held at the University of Sydney on 11th August 1972.

Members are entitled to receive one copy of the Proceedings free; non-members may purchase copies for two dollars.

Applications for membership, payment of subscription and orders for copies of the Proceedings should be sent to the Treasurer, Weed Society of N.S.W., P.O. Box K287, Haymarket, N.S.W. 2000.

CONTENTS

THE WEEDS THEMSELVES — EARLY HISTORY AND IDENTIFICATION

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Introduction

In this paper, I am restricting my attention to observations and studies on weeds in the period from the beginning of European settlement in Australia up to about 1925, concentrating especially on records before 1890. Material concerning this earlier period is much less readily available than the journals of the various State Departments of Agriculture, which began to appear in the late 1880s. These journals are the main source of information on weeds from about 1890 to 1925. The most important articles on individual weeds in this later period are those in the *Agricultural Gazette of New South Wales* beginning with Turner (1890a) on stagger weed (*Stachys arvensis*) and followed later by a long series by Maiden. Maiden (1920) brought together a number of these papers in his well known book "The Weeds of New South Wales". Even today Maiden's taxonomic and bibliographic treatment of weeds is often most helpful.

For general information on the beginnings of agricultural settlement in Australia, the long works by Campbell (1901) and King (1948, 1949) and the book by Perry (1963) should be consulted. Jeans (1972) provides further useful background material.

Early Lists of Alien Plants

Any investigation into the early history of weeds in Australia is made extremely difficult because of the limited attention given to them by the early botanists who were, indeed, too few. Gouger (1838) wrote "I can give you but little information relative to the botany of the place, having no lore that way. Almost all the flowers which from time to time spring up around Adelaide—whether yellow, blue, pink or cream-colour, are called by our botanists of the genus orchideæ; the fact is, I believe, none of our colonists are learned in plants, and I at last got tired of asking the name of any flower I found—it was always an orchis. With the exception of marshmallow then, lupins, butter-cups, a large daisy, and different kinds of vetch, believe all our flowers to be beautiful and very plentiful, but all orchideæ".

Most of the weeds we know today are alien plants which have been introduced intentionally or accidentally. Bentham (1863-1878), in the first and only flora for the whole of Australia, did not pretend to give an adequate cover of naturalized species. There are, however, a number of early lists or brief reports of alien species or censuses including alien species.

The most important, arranged according to region covered, are:

General

Hooker (1860); Tenison-Woods (1881); Helms (1897).

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New South Wales

Robert Brown (Britten, 1906; Maiden, 1916); Woolls (1867, 1869, 1871, 1880, 1885); Moore (1884); Turner (1890b), excluding grasses; Moore and Betche (1893). Blakely (1923) presented a list of about 800 weeds and naturalized plants of New South Wales to a Pan-Pacific Science Congress. This valuable list with annotations was never published. Fortunately, what appears to be the final draft of this list is held in the Library of the National Herbarium of New South Wales. Blakely's list is important because it contains a large number of native species and aquatic weeds. Maiden (1895) had earlier drawn attention to the importance of a number of native plants as weeds or poisonous plants.

Victoria

Mueller (1888, 1894); Ewart and Tovey (1909); Audas and Morris (1925).

Queensland

Bailey (1880, 1906) and other useful lists or synopses referred to by Everist (1960).

South Australia

Francis, in 1855, in a letter to W. J. Hooker, published in Best (1966); Schomburgk (1879), with an earlier brief account in the 1873 report and amplifications in the 1883 and 1888 reports of the Adelaide Botanic Gardens; Tepper (1880); Black (1909).

Western Australia

Drummond (1840); Helms (1897); Alexander *et al.* (1921); Gardner (1925).

Northern Territory

Holtze (1892).

Taken broadly these lists and/or brief dissertations serve as a useful weed history, but critical interpretation or assessment can only be done with reference to any existing collections made by or apparently known by the compilers of the lists or floras, and not without a thorough knowledge of weeds as they occur in Australia today and, furthermore, a fair degree of taxonomic nous. And even then, one may have to make intelligent guesses as to the identity of certain plants listed. However, without the work of these authors, who have provided the raw materials for further research, we would have very little chance of making intelligible earlier references to weeds in scientific journals, historical records, parliamentary reports, early accounts of life in Australia and, in newspapers. Let us, as an example, take the history of introduced weedy species of *Amaranthus* in New South Wales. I shall begin, not in the past, but in the present where I feel I am on somewhat firmer ground. As far as I know the well-naturalized species in New South Wales today are *A. albus, A. deflexus, A. hybridus, A. powellii, A. quitensis, A. retroflexus, A. spinosus* and *A. viridis*. *A. lividus* is quite minor and *A. caudatus* and *A. cruentus* may occasionally be weedy in gardens. Anderson (1939) listed *A. albus, A. blitum, A. deflexus, A. paniculatus* and *A. retroflexus* as naturalized species. His *A. blitum* is probably *A. viridis* and his *A. paniculatus* must be taken to include at least *A. hybridus* and possibly also the closely related *A. powellii*, but probably not *A. quitensis*, the earliest specimen in the National Herbarium of New South Wales, not having been collected until 1949. Blakely in 1923 listed *A. albus, A. chloro-*

stachys, A. caudatus, A. deflexus, A. lividus (syn. *A. blitum*), *A. paniculatus, A. retroflexus, A. spinosus* and *A. viridis.* His *A. chlorostachys* is probably *A. hybridus* and his *A. paniculatus* is *A. powellii.*

Moore and Betche (1893) considered *A. viridis* to be native and listed *A. blitum, A. paniculatus* and *A. spinosus* as naturalized. Their *A. blitum* is almost certainly *A. lividus,* while *A. paniculatus* may include both *A. hybridus* and *A. powellii.* Woolls (1885) listed *A. blitum, A. paniculatus* and *A. viridis.* The same comments may be applied to his *A. blitum* and *A. paniculatus* as to these names in Moore and Betche's list. Woolls (1867) mentions *A. oleraceus* and *A. blitum* as spreading almost everywhere in the Sydney area. *A. oleraceus* appears to have been an error for *Portulaca oleracea,* which suggests in turn that his *A. blitum* could have included *A. viridis* and/or *A. lividus.* We could resolve this only by studying any specimens which he may have collected.

Much earlier Governor P. G. King (1803), in a "List of Plants in the Colony of New South Wales that are not indigenous" included a large number of cultivated plants with remarks on their success in the colony. He noted that green and golden purslane had become common weeds. I think it likely that these were *Amaranthus* sp. or spp. and *Portulaca oleracea.* He also listed, as being in common use, love-lies-bleeding (*Amaranthus caudatus*) and Prince's feather (often referred to *A. hypochondriacus*). The latter may well have been the progenitors of *A. powellii* so abundant today in the Windsor area.

As another example just let us think of *Bromus.* It would be hopeless to try and sort out this group without first coming to grips with the species which occur in Australia today, a formidable task indeed.

It was not often easy for the early botanists, as indeed it is often not easy for us today, to identify recently introduced species. In South Australia (Anon., 1887) there was much confusion between the pink-flowered *Centaurea calcitrapa* and the yellow-flowered *Carthamus lanatus.* The following dialogue is worth recording. Schomburgk gave the answers.

> Do you know what is the color of the flower of the star thistle? It is yellowish.
>
> Are there two varieties; some witnesses say the flower is yellow, some say it is pink?
>
> It is not true pink and it is not true yellow. It is between the two—a very dirty dark-yellow.

The difficulty in distinguishing alien from indigenous plants exercized the minds of the early botanists—for example—Bicheno in Anon. (1846), Hooker (1860), Spicer (1878), Woolls (1867, 1869). They were also interested in observing any changes in aliens in their new environment. Schomburgk (1879) wrote "It remains to be seen whether the altered circumstances of the acclimatised weeds, which seem to be so favourable to their growth, will prove permanent, or by an over-stimulation, a change gradually effected in the constitution of the intruders, bringing about degeneracy and subsequent extinction. But such an influence is not yet observable for they extend further and further, and grow just as luxuriantly in the districts whence they spread as far back as from eighteen to twenty-five years".

Although, through the years there have been many disagreements among botanists, it now seems clear that we do have native forms of *Oxalis corniculata* sens. lat. (Gouger, 1838; Gunn, 1842), and that *Cynodon dactylon* is at least, in part, introduced (Cunningham, 1828; Rudder, 1857). Rudder mentions the intentional transportation of *Cynodon* from the streets of Sydney to Hobart and Kempsey. Nut grass (*Cyperus rotundus*), which used to be known here as *C. hydra* has been introduced at least into southern Australia (Woolls, 1867, 1869). The earliest record I have found of nut grass as a weed problem is in the 1858 Report of the Sydney Botanic Gardens. There are probably a number of subtropical or tropical plants which are indigenous in northern Australia, but introduced in the south, either from northern Australia or other parts of the world.

Nursery and Botanic Gardens Catalogues

Other raw materials, useful in tracing the origins and spread of weeds in Australia are the early catalogues of nurseries and botanic gardens. In such studies, however, their use has generally been neglected. I have elsewhere shown the usefulness of this exercise in *Oxalis* (Michael, 1964) and now wish to show that they can be of use in the study of the prickly pears in Australia. By the late 1870s the common pest prickly pear had spread widely in Queensland and the Upper Hunter region of New South Wales (Bailey, 1880).

Although the nomenclature of some of the prickly pears naturalized in Australia is still uncertain, they have, at least, been adequately described, together with a number of black and white photographs and coloured plates by the Commonwealth Prickly Pear Board (1925) and Mann (1970). In the former treatment the prickly pears were grouped into those that had become pests and those (with other cactus plants) that were not yet pests. In the former group the following species, all of *Opuntia*, were included:

*O. bentonii** (*O. inermis, O. vulgaris*), *O. stricta* (*O. dillenii, O. airampo*), *O. aurantiaca* (*O. ferox*), *O. vulgaris* (*O. monocantha*), *O. tomentosa, O. imbricata, O. streptacantha* (*O. megacantha*), *O.* sp. and *O. elatior* (*O. nigricans, O. tuna*).

The latter group included the following *Opuntia* species:

O. dillenii, O. ficus-indica, O. amyclea, O. megacantha, O. pachona, O. microdasys, O. subulata, Nopalea (*O.*) *cochenillifera, N.* (*O.*) *dejecta.*

Darnell-Smith (1927) in a list of *Opuntia* spp. wild in Australia included:

*O. aurantiaca** (*O. ferox, O. horrida, O. dejecta*), *O. imbricata, O. nigricans* (*O. horrida, O. humilis, O. elatior, O. tuna*), *O. inermis* (*O. stricta, O. airampo, O. bentonii*), *O. tomentosa, O. ficus-indica, O. monocantha* = *O. vulgaris, O. dillenii* and *O. microdasys.*

Mann (1970) in his treatment of the cacti naturalized in Australia included the following *Opuntia* spp.—the pest species *O. inermis** (*O. bentonii, O. tuna, O. vulgaris, O. stricta), O. stricta (O. dillenii, O. airampo), O. aurantiaca, O. monocantha* (*O. vulgaris*), *O. tomentosa, O. streptacantha* (*O. megacantha* and *O. imbricata*) and as less important species *O. megacantha, O.* sp., *O. ficus-indica, O. amyclea, O. pachona, O. lindheimeri, O. rufida, O. elatior, O. dillenii, O. opuntia, O. microdasys, O. sulphurea* (*O.* sp. near *aurantiaca*) and *O. subulata.*

The following early lists of *Opuntia* species from the catalogues of two overseas botanic gardens, two Australian nurseries and two Australian botanic gardens are now given for comparison:

Royal Botanic Garden, Glasgow (1825)*: *O. brasiliensis, O. coccinellifera, O. curassavica, O. decumana, O. elatior, O. ferox, O. ficus-indica,

*** The authors' synonyms are included in brackets.**

O. humilis, O. lanceolata, O. nigricans, O. polyantha, O. pusilla, O. speciosa, O. spinosissima, O. stricta, O. triacantha, O. tuna, O. vulgaris.

Botanic Garden, Capetown (1858): *O. aurantiaca, O. brazilienses, O. cochinillifera, O. decumana, O. ferox, O. leucotriche, O. maxima, O. polyantha, O. sulphurea, O. tomentosa, O. triacantha,* several unnamed.

Macarthur (Anon., 1843), Camden Park, N.S.W.: *O. cochinellifera.*

Shepherd (1851), Sydney: *O. brasiliensis, O. cochinillifera, O. decipiens, O. decumana, O. ferox, O. ficus-indica, O. pseudo-tuna, O. tuna, O. vulgaris.*

Botanic Garden, Sydney (1857): *O. brasiliensis, O. cochinellifera, O. cylindrica, O. decumana, O. ficus-indica, O. leucacantha, O. nigricans, O. polyantha, O. pseudotuna, O. tomentosa, O. tuna.*

Botanic Gardens, Sydney (1866): same as for 1857 with, in addition, *O. dejecta, O. dillenii, O. elatior.*

Botanic Garden, Brisbane (Hill, 1875): *O. amyclea, O. brasiliensis, O. cochinillifera, O. crassa, O. crinifera, O. curassavica, O. decumana, O. dillenii, O. ferox, O. ficus-indica, O. glaucophylla, O. kleiniæ, O. leucantha, O. microdasys, O. nigricans, O. tuna, O. vulgaris.*

Because of great confusion in nomenclature, it is difficult, if not impossible, to match the plants in Darnell-Smith (1927), the Commonwealth Prickly Pear Board (1925) and Mann (1970) with the plants listed in the catalogues, but it takes little imagination to suggest that they were primary sources of the introduction of the prickly pears to various places in Australia. They are ignored in the reports of Alexander (1919), Commonwealth Prickly Pear Board (1925) and Dodd (1940).

Mueller (1871, 1881) listed *O. coccinellifera, O. dillenii, O. elatior, O. spinosissima, O. ficus-indica, O. hernandezii, O. missouriensis, O. rafinesquii, O. tuna* and *O. vulgaris* as plants "readily eligible for industrial trial culture or naturalisation". It is clear, in retrospect, that the early botanists did not know the weedy potential of many of the plants they grew in gardens. Turner in an article in the *Sydney Morning Herald* (7th December 1912), writing about the intentional introduction of *Emex australis* into Australia as a garden vegetable, warned amateurs about the dangers of introducing plants and suggested leaving it to the botanists who knew what they were about. Schomburgk (Anon., 1871), when asked whether he had any dangerous plants in the Botanic Gardens in Adelaide, implied that even if he had he knew how to contain them.

In William Macarthur's earliest catalogue (Anon., 1843) *Coreopsis, Echium violaceum* (probably *E. vulgare*), *Polygonum persicaria, Verbascum, Homeria collina* = *H. breyniana,* various *Oxalis* spp., *Sisyrinchium, Celtis occidentalis, Cratægeus oxycantha, Lantana camara* and *Ligustrum* are among the plants included. In a later catalogue (Anon., 1845) he included *Carthamus campestris.* It is tempting to think that this could have been *C. lanatus,* a weed of uncertain history in Australia. It seems to have been first discussed in Anon. (1887).

In a seeds list of T. M'Millan & Co. in the *Melbourne Argus* (20th March 1856) *Senecio jacobæa* and *Reseda luteola* were included as dye plants.

Other Early Records of Weeds

Governor King (1798) wrote to Sir Joseph Banks asking for seeds of a large number of plants including *Carduus benedictus,* fennels, marshmallows, various clovers, rye grass, guinea grass, and the best kind of broom seed as a substitute for hops. Francis (Anon., 1862) who illustrated a number of thistles and Bathurst burr, gave *Carduus marianus, C. benedictus,* milk thistle, lady's thistle. holy thistle, variegated thistle and Scotch thistle as other names for *Silybum marianum,* which was the first weed to figure in legislative control of weeds in Australia (Michael, 1968a). R.D. in the *Manaro Mercury* (17th December 1870) also wrote of *Carduus benedictus*—"The variegated thistle is the *Carduus benedictus,* the sacred thistle of Ireland in the 13th and 14th centuries. The seed of this variety was steeped in usquebaugh by the monks, and given to the peasants as a cure in epilepsy and all neuralgic complaints". King's "*Carduus benedictus*" then, may well be the beginning of a long official documentation of thistles in Australia (Anon., 1848, 1852, 1862a, 1869, 1870, 1871, 1887), culminating last century in "Illustrated Descriptions of Thistles, etc. Included Within the Provisions of the Thistle Act of 1890—Dept. of Agric., Victoria 1893". The first of these reports (Anon., 1848) contains a circular addressed to the principal landholders in Tasmania. This must be the earliest Australian questionnaire related to weeds and weed control. Unfortunately, the replies do not seem to have been printed. The second report (Anon., 1852), from New South Wales, is much more enlightening, giving replies to a circular letter addressed to the several benches of magistrates, relative to the Scotch thistle and Bathurst burr.

King's "broom seed" was probably intended for *Cytisus scoparius.* Meston (1857a) refers to the intended sowing of this species on the hills and ridges in the Darling Downs and in the elevated parts of New England and the dividing ranges of the Clarence district. Meston refers to it as "a shrub which requires no culture, as a tonic which needs no administration, few plants will rate superior". It is now considered a bad weed in parts of the Upper Hunter region.

We read, too, of the intentional planting of *Agropyron repens* in a description of Alderman Pye's orange orchard near Parramatta in the *Sydney Morning Herald* (18th July 1871):

> "The side of the nursery bounded by the creek is protected by a high bank thickly sown with "couch" or "twitch" grass. This grass is not only a valuable food for cattle in the winter months, but by the interlacing of its roots, and the rapid growth of its "layers" so strengthens the soil in which it is planted as to defy the otherwise ruinous effects of flood-water. Indeed, a good twitch grass bank rather gains than loses by a flood for it catches in its network a large quantity of soil, and retains it there to fertilise itself withal."

It may still be found in a weak state on the banks of this creek at Northmead, near Parramatta. It is, however, only a minor weed problem in New South Wales today.

Governor King in his list of 1803, in addition to the plants already mentioned in the discussion on *Amaranthus,* noted that English broom (*Cytisus scoparius*), English furze (*Ulex europæus*) grew luxuriantly, sweet brier (*Rosa rubiginosa*) was plentiful, French marigold (possibly *Tagetes*), curled mallow (*Malva crispa*), Palma Christi (*Ricinus communis*) and bladder ketmia (*Hibiscus trionum*) were in common use and that false saffron (*Carthamus*—perhaps *C. tinctorius*) was scarce.

Caley in "A short account relative to the proceedings in New South Wales from the year 1800-1803, with hints and critical remarks" (Historical Records of New South Wales, Vol. 5, p. 290) refers to the presence of oats (presumably wild oats) and the annual darnel or drake (*Lolium temulentum*) in wheat. He describes the latter as "a noxious grass, whose seeds probably when ergotized are exceedingly deleterious, acting as a narcotic poison". Collins (1798) and Atkinson (1826) also mention drake in their early histories. Drummond (1840) mentions wild oats and *Lolium temulentum* in Western Australia. In the *Adelaide Observer* (23rd March 1844) there is a reference to the effect of drake on the aborigines—"too much make him tumble down—all same grog—no good, no good". In the same newspaper (13th April, 1844) there is a reference to wire screens able to clean drake out of wheat. In the *Launceston Examiner* (6th January 1849) we read "wild oats and canary grass aided by drake vie for the mastery". *Lolium temulentum* is apparently of much less importance today.

Another weed reported to have been of concern to aborigines is Bathurst burr (*Xanthium spinosum*). Gardner (1854) wrote "The native blacks of Australia hate the sight of it and say it is *bail budgery* (not good)". The early history of Bathurst burr is well documented in Anon. (1852). It appears to have been introduced to Australia on horses from Valparaiso and/or with garden seed from Europe. It became prevalent in New South Wales in the 1840s. In a description of Albury in 1853, Howitt (1855) wrote:

> "(Albury) is a village of 1-storied houses, scattered about on a wretchedly flat sheet of baked clay, which at this time of the year grows only goosegrass, chenopodium, and the Bathurst bur (Xanthium spinosum), a plant with long triple spines like the barberry, and burs which are ruinous to the wool of the sheep—otherwise, itself very like a chenopodium, or good-fat-hen."

Clarke (1853), found it "forming well defined borders to the tracks nearly all the way from Wellington to Bingera. It was our guide on the black mud flats of the Macintyre; a pretty prospect for sheep farmers. It is all due to the carelessness of the cattle owners". Rachel Henning in 1861 (first published in *The Bulletin,* 12th September 1951) wrote in a letter from Bathurst:

> ". . . The most objectionable things in the paddock to my mind are the "Bathurst burrs", which are a real nuisance.
>
> Amy got the fringe of her shawl full of them the other day, and it took her the whole evening to pick them out. It is not an indigenous plant, but was introduced from Valparaiso in the wool of some sheep that were imported. Now it has spread everywhere in this district, and is an awful nuisance to the woolgrowers, as it spoils the fleece".

She continued to write about other weeds:

> "Another unlucky importation was the Scotch thistle, which a patriotic Scotch lady near here planted in her garden and which, like most of its compatriots, took so kindly to the country that it grows everywhere. The paddock is half-full of it. We have, also, rather too much of even such a good thing as sweet briar. My friend Mrs. Ranken first planted it about twenty years ago, and it has spread so on her land that some of her paddocks are a mere jungle of sweet briar. It must be lovely when in flower, but is not exactly "adapted to the wants" of sheep and cattle, and it is extremely difficult to extirpate. However, I have not taken warning, but have collected some seeds to sow at Marlborough. I saw it growing wild in the bush as I came up to Bathurst, and rejoiced greatly, as it is the only approach we have in this country to wild roses."

Morris (Anon., 1862b) wrote "It is a well known fact that in the districts where the burr grows, that if a shepherd owes his master a grudge from any supposed injury, he seeks satisfaction by driving his flock through a bed of the Bathurst burr, knowing by doing so, that he inflicts a very serious injury upon him".

In Robert Brown's early list (Britten, 1906; Maiden, 1916) the important field weeds *Datura* and *Stachys arvensis* and the common weeds *Poa annua* and *Anagallis* are mentioned for the first time. Bailey (1880) noted that the latter two were among the first European plants to become established in South Australia. Woolls (1869) wrote that many cart-loads of *Stachys arvensis* had been cut in the orange orchards near Parramatta to feed cows, but that he had heard that the plants, when old, imparted an unpleasant flavour to milk.

Bigge in Anon. (1823) mentioned the intentional introduction of "silk cotton" (*Asclepias fruticosa*), which Mr. Simeon Lord thought would be useful in the making of hats. It was then wild on the tops of dry hills and in open spaces. Cunningham (1828) referred to it as a wild cotton plant, introduced from Barbary and as "a great pest as, having a flying seed like the thistle, it spreads everywhere".

In the *Maitland Mercury* (12th August 1843), the castor-oil tree (*Ricinus communis*) is mentioned as a weed around country dwellings. It was suggested that it might be made to yield a valuable article of commerce on the London market. A little later in the *Adelaide Observer* (29th June 1844) there was an offer from a chemist in Hindley Street of ten shillings a bushel of fifty pounds for castor oil seeds.

In the *Geelong Advertiser and Squatter's Advocate* (2nd February 1847) there is a reference to an account (originally appearing in the *Launceston Examiner*) of "a horse stung to death by nettles—with blood black as ink". This is probably a very early record of nitrate-nitrite poisoning.

In the *Launceston Examiner* (6th January, 1849) silver grass (*Vulpia*) is mentioned as a competitor of rye.

Gardner (1854) wrote of the "growing injury" of the yellow lucerne (*Melilotus indica*):

> "This noxious weed commonly called the yellow lucerne which grows freely in the moist lands where wheat is sown on the lower Hunter is steadily progressing further and further yearly. The flower of this weed possesses so permanent a scent that when the wheat which grows around it has been reaped and threshed the scent is just faintly perceivable in the grain; when the wheat is ground into flour it becomes quite strong; and when the flour has been made into bread it is so offensive that many persons refuse to eat the bread, imagining it to be bad."

The weeds which were of greatest importance to farmers and graziers in New South Wales in the 1850s were Bathurst burr, *Silybum marianum* and burr medic (Creswick, 1858; Shepherd, 1857; Meston, 1857b). Meston (1857b) also mentioned wild oats, gamboge plant (probably *Argemone ochroleuca*), horehound, marigolds (*Tagetes*) and docks. In the same period Harvey (1855) mentioned horehound, chamomile (*Anthemis*), thistles, sweet briar, furze and hawthorn for Tasmania.

Francis wrote in the *Farm and Garden* (17th April 1862):

> "It is astonishing what an amount of self-glorification is sometimes got up under the discovery of things long and well-known previously

except to the new discoverer. . . . As to the *Phytolacea decandra* (*probably *Phytolacca octandra*), it has been in the colony long enough. Mr. Bailey had it, and I have thrown away lately cartloads; and in Sydney it covers the sides of the roads and the pastures . . . and I believe the subject of an Act of Parliament to eradicate it, just the same as the *Carduus benedictus* is with us."

In New South Wales in the counties of Cumberland and Camden (Anon., 1870), special attention was given to *Silybum marianum, Cirsium vulgare, Xanthium spinosum, Rosa rubiginosa* and *Rumex obtusifolius,* the last named perhaps referring to more than one species of dock (Anon., 1870). Sorrel and sow thistle and *Asclepias* were well known. In South Australia (Anon., 1871), bracken, *Euphorbia* sp., burr medic, sorrel, *Silene gallica, Datura stramonium, Lithospermum arvense, Cirsium vulgare, Silybum marianum, Xanthium spinosum, Cynara cardunculus, Inula graveolens, Centaurea* spp., *Sonchus oleraceus* and *Onopordum acaulon* were discussed at a parliamentary hearing.

Campbell in 1886 (Anon., 1888) noted a number of weeds as important in various districts of New South Wales. They included sweet briar, thistles and sorrel for the tableland areas, docks and *Ranunculus muricatus* in the Tumut district, *Centaurea* spp. around Tenterfield and Inverell, *Phytolacca, Sida, Lantana, Cyperus rotundus, Verbena, Tagetes,* prickly pear and *Lepidium campestre* in the far north coast region and *Argemone* (probably *A. ochroleuca*) in the Inverell district. Bathurst burr was still prevalent and he recorded "seedy grass", whose identity I cannot guess, for the Orange district.

McBarron (1955) has given a number of interesting reports on some of the weeds already mentioned, taken from the *Border Post* (Albury) in the period 1860 to 1890.

It is now appropriate to list the 20 worst weeds of New South Wales given by Maiden (1895) and Maiden (1920). I have taken the liberty of bringing some of the botanical names up to date.

1895	1920
Xanthium spinosum	*Xanthium spinosum*
Rosa rubiginosa	*Rubus fruticosus*
Lantana camara	*Centaurea calcitrapa*
Opuntia spp.	*Xanthium* sp. ("Noogoora† burr")
Centaurea calcitrapa	*Rosa rubiginosa*
C. melitensis	*Echium lycopsis*
Carthamus lanatus	*Cirsium vulgare*
Cirsium vulgare	*Inula graveolens*
Arctotheca calendula	*Carthamus lanatus*
Inula graveolens	*Lantana camara*
Rumex acetosella	*Arctotheca calendula*
R. crispus and others	*Argemone ochroleuca*
Polygonum spp.	*Hypericum perforatum*
Verbena bonariensis and others	*Eichhornia crassipes*
Lithospermum arvense	*Datura stramonium*
Argemone ochroleuca	*Nicotiana glauca*
Modiola caroliniana	*Phytolacca octandra*
Datura stramonium	*Ricinus communis*
Cyperus rotundus	*Centaurea melitensis*
Avena fatua	*Solanum cinereum*

† "Noogoora burr" requires intensive taxonomic investigation.

* My addition.

Observations on Biology and Distribution

Early observations on the biology of weeds in Australia are very limited and almost entirely restricted to methods of spread and habits of vegetative reproduction—for example, to the spread of thistle seeds by wind and water, of seeds of briar by opossums and birds and to the underground system of nut grass (Anon., 1869, 1870). Badgery in Anon. (1869) referred to the recent introduction of *Cirsium vulgare* in rye grass seed.

Early writers on thistles, I think essentially on *Silybum marianum,* in Tasmania and New South Wales, observed their preference for the more fertile soils:

> "If Mt. Wellington were alone infested we wouldn't complain—but instead of that the most fertile spots are always the first to be covered as well with this as the sow thistle and three or four other syngenisious, unsightly wasting plants."
>
> *Hobart Town Courier* (28th January 1832).

> "Many of the gullies in the interior, where it finds adequate moisture and good soil, are actually impassable, being one mass of dense thistles."
>
> —*Hobart Town Advertiser* (23rd January 1846).

> "Though flats may not be the characteristic of Van Diemen's Land they can nearly rival the Pampas in the prolific production of thistles. They are really occupying the best parts of the colony."
>
> —*Hobart Town Advertiser* (7th June 1848).

> "I am astonished at the rapid increase of the thistle, occupying and almost destroying some of the most valuable localities; for it is in the rich alluvial deposits that it flourishes in the greatest luxuriance, completely eradicating the more valuable herbage."
>
> —R.D. in the *Manaro Mercury* (Cooma) (17th December 1870).

Bailey (1880), however, remarked that *Silybum marianum* grew in poor soils.

Tenison-Woods (1881) attempted to relate ecological factors to the distribution of a number of our important weeds. He suggested that dry summers and hot dry winds, as experienced in southern Australia, were necessary for the successful spread of *Arctotheca calendula* (cape weed), the humid, wet summers of coastal New South Wales and Queensland being quite unsuitable. Bailey (1880) had earlier remarked on the unsuitability of cape weed for the coastal areas of Queensland but, in error, supposed it was a threat to western parts of Queensland, giving as an instance, the Diamantina region. Tenison-Woods (1881) also noted that the briar (*Rosa rubiginosa*) was much more at home in the cold tableland areas of New South Wales than on the coast. He appears to have been familiar with weeds from Tasmania to Port Denison (Bowen) in Queensland.

Bailey (1880) after referring to the spread of *Sida rhombifolia* southwards wrote "Why it should have existed all the years it did in North Australia, without spreading, and then come trooping all over the land, must remain an unsolved problem". Its aggressive nature and the opening of new lands must surely be an adequate answer.

Macarthur in Anon. (1869) observed that the loose earth on railway embankments was very favourable for the growth of weeds.

Bigge in Anon. (1823) mentioned the abundance of weeds consequent to floods along the Hawkesbury.

Succession and the Effects of Grazing and Cropping

Changes in weed populations were observed by Morrice in Anon. (1869) "on the banks of the Murrumbidgee I have seen the flats covered with the most beautiful clover; in a year or two came a flood, and then the whole of the banks, instead of clover, were covered with Bathurst-burr, so thick that you could not walk through it; in a year or two afterwards came another flood, and then the banks became covered with thistles, which have been there ever since".

Tenison-Woods (1881) noted the seasonality of thistles (see also Michael, 1968b). R. Smith in Anon. (1887), in reference to the two "star" thistles, *Centaurea* and *Carthamus,* philosophically remarked "I think these things all pass away in their time". The ephemeral nature of *Cirsium vulgare* which appeared soon after the felling or ringbarking of timber was noted (Anon., 1869, 1890).

The effects of cropping and grazing were, in turn, noted

by—

Atkinson (1826)—"Lands that had been exhausted by a repetition of corn crops, and were full of seed weeds, have been sown with grasses, without being properly cleared, and the consequence has been that the grasses have soon been overpowered and destroyed by the weeds."

by—

Meston (1857a)—"On all the earliest settled districts or occupied runs, overstocking, like extra population, usually brings along the penalties pertaining. The primitive grasses become extirpated, or are eaten out—and crowfoots, marshmallows, nettles with many other useless or deleterious weeds usurp the soil."

and by—

Smith (1895) who noted the impoverishment of land in Tasmania and the appearance of silver grass, docks, stone weed and thistles.

The Utility of Weeds for Livestock

There are a number of early references to the utility of weeds for livestock. Drummond (1840) mentioned that *Polygonum aviculare* was "relished by cattle", a yellow-flowered weed brought from the Cape of Good Hope (probably cape weed) was described as "capital sheep feed" (Anon., 1862). Thistles were said to be useful winter and drought feed (Anon., 1869, 1870). Henry Rotton, in a letter from Bathurst to the *Sydney Morning Herald* (22nd March 1871) wrote "Although the thistle (*probably *Silybum marianum*) is not a desirable plant, and most proprietors would be but too glad to see it eradicated, and would most willingly do or pay anything reasonable to attain that object, it is by no means a useless plant; sheep when used to it, will eat it and do well upon it—even fatten on it—in proof of which I may state that since my land has become infested, besides adopting the means (*cutting, burning, ploughing) already mentioned, I have stocked it heavily with sheep, in hopes they would destroy the thistles by feeding them out. I have run an average of four sheep to the acre, and fattened most of them; and I am aware that on some runs the thistles have been considered the salvation of the sheep in a very dry season". Later, *Silybum marianum* was, at times, ensiled (Anon., 1890) or made into hay (Maiden, 1897). Prickly pear could also serve as useful fodder (Anon., 1898). The story of Paterson's curse or Salvation Jane (*Echium lycopsis*) is well known (Maiden, 1920).

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* My addition.

Weed Control

Maiden (1895) gave a list of the methods of exterminating weeds. Briefly they were:

1. The prevention of seeding by cutting the weeds when flowering or in early fruiting stage.
2. Continual cutting to cause "atrophy of the root".
3. If necessary cutting a few inches below the soil surface to prevent production of lateral branching. He mentioned a "scuffle-plough" with a double cutting blade formed like a "V" for this purpose.
4. The use of a mechanical extractor when necessary. He refers to one described in the *Agricultural Gazette of N.S.W.*, Vol. 2, 1891, p. 814.
5. The sowing of crops to smother weeds. Change of crop often useful and especially the introduction of root or other crops.
6. The use of chemical exterminators such as salt and kerosene.

But methods of control were not really Maiden's forte, so let us turn to older records.

Mechanical Methods

There are various references to the cutting, mowing and burning of thistles in early newspapers, for example:

> "If cut off close under the ground, so that their wound is protected from the sun, the roots will bleed to death. On the New Town Road several men have been employed by the government in this praiseworthy employment."
>
> —*Hobart Town Advertiser,* 23rd January 1846.

In answer to a memorandum, dated 3rd December 1846, from Capt. E. C. Frome of the Surveyor General's Office in Adelaide, the expenditure of £15 or £18 was authorized for the extermination of thistles along the River Torrens. They were mowed before going to seed and burnt. The first payment, under the provisions of the South Australian Thistle Act of 1851 was £1, paid to natives for clearing thistles from the Police Paddock in Adelaide in 1852 (Anon., 1858).

Shepherd (1857) suggested hoeing for control of Bathurst burr and noted that there was little germination of this weed after December. With burr medic, he suggested burning in heaps after drying. He advocated the use of the Dutch hoe.

Meston (1857b) including cutting, burning, rolling and scarification after each germination in his methods.

Chemical Methods

There are a number of brief references to chemicals—for example:

> "A thistle may be destroyed by common salt."
>
> —*Adelaide Observer,* 5th October 1844.

In relation to thistles:

> "it is now gravely proposed to cut them down and sprinkle a little salt or arsenic on the root of each plant to render them 'wholly innocuous'."
>
> —*Melbourne Argus,* 1st December 1859.

Francis in Anon. (1862) stated that "a thistle could be destroyed by a drop of nitric acid dropped on it when very young, but cutting was better".

Meston (1857b) indicated that hydrate of lime, potassium nitrate and common salt were useful and that the first two substances could be beneficial to desired plants.

Common salt was recommended for killing of *Cirsium vulgare* and *Rumex* spp. (Anon., 1869, 1870). Salt was believed to affect thistles by "mixing with the sap" (Anon., 1869).

Mr. Lansdowne, an Agricultural Society delegate from Goulburn, in reference to sorrel, thistles, docks and sweet briar, mentioned the application of salt, arsenic and lime but noted that valuable plants could often be destroyed (Anon., 1891).

Competitive Species

Occasional references were made last century to the use of sown pasture species in weed control:

> "How long will the proprietors of the soil continue blind to their true interests; persisting in the present rack-rent system, thus taxing lands for corn which have been under crop for 20 years and upwards? Such can only give for one or two years more even their present paltry return; they should be at once laid down in grass and white clover, the latter is the most powerful enemy we have to sorrel which is making rapid progress here."
>
> —*Launceston Examiner,* 6th January 1849.

Meston (1857a) wrote *"Trifolium repens,* white clover is admirably adapted for many parts of New England and such soils and climes. It spreads both by roots and seeds, and extirpates rushes, juncus, blady grass and every other grass in its extended progress".

Moore in Anon. (1870) noted the usefulness of buffalo grass in controlling nut grass.

Abbott (1879) advocated the control of *Cirsium arvense* by sowing down to grass.

Campbell in Anon. (1888) implied that lucerne was effective in control of *Silybum marianum* (see also Michael, 1968a).

The use of smother crops, as Maiden understood them, seems to have been later. In Anon. (1891) there is mention of the use of heavy manuring followed by Cape Barley sown thickly and cut with a long stubble in weed control.

Control by Grazing

The attempt by Rotton to control thistles by grazing is mentioned in the quotation from his letter (*Sydney Morning Herald,* 22nd March, 1871) under "The utility of weeds for livestock".

Conclusion

The Frenchman, Péron, during his visit to Sydney in 1802 contemplated "these new fields where the feeble grass of the north arises from the decay of the powerful Eucalyptus" (Péron, 1809). Smith (1895) wrote of the early days in Tasmania:

> "This lovely isle was inhabited by perhaps the lowest type of savages on the face of the earth, together with a few wild animals which they hunted down for food. Now I would ask what has the most enlightened race of human beings done by way of improvement in a short century? I look across the land I have been describing and what do I see? Briars and gorse, docks and thistles, and every other obnoxious weed and I say 'How deplorable!'."

To be sure, with the growth of settlement in Australia we had, by 1920, built up an extraordinary collection of weeds, and much useful information concerning them, which will provide materials for continuing enquiry. I believe that the problems of identity are of prime importance in any programme of research or teaching on weeds. It is regrettable that in the history of weed research in Australia no thoroughly critical, concerted attempt has ever been made to solve these problems.

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A JUBILEE OF RESEARCH ADMINISTRATION 1920-70.

J. Strang*

Current opinion, expressed by Henry Mayer, *The Australian,* 20th June 1972, is that the Government has no science policy. More than 50 years ago the late Hon. W. M. Hughes said in an address to the National Laboratory Conference, 1916, "that science with its magic wand can turn heaps of refuse into shining gold" and then promised £500,000 to establish a National Laboratory (Currie and Graham, 1966). Although the Government was then committed to establish a national scientific institution, Hughes' promise of £500,000 was considerably diluted.

It was not until 1920 that Hughes' words about the organization of scientific research were partly fulfilled in the formation of the Advisory Council for Science and Industry. This body co-operated with the Commonwealth Prickly Pear Board also established in the same year. The Board guided the prickly pear control programme and remained corporate until 1939. The headquarters of the Board was established at Sherwood with field stations at Westwood (1922), Chinchilla, Queensland, and Biniguy, N.S.W. (1923).

C.S.I.R. formed in 1926 and the Division of Economic Botany in 1927. Dickson in 1929, wrote a blueprint for organization of the Division and included weeds research (Dickson, 1929).

Currie (1940) led weeds research in C.S.I.R. and this had its beginnings in the Division of Entomology 1929, as insect control of weeds was fashionable. The stimulus for weeds research has arisen from public outcry about the expenditure of large sums of money in paying noxious weeds inspectors to enforce the State Acts but little was being done to discover more efficient means of controlling weeds. In 1927 the Commonwealth Poison Plants Committee was formed and both the Queensland and N.S.W. Committees became active although their activities ceased soon after the outbreak of World War II (Anon., 1934; Hurst, 1942; Webb, 1948).

1930-40

Grogan (1957) outlined the 1934 conference convened by the late Hon. S. M. Bruce, which resulted in the formation of the Australian Agricultural Council and Standing Committee on Agriculture. The duties of Standing Committee included the securement of co-operation and co-ordination of agricultural research throughout Australia. The State Co-ordinating Committees on Weeds Research were established in 1935, and they commenced to liaise and co-ordinate research within each State and C.S.I.R. representatives acted as collators and distributors of information.

One result was to arrange a survey of the extent of the weed problem, the economic importance of specific weeds, control methods and recommendations for co-operative work (Currie, 1936). The recommendation resulted in skeleton weed research (Greenham *et al.,* 1940), an ecological approach to the control

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of St. John's wort (Moore and Cashmore, 1942), and prospects for insect control of the wort (Wilson, 1946).

Meanwhile *Cactoblastis cactorum* had exploded and caused the almost total collapse of *Opuntia inermis* and *O. stricta* by 1934 (Mann, 1970).

The efforts of the State Weeds Co-ordinating Committees commenced to bear fruit by a greater awareness of weeds (Judd and Carne, 1935), identification of weeds and their control (Morgan, 1931; Carne, 1935; Clarke, 1936; Cashmore and Carne, 1938). An article by Ross and Taylor (1935) proposed the use of lucerne to compete with skeleton weed.

1940-60

We do not know of any significant changes in the administration of research during and after the Second World War until 1954.

The first Australian Weed Control Conference was held at Roseworthy in that year where overall research progress was reported for the first time. Interesting appendages to the Conference included separate statements by each State weeds authority about their research organization. A notable feature of the Conference was the vigorous entry by private industry into the evaluation of individual herbicides (products). South Australia's organizational chart placed private industry ahead of the Waite Research Institute. Also summaries of research activities and priority weeds lists were presented. Resolutions from the Conference allocated the evaluation of herbicides to State authorities and it was proposed that the six State weeds co-ordination committees be re-formed into a single Weeds Committee.

The Last Decade

The second Australian Weeds Conference, Canberra, 1960, attracted contributions on a wide range of topics. Its outcome revealed the need to treat skeleton weed as a special problem and to increase communication between weed researchers. The former resulted in the formation of the Skeleton Weed Committee, 1960, and the latter in the publication by C.S.I.R.O. of the *Australian Weeds Research Newsletter,* 1962.

In regard to the Skeleton Weed committee the Australian Agricultural Council approved of its principal objectives as:

(*a*) recommending priorities for research projects which Council's contributions and similar contributions should be applied.
(*b*) co-ordinating all skeleton weed research undertaken as a result of decisions of Standing Committee on Agriculture and the Australian Agricultural Council.
(*c*) recommending any additional research on skeleton weed found necessary or desirable from time to time.
(*d*) providing liaison between the various skeleton weed research groups and the Standing Committee on Agriculture.

An upsurge in skeleton weed research was made possible by the acquisition of funds from the Wheat Research Council and State Wheat Industry Research Committees. The outcome of this research was a better understanding of the plant's biological performance, herbicides to eradicate small areas of new infestations, suitable legumes to compete successfully with the weed and the release of biological control agents.* The Committee disbanded in 1971.

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* Biological control agents, liberated for weed control in Australia, are listed in the appendix to this paper.

The third Australian Weeds Conference, Toowoomba, 1965, was attended by 140 delegates. This Conference was highly successful but failed to tap further Wheat Industry Funds for research on wild oat control on an organized basis.

The gains achieved were:

(1) the formation of the Australian Weeds Committee 1966, to co-ordinate weeds research in agriculture.

(2) the subsequent creation of State Weed Societies.

(3) the clearance of herbicides prior to registration at the national level.

Financial support for individual projects commenced to flow from Wheat, Wool, Meat, Dairy Industry Research Funds from 1962 on. This led to a solution for the serrated tussock problem (Campbell, 1966, 1969), weed control in cereals (Baldwin, 1969), and blackberry control (Amor, 1971). Allocations based on the merit of individual projects, although establishing priority and preventing duplication, did not provide for long-term continuity because of Industry constraints thus leading to re-allocation of resources including staff on completion of a project.

Weeds research spread into new areas of investigation heightened by the injection of Commonwealth Extension Services Grant (C.E.S.G.) funds, although an extension allocation for a socio-economic research survey on serrated tussock (Fallding, 1957) had been made earlier. In 1966 the Commonwealth Department of Primary Industry commenced to allocate moneys on a research project basis. This Government to Government arrangement supported long-term research. Research progress was (and still is) reviewed by economic programme planning based on overlapping triennial forecasts of estimated expenditure compared with actual expenditure and a five yearly overall State/Commonwealth review.

State weed projects are financed by industry, C.E.S.G. and Consolidated Revenue. However, the general nature of weed problems often requiring an understanding of a number of disciplines would tend to draw on long-term support which is already substantially committed.

An important conference on wild oat control in wheat was convened at Tamworth, 1968, with the view to rationalizing research work as this grass weed was receiving considerable attention by researchers (Quail and Carter, 1968, 1969; Watkins, 1969; McNamara, 1972).

The first Victorian Weeds Conference 1968, was a useful contribution updating research information on weeds and weed control for most parts of Australia. It is significant that this Conference was convened by the Weed Society of Victoria. Also the Weed Society of N.S.W. sponsored symposia in 1967, 1969 and 1970. Much of this information is unavailable elsewhere, thus the Societies started to play a valuable role in keeping their members and the community informed on research activities by their members.

Research on the use of different herbicides spread to a number of specific areas, namely, sugar cane (Annual Reports of the Bureau of Sugar Experiment Stations for 1967, 1968 and 1969), aquatic situations (Bill and Graham, 1970), sylviculture (Truman, 1970), orchard management (Turpin *et al.*, 1970) and vegetation management *per se* (see Mears and Swain, this symposium).

The new Keith Turnbull Research Station, established in 1967 at Frankston, Victoria, permitted more active research, and this blossomed into research on the biology and ecology of individual plants, the use of non-herbicidal control and effects of management techniques, and the evaluation of herbicides (Welsh, 1972).

The fourth Australian Weeds Conference, Hobart, 1970, recommended:

(i) the provision of a national data bank on the deleterious effects of plants on animals.

(ii) the establishment of a national research laboratory for the study of plant poisons on animals.

It is too early to gauge the usefulness of these proposals.

In 1920 weeds research had barely started. The farmer was faced with the awesome problem of combatting prickly pears, burrs and other serious weeds. The organization of research has grown to service not only agriculture but also other primary industries as well as public facilities and transport services. Considerble spin-off has brought advantages to other areas, such as health, and real estate development.

The year of Jubilee was a time when slaves were released. Thus it is fitting to nominate 1970 a Jubilee year of Weeds Research. This is a time of rejoicing for the community as organization has enabled weeds research to release the community from much of the bondage of hand labour which was the principal method of weed control in 1920.

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APPENDIX

LIBERATION OF BIOLOGICAL CONTROL AGENTS FOR WEED CONTROL IN AUSTRALIA

Plant	Agent Introduced	Years Liberated	States
Cacti	Cactoblastis cactorum	1926-33	Qld., N.S.W.
	Tucumania tapiacola	1935-9	Qld., N.S.W.
	Olycella junctolineella	1924-7	Qld., N.S.W.
	Moneilema ulkei	1926-39	Qld., N.S.W.
	Moneilema variolare	1932-4	N.S.W.
	Lagochirus funestus	1936-40	Qld.
	Chelinidea tabulata	1922-9	Qld., N.S.W.
	Chelinidea vittiger	1925-9	Qld., N.S.W.
	Dactylopius opuntiæ	1921-6	Qld., N.S.W.
	Dactylopius newsteadi	1925-6	Qld., N.S.W.
	Dactylopius ceylonicus	1935	N.S.W.
	Dactylopius sp. near confusus	1933-7	Qld., N.S.W.
	Cactoblastis cactorum	1934	Sth. Aust.
	Melitara prodenialis	1928-36	Qld., N.S.W.
	Melitara dentata	1927	Qld.
	Melitara doddalis	1926-9	Qld., N.S.W.
	Melitara sp.	1925-9	Qld., N.S.W.
	Cactoblastis doddi	1935, 1936	Qld.
	Dactylopius confusus	1933	Qld.
St. John's wort *Hypericum perforatum*	Chrysomela hyperici	1930-4	Vic.
	Chrysomela varians	1930-3	Vic.
		1930	N.S.W.
	Chrysomela brunsvicensis	1930-4	Vic.
		1930	N.S.W.
	Chrysomela quadrigemina	1938, 1939	Vic.
	Agrilus hyperici	1939, 1940	Vic.
		1940	N.S.W.
	Anaitis efformata	1933-8	Vic.
	Anaitis plagiata	1933-8	Vic.
	Zeuxidiplosis giardi	1953, 1954	N.S.W.
		1954, 1955	Vic.
Lantana *Lantana camara*	Ophiomyia lantanæ	1914	Qld.
		1917	Qld., N.S.W.
	Epinotia lantana	1914	Qld.
	Eutreta sparsa	1914	Qld.
	Thecla agra	1914	Qld.
	Teleonemia scrupulosa	1935, 1969	Qld., N.S.W.
	Catabena esula	1956	Qld.
	Syngamia hæmorrhoidalis	1962	Qld.
	Hypena strigata	1965, 1966	Qld.
	Uroplata girardi	1966	Qld., N.S.W.
	Octotoma scabripennis	1966	Qld., N.S.W.
	Plagiohammus spinipennis	1966	Qld., N.S.W.
	Diastema tigris	1966	Qld.
	Leptobyrsa decora	1969	Qld., N.S.W.
	Teleonemia elata	1969	Qld., N.S.W.

Plant	Agent Introduced	Years Liberated	States
Crofton weed *Eupatorium adenophorum*	Procecidochares utilis	1952-4 1953-4	Qld. N.S.W.
Mist flower *Eupatorium riparium*	Cercospora eupatorii	1957	Qld., N.S.W. (accidental)
Gorse *Ulex europæus*	Apion ulicis	1939	Tas.
Noogoora burr *Xanthium pungens*	Euaresta æqualis Mecas saturnina Nupserha antennata	1932-40 1963 1964 1971	Qld. Qld. Qld. N.S.W.
Bathurst burr *Xanthium spinosum*	Camaromyia bullans	1928	N.S.W. (accidental)
Ragwort *Senecio jacobæa*	Callimorpha jacobææ	1930-2 1934, 1936, 1937	Tas., Vic.
Groundsel bush *Baccharis halimifolia*	Trirhabda baccharidis Aristotelia sp. Oidæmatophorus lacteodactylus Cecidomyia sp. Phalonia sp. Rhopalomyia californica	1969 1969 1969 1969 1969 1968	Qld. Qld. Qld. Qld. Qld. Qld.
Skeleton weed *Chondrilla juncea*	Uroleucon chondrillina Aceria chondrillina Puccinia chondrillina	1971 1971 1971	S.A., Vic., N.S.W. S.A., Vic., N.S.W. S.A., Vic., N.S.W.

N.B.: Native insect and fungus species are excluded.

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ECOLOGICAL AND CULTURAL STUDIES

B. A. Auld*

Introduction

Real interest in ecological and cultural studies of weeds was not apparent until the mid-1930's; between 1920 and 1936 most emphasis was placed on poisonous plants, biological control and the use of "poison salts".

During the early years of the 1920's State Government botanists continued to publish useful descriptive notes on troublesome plants (e.g., White, 1925; Anderson, 1926) and an increasing awareness of poison plants developed. In 1927 the N.S.W. Department of Agriculture, the University of Sydney and the Council for Scientific and Industrial Research formed a committee to investigate poison plants "alleged to cause heavy losses to stock in Australia" (*J. Coun. Sci. Ind. Res. (Aust.)*, 1: 56, 1927). The influence of this committee is seen in the literature of the next few years (Hindmarsh, 1930; Seddon and King, 1930; Gilruth, 1931; Albert, 1935) in which lethal doses of chemicals which occur in plants and the plants themselves were investigated.

Interest in biological (or entomological) control had been growing since Koebele first employed the technique (as a method of weed control) in 1902 in Hawaii. [The concept of biological control was apparently first manifest in the control of an insect by a bird in Mauritius in 1762 (Moutia and Mamet, 1946)]. It was heightened with the apparent success of *Cactoblastis* on prickly pear by 1927 (*J. Coun. Sci. Ind. Res. (Aust.)*, 1: 369). The control of Noogoora burr and Bathurst burr was suggested (Kelly, 1931) as well as the control of bracken. Tillyard (1929) presented an interesting account of the work of the period. With the confirmation of the success of *Cactoblastis* (Dodd, 1932), further prospects: nut grass (Summerville, 1933) and *Rubus* spp. were examined.

During the 1920's and 1930's most trained ecologists found more interest in native rather than introduced flora and especially in descriptive surveys (Collins, 1923; Patton, 1933; Pidgeon, 1937; Stephens and Cane, 1938). Autecological studies were uncommon (Brough, 1933) and ventures into applied ecology rare. Thomas (1932) investigated the readvancement of vegetation over mined areas in Victoria and Blake (1937) observed the effect of grazing on plant communities in western Queensland.

The First Experiments—A Prelude

A record of the first experiments using pasture species to control weeds (one form of "ecological control") appeared in the *Agricultural Gazette of New South Wales* in 1933. Stening (1933) described the successful "experiments" of Bartlett which began at Tumbarumba in 1928 using sub-clover to control *Hypericum perforatum*, St. John's wort. In spite of its apparent success, the idea of weed control by pasture species did not gain momentum, partly due to the fact that it was not directly applicable to all infested areas. Reuss (1936) complained that clovers would be unsuitable to control

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H. perforatum in the Mudgee climate but did not suggest the possibility of using summer growing species.

Weed control in the early thirties was obviously distracted by the success of *Cactoblastis* and apart from that, the use of poison salts "dominated thinking" (Costin, 1959). It became evident, however, that some chemical methods were not economically realistic. In 1935 the cost of control of *Chondrilla juncea,* skeleton weed, by sodium chlorate was £4 to £5 per acre (Ross and Taylor, 1935) ; an untenable control recommendation at the time. As an opiate to the people, the New South Wales Government offered a £5,000 reward for a practicable method for "eradication" of skeleton weed (*Agric. Gaz. N.S.W.,* 46: 378, 1935). Costin (1959) tells of a "notable Temora farmer, the late William Giles (who) applied for the reward on the basis that the weed could not only be controlled but also put to good use by incorporating a year or two of grazing by sheep into the usual wheat rotation". Costin records that the claim was not seriously considered. Earlier in the very year in which the reward was offered two of that government's own officers had written an article on the control of skeleton weed by lucerne (Ross and Taylor, 1935). Apparently this was not the panacea expected; nevertheless, Ross and Taylor (1936) persevered. Clearly, the possibilities for ecological control had not been fully appreciated at this stage.

Reassessment and Development

The period from 1936 to 1942 marked the real genesis of ecological weed research in Australia. The late 1930's was a time of re-examination of approaches to weed problems (Clarke, 1937) and increasing interest in ecology (Trumble, 1938). Currie (1936) in "A Report on a Survey of Weed Problems in Australia" stressed the use of pasture to control weeds: "in pastoral areas, too great stress appears to be placed on the destruction of weeds and too little on the pasture conditions. . . ."

In 1936 the Council for Scientific and Industrial Research appointed an ecologist to study skeleton weed and weeds of pastures and an assistant ecologist to study *Bassia* species and nut grass (*J. Coun. Sci. Ind. Res. (Aust.),* 9: 145). This represents something of a landmark in the study of the ecology of weeds in Australia. Although B. T. Dickson, Chief of the Council's Division of Economic Botany, had commented on the paucity of autecological data on Noogoora burr in 1927 (*J. Coun. Sci. Ind. Res. (Aust.),* 1: 375) little had followed (Calvert, 1932), and the need for this kind of information for other species had not been widely acknowledged.

Paradoxically, the first publication to arise from this newly conceived ecological approach was one dealing with "experiments with weed-killers" on skeleton weed (Cashmore and Carn, 1938). Notwithstanding this uncertain start, autecological work was soon published (Cashmore, 1938; Prunster, 1941) and Pemberton and Prunster (1940) produced an ecological survey of a weed in Victoria; some of the work done during this period remains unpublished (e.g., Roe's field studies of *Bassia birchii*).

It was during this period also, that ecological control of a weed by pasture was admirably demonstrated and clearly reported by Moore and Cashmore (1942). They examined six pasture mixtures and three different seedbed preparations in separate experiments in the control of St. John's wort. They concluded that "subterranean clover in association with perennial grasses . . . almost completely eradicated St. John's wort". Stening (1933) in claiming that sub-clover would "choke out" St. John's wort had already demonstrated the principle of ecological control, but without the support of experimental data and following so soon after the success of *Cactoblastis,* the work failed to have the impact of Moore and Cashmore's study.

Post-War Research

After the Second World War weed control by pastures became a major branch of weed research. In fact, as early as 1946, in a review of the weed problems in Australia, Cashmore and Campbell made the rather sweeping assertion that "The method of control found most generally applicable in Australian experience is the introduction of a vigorous pasture into the farming rotation or the improvement of pastures in pastoral areas."

The early 1950's, with the wider adoption of the concept of "improved pastures", saw much of this type of work (Hexter, 1950; Pearson, 1950; Goodchild, 1951; Roark and Donald, 1954). The use of fertilizers alone as an ecological control tool was also first examined at this time (Myers and Moore, 1952; Rossiter and Ozanne, 1955).

In what was to be something of a parallel to the history of St. John's wort control, in 1956, the publication by Green of results of field experience with serrated tussock was to form a basis for the later extensive studies by Campbell (1968).

The need for more life history and ecological studies was expressed at the First Australian Weed Control Conference in 1954. There followed few autecological (Moore, 1956; Williams, 1957) and biological studies (Ballard, 1956; Ballard and Grant Lipp, 1959). However, two papers on the relationship of nitrogen response to competitive effect of weeds (Hawkins and Black, 1958; Myers and Lipsett, 1958) were among the first attempts to quantitatively estimate the effect of weeds.

In contrast to the previous forty years, the literature after 1960 is almost overwhelming. It is difficult to treat this period fairly with the limited historical perspective available. Competition studies continued (Moore and Robertson, 1964; Kleinig and Noble, 1968; Smith, 1968) and with them a need for greater understanding of competitive mechanisms was expressed (Connor, 1965). The increase in number of long-term field studies (Michael, 1968*a*; Quinlivan and Peirce, 1968; Wells, 1969) and the possibility of examining several weeds in relation to one crop (van Rijn, 1968) have been pleasing developments.

An increased interest in autecology and biology of weeds has been a principal feature of the 1960's (e.g., Cuthbertson, 1966; McVean, 1966; Caso and Kefford, 1968; Quail and Carter, 1969; Cartledge and Carnahan, 1970). The trend has been so strong that Doing (1966) has stressed the need for autecological work to be complemented by synecological studies of weeds and pasture species. One of the more significant papers of this period to my mind, is the morphological work of O'Brien (1963) which helped elucidate the reasons for the lack of success in chemical control of austral bracken (*Pteridium esculentum*).

More imaginative control programmes were conceived with scientific bases. The use of herbicides as an ecological tool increased (Pearce, 1964; Bachelard, 1968; Michael, 1968b) and the need for tactical timing of control procedures in relation to growth (Michael, 1965) and germination (Myers and Squires, 1970) demonstrated. The technique of barley grass control by grazing management alone by Myers and Squires (1970) represents an ultimate expression of potential of ecological control.

Retrospect

The success in ecological control of many weeds is largely dependent on the availability of suitable, competitive replacement species. The concept of improved pastures, the development of these species and their adoption, has obviously been a prime factor in the progress of ecological weed control in Australia.

Unfortunately, few scientists (Everist, 1959; Moore, 1967) have taken an interest in the history of the introduced flora; even lists (Raphael, 1955) are useful. There have been few published accounts of distribution (apart from maps of known range from herbarium records) and even fewer (e.g., Roe and Shaw, 1947; Auld, 1969) relating distribution to environmental factors. These deficiencies mean that for many of our weed species we have little understanding of their ecological amplitude: the possibility and direction of their further spread.

Research workers have displayed meagre interest in the development of machinery specifically for weed control. A. C. Howard, a Gilgandra farmer, invented the rotary hoe in 1920 and in the next few years developed modified types for weed control (Wheelhouse, 1966); a hand operated rotary weeder was described by Powell in 1952. I doubt if anyone in Australia has investigated Anderson's (1963) tool for manual control of *Lantana,* in spite of the fact that thousands of dollars have been spent in attempts to control it by insects and chemicals.

One of the more unfortunate aspects of weed research has been the general lack of interest in introduced flora by systematic botanists. The consequences of incompletely or incorrectly established identity can be disastrous. For example (although White (1929) had made some attempt) it is incredible that the true nature of *Lantana camara* was not apparent (L. S. Smith, unpublished data) until over fifty years after the first insects were introduced for its control. The taxonomic complexity of some of our other weeds has recently become apparent (Ali, 1964; Michael, 1964) and an identity imbroglio in other "species" is emergent.

However, developments in the recent past are encouraging. The work of the last ten years in particular, in the study of weed ecology and ecological and cultural control has undoubtedly established a broad and substantial foundation for the future. The increasing number of agricultural scientists employed in this field and a wider appreciation of ecology in the community is further cause for optimism.

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THE EARLY HISTORY OF CHEMICAL WEED CONTROL IN AUSTRALIA

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Now aware of the need to minimize environmental pollution man has reached a turning point in his occupation of this planet. It is, then, a logical time at which to discuss aspects of weed control in this country paying particular attention to chemical methods of control. By so doing one might pinpoint the mistakes of the past and, hopefully, provide guidelines for the future. Of necessity one must set the stage so I offer no apology for briefly surveying weed control throughout history.

Weed Control in Antiquity

The plants we know as weeds have always been with us. Primitive man, however, did not recognize them as such: those he learned were edible and not harmful he used as food. The last meal of the Iron Age man buried in the Danish bog near Tollund, for example, included seeds of *Polygonum convolvulus, P. lapathifolium, Spergula arvensis* and *Chenopodium album* (Glob, 1959). These plants did not become "weeds" until long after man planted his first crop.

Primitive agriculture almost certainly began with the conscious planting of gramineous species, probably wheat, by the nomadic hunter tribesmen some 10,000 to 12,000 years ago. Seed broadcast onto the better watered, low-lying areas on the outskirts of the settlement and trampled in with stock assured a reasonable harvest. Any weeds present were probably harvested indiscriminately with the crop unless they were recognized as harmful. Later, as the crop increased in importance, such areas were "farmed" until declining fertility or the accumulation of weeds, prevented crop growth. At this stage the tribe moved to a new site and the cycle starts all over again; a system practised well into the present century by the more primitive communities of the underdeveloped areas of the world.

Despite the development of irrigation along the great rivers of the "fertile crescent" and of primitive agricultural implements—the hoe, the plough, the harrow and even the *carpentum* the forerunner of the "Ridley Stripper" (White, 1967)—there is no record in the Euro-Asian region of any conscious attempt to remove weeds until the Roman Epoch. Roman writers, however, provide much information on agricultural operations. Harvesting, hoeing, weed and pest control are fully documented (Ordish, 1963; White, 1967). This "western" situation contrasts sharply with contemporary Chinese writings which suggest a long history of active weed control.

> "Some weed with hands, some with hoe,
> exuberant let the millet grow.",

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So says the *Shih Ching*—The Book of Odes—written between the 10th and 6th Centuries B.C. (Shih, 1958), while a popular Chinese ballad of the same period (Anon., 1912) contains these lines:

> "Mid the young and thriving grain
> Weeders wade, a numerous train."

Weed Control in the Christian Era

From the late Roman period on, although weed control became more important, cultivation methods limited its effectiveness. After the plough broke the land labourers were set to breaking the clods with a variety of mallets and other tools. On the other hand a definite sequence of cropping, typified in feudal England by the "three field" system (Bryant, 1953) gradually developed. In this rotation winter wheat was followed by spring wheat while the third year was a fallow year.

Cultivation methods improved over the years, when harrows made of "wooden frames through which iron tines were set" (Goodland, 1955) were introduced in Norman times. Nevertheless, while Shakespeare's words:

> "I will go root away
> The noisome weeds, that without profit suck
> The soil's fertility from the wholesome flowers."
>
> —(*Richard II*, 3. iv.)

reflect an increasing awareness of the role of weeds, no marked changes in methods of tillage and of weed control, occurred until well into the eighteenth century. Then, because Jethro Tull in 1731 advocated interplant cultivation for the purposes of aeration, water conservation and weed control, horse hoes with three or more tines were produced. Goodlands (1955) reports that the inner tines had triangular blades fitted, but that the outer ones were L-shaped to allow cultivation as close to the rows as possible.

During the 19th century the production of new types of agricultural machinery was a concomitant of the industrial revolution. Similar advances were made in Australia: the stripper developed by Bull and Ridley in 1843 and the stump jump plough of Robert Bowyer Smith in 1876 are well known (Wheelhouse, 1966). Yet in 1856, His Excellency, Sir William Denison, in a Presidential Address to the Australian Horticultural and Agricultural Society, had occasion to say:

> "We are deficient in what may be termed the economy of horticulture. The cultivation of the ground is slovenly; weeds are allowed to absorb much of the nutriment which should go to the plant . . . yet few or no efforts have been made to devise a remedy for this evil. . . ."
>
> (Campbell, 1901).

Thus the situation in this country was very little different from that obtaining in Europe. There were, however, two very important differences influencing the development of weed control practices generally and chemical methods in particular:

(i) an extensive as opposed to an intensive system of agriculture, and
(ii) a preponderance of deep-rooted perennial weeds as opposed to annuals.

The Beginnings of Chemical Weed Control

Germany seems to be the birthplace of chemical weed control. Although common salt was probably used much earlier, Mukula and Ruutunen (refer Timmons, 1970) indicate that it was recommended as a herbicide in Germany during 1854 and that lime was recommended for the control of horsetail (*Equisetum* sp.) as early as 1840. In the same country Kirchof (1855) recommended sulphuric acid and iron sulphate as herbicides.

Notwithstanding their isolation Australian agriculturalists, like their industrial counterparts, were not far behind. I can find no record as to the source of the work but the chemical eradication of dodder from lucerne is described in the following terms (Anon., 1891):

> ". . . the first steps towards eradication is to carefully cut the dodder spot and burn the whole of the cuttings. The spots thus cleared should be syringed by means of the finest pump available with a solution of sulphate of iron 1 lb to 8 gallons of water."

A later comment (Anon., 1900a) also suggests an application of lime for the elimination of sorrel.

In general, the cultivation methods used in the Australian cereal growing areas were such that annual weeds were not regarded as a major problem, until wild turnip (*Brassica tournefortii* Gouan.) invaded the Western Australian cereal areas. Consequently it is in the realm of perennial weed control—St. John's wort (*Hypericum perforatum* L. var. *angustifolium* D.C.), prickly pear (*Opuntia* sp. L.), hoary cress (*Cardaria draba* (L.) Desv.), skeleton weed (*Chondrilla juncea* L.) and others—that Australians made their greatest contribution. State Departments of Agriculture and later the Council for Scientific and Industrial Research were active from the beginning. Their work provided several firsts, most of which, regrettably, have received scant attention outside this country.

Both common salt and kerosene were used in eradication techniques prior to 1900 but Maiden (1895) suggests that they were "too expensive and too uncertain to be used on anything but special weeds like prickly pear". French (1903, 1905), on the other hand, showed that salt gave better control of St. John's wort than any of the other chemicals tried. As a result salt was used extensively for the control of the wort near Myrtleford in Victoria (Calvert, 1932) and was tried successfully against ragwort (*Senecio jacobœa* L.), skeleton weed and hoary cress (Judd and Carn, 1935; Prunster, 1940b, Gardner and Meadly, 1944; and others). The lack of response to salt reported by Morgan (1931, 1934), which he attributed to lack of penetration because of the heavy clay subsoil at Werribee, then compared with the successful control obtained by the Victorian Department of Crown Lands and Survey in the Wimmera, and the experiments of Gardner and Meadly (1944), indicates the importance of soil texture in soil sterilization techniques. Salt continued in vogue for spot eradication of skeleton weed at least as late as 1962 (Orchard, 1950; Tully, 1962).

Prickly pear, however, was undoubtedly the first important weed to be given major attention. By 1900 numerous specifics, including potassium chlorate—to my knowledge the first ever mention of the use of chlorates as herbicides (Anon., 1901)—copper sulphate, sulphuric acid, carbolic acid and sodium arsenite (Valder, 1902) had been tested. Of all of them sodium arsenite was reported as being quicker and more deadly than the others.

Even at this early stage potential soil residues were given attention in the work of Guthrie and Helms (1903, 1904, 1905) in New South Wales. They conducted tolerance tests with the major crops wheat, maize, barley and rye. The growth of wheat, for example, was found to cease when the concentration of sodium chlorate in the soil reached 0·03 per cent, ammonium sulphocyanide 0·005 per cent and arsenious acid 0·1 per cent. Maize, barley and rye were reported as being somewhat more tolerant of these herbicides.

Surface application and injection experiments for the control of prickly pear continued in Queensland and New South Wales (Brunnich, 1909, 1911; Darnell-Smith, 1913), until an exhaustive survey of potential herbicides by Dr. Jean White-Haney (1916) showed arsenic pentoxide to be the most effective compound available. The control of prickly pear thus obtained widened the investigational field considerably. Arsenicals were used, with varying success, on ragwort (*Senecio jacobæa* L.), Noogoora burr (*Xanthium pungens* Wallr.), St. John's wort, hoary cress, cumbungi (*Typha* sp. L.) and skeleton weed (White-Haney, 1930; Morgan, 1931, 1934; Calvert, 1932; Cashmore and Carn, 1938, 1940; Prunster, 1940 a, b; Gardner and Royce, 1948).

Eradication of deep-rooted perennials like hoary cress and skeleton weed requires that the roots be killed to a considerable depth. This can be achieved chemically by soil sterilization or, preferably, by the use of translocated sprays. Such sprays when applied to the leaf or stem, are absorbed into the vascular system and carried into the root. White-Haney (1915) was the first to report movement of arsenicals from the leaf to root, but only in the shallow-rooted prickly pear. Subsequently, however, Gray (1917), working in California, described movement of arsenic into the roots of the deep-rooted wild morning glory. Even so, successful control of these weeds with the arsenicals was not assured. It was apparent, therefore, that factors affecting the efficiency of translocated sprays required investigation.

In Australia, Morgan (1931) working with hoary cress noted that "the conditions . . . most favourable to remote penetration (translocation) of arsenic pentoxide spray were those producing a high rate of transpiration and photosynthesis . . . the especially favourable weather conditions may be broadly defined as a week of hot weather preceding the spraying". In other words a marked water deficit was required. Working concurrently with Morgan but in California, Kennedy and Crafts (1927, 1930) using wild morning glory came to the same broad conclusions. They also showed that the arsenical solutions applied externally rapidly killed the outer tissues of the leaf making them permeable. Thus the plant sap, mixed with the arsenical solution provided a "volume of liquid" at the tops of the leaf tracheæ which, as a result of the loss of water tension, was sucked downwards into the xylem. Herbicidal effectiveness then, depended upon spray retention on the leaf surface, penetration of the cuticle, the presence of a water deficit (c.f. current requirements for active growth) and a highly toxic chemical.

The later work of Hellquist and Bengtsson (1954) and Brunskill (1956) and others on spray retention, and of Aslander (1927), Loomis, Bissey and Smith (1931), Crafts (1931) and others on mode of penetration, was to some extent foreshadowed by White-Haney (1913, 1915, 1916). She found that with prickly pear, spray applications with an atomizer did more damage than coarser droplets for equivalent amounts of arsenic pentoxide. Mode of penetration was shown to be via the cuticle and not the stomata while, to reduce evaporation from spray droplets, which slows down the rate of entry, she recommended spraying in a "fairly moist" atmosphere.

Dr. Charles Greenham and his co-workers subsequently extended these physiological studies to skeleton weed. The early work by Cashmore and Carn (1938, 1940) suggested that eradication of skeleton weed could be achieved only by soil sterilization. Greenham, Currie and Allan (1940), however, showed that acid arsenicals as used by Crafts (1933b, 1937) translocated readily in skeleton weed. They offered the prospect of a deep root kill without sterilization of the soil. Further, in contrast to the findings of Crafts (1933a) and Brenchley (1927), they showed that arsenic acid (arsenic pentoxide) was more toxic than arsenious acid (arsenic trioxide) thus confirming the earlier work of White-Haney (1916). They also presented the first evidence of the association of metabolic activity and the translocation of arsenicals without the assistance of a water deficit.

This series of experiments also provided the first literature record (Greenham, Currie and Allan, 1940; Greenham and Wilkinson, 1942) of the use, as herbicides, of the less toxic organic arsenicals, some of which are currently used as herbicides in turf management and other situations (Singh and Campbell, 1965; Butler and Slife, 1965; Harrison-Smith, 1965; and others). The experiments also showed that "arsenic trioxide exhibited a remote toxicity that was almost significantly greater than that of dimethylarsinic acid or phenyl arsonic acid, at equivalent concentrations of arsenic".

As might be anticipated determination of depth of root kill became a critical factor in these translocation experiments. At first coagulation of the latex was the main criterion used. However, because of disadvantages associated with timing, and "since it was more difficult to locate the lowest point of dead tissue sprayed with organic than in those sprayed with inorganic arsenicals" (Greenham, Currie and Allan, 1940), the latex test was replaced by a test in which the electrical resistance between two points of a probe was measured (Greenham, 1946; Greenham and Cole, 1950). This test, based on the difference in resistance to electrical current between dead and living tissue, proved most satisfactory. It has since been used (Greenham, personal communication) to diagnose the presence of viruses in potatoes and even to differentiate between morphological strains of skeleton weed.

Chlorates did not come into general use until the French employed sodium chlorate to control weeds in spring cereals (Loyer, 1923). Despite intensive testing (Latshaw and Zahnley, 1927; Aslander, 1928; Hulbert, Remsberg and Spence, 1937; Hicks, 1930; Loomis, Bissey and Smith, 1931; Anon., 1931, 1932; Calvert, 1932; Cashmore and Carn, 1938, 1940; Cashmore and Campbell, 1946) the chlorates experienced only a brief popularity in this country because of "the dangers of ignition associated with their use" (Magee, 1951) and the development of more effective materials. They are, nevertheless, still recommended and used in a number of non-crop situations (Donaldson, 1959, 1960; Anon., 1967).

Other herbicides like carbon bisulphide, mineral oils, sulphuric acid, cyanamid, ammonium thiocyanate and borax which have had wide use in some situations overseas at various times (Wilcox, 1909; Aslander, 1927; Raynor, 1937; Spence, 1937; Helgeson and Gebracht, 1940; and others), though tested against several perennial weeds in Australia had little field use, largely because of the costs involved (Morgan, 1931; Pemberton and Prunster, 1940; Donaldson, 1959, 1960).

The Beginnings of Selective Weed Control

Selective chemical weed control began with the discovery (Bonnet, 1896; Bolley, 1908; Schultz, 1909) that copper sulphate killed weeds like charlock (*Sinapis arvensis* L.) without injuring the wheat crop. Sulphuric acid, iron sulphate and nitric acid were also used (Hitier, 1897; Rabate, 1911; Schultz, 1909). Copper sulphate and iron sulphate were not particularly good but sulphuric acid has been used extensively as a selective herbicide in France and the British Isles (Fryer and Evans, 1968). However, although mentioned occasionally in extension articles (e.g., Anon., 1900b; Maiden, 1916; Blakely, 1923), selective chemical control was not attempted in this country until 1937-39. By this time wild turnip was firmly established in the Western Australian wheat areas and seriously reduced yields. Control was attempted with copper sulphate and sulphuric acid sprays in a series of co-operative experiments (State Department and the C.S.I.R.O.). But, although the weed population was reduced, damage to the crop prevented any yield increase (Thomas, Nunn and Knapp, 1940).

Expansion of selective control investigations was prevented by World War II until kerosene and the French patented dinitro-ortho-cresylate herbicides were introduced by United States Army-sponsored farm advisers (Magee, 1951). Both proved eminently successful in vegetables (Hardy, 1944; Anon., 1945a) and the dinitros, under the name "Dinoc (R)", were tested and used on a variety of other crops (Anon., 1945b; Meadly, 1945; Raw, 1945; Scott, 1945; Clydesdale, 1950).

In the immediate post-war years the State Departments of Agriculture and the C.S.I.R.O., joined the manufacturing firms in an intense study of the phenoxyacetic acid and the carbamate herbicides (Pearson, 1946; Moore, 1947; Orchard, 1947; Tilt, 1947; Sims, 1948; Clydesdale, 1950; Meadly, 1950). The early release of these wartime discoveries (Hamner and Tukey, 1944; Nutman, Thornton and Quastel, 1945; Templeman and Sexton, 1945) curtailed work on the substituted phenols. These investigations did not stop altogether and at least in Queensland resulted in the use of pentachlorphenols as pre- and post-emergence sprays in sugar cane, pineapples, bananas and vegetables (Donaldson, 1959, 1960).

The phenoxyacetic acid herbicides (2,4-D, MCPA, 2,4,5-T) were an immediate success. Annual broadleaf species succumbed quickly, perennial herbs and some woody species were susceptible and even grasses were not wholly resistant (Moore, 1947; Cuthbertson, 1949, 1951; Johnson, 1948; Anon., 1949a, b, 1950b; Green, 1950a; Richardson, 1953; Cock, 1951).

The control of perennial species was not straightforward. Greenham (1947) soon gave warning of the need to include suitable reference compounds as a check to environmental response and, later (1950), implicated time of spray application as a mediating factor in control. With skeleton weed, in particular, application of the sprays to weeds growing on the fallow, as was successfully employed with the acid arsenicals and chlorates, was disappointing: weed control in the crop was poor and yield low. Not until post-emergence applications were made during crop growth (Tindale, 1954) was any success achieved. Obviously the competition supplied by the crop was an essential part of the control mechanism. Similar problems were encountered with other perennials. Reduction in populations were only obtained after repeated applications of 2,4-D (Moore, 1953, 1954; Tindale, 1954).

The discovery of the phytocidal activity of the aliphatic acid, TCA (Anon., 1950c), together with the previously known carbamates, IPC and CIPC, complemented the phenoxyacetic acids. Pre-emergence application of both groups providing satisfactory control of several grass species (Moore, 1947, 1950a, b; Anon., 1950b; Green, 1950b).

The successful application of these herbicides in the field stimulated research, leading to the discovery of the phenoxyproprionic acids (Coulter, 1954) and the phenoxy-butyric acids (Wain, 1955) and many others. There is no doubt, however, that herbicides owe their present position in Australia to the work of State Departments of Agriculture and of private firms like Timbrol Ltd. (now Union Carbide (Aust.) Ltd.), I.C.I.A.N.Z. and all the others now established. Timbrol, for example, were active in developing 2,4,5-T, even the British "Unit of Experimental Agriculture" at Oxford getting their early supplies of that chemical from them (Greenham, personal communication).

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CHEMICAL WEED CONTROL AFTER 1950 — GOVERNMENT

A. D. Mears*

The discovery of the synthetic plant hormones had three important effects: better logistics in selective weed control; impetus to the later development of other herbicides; and gradual elimination of chemicals which were difficult to handle and of high mammalian toxicity. Commercial interests have played the major role in the revolution in weed control since 1950. Non-commercial research has basically followed that of commercial interests.

Environmental problems arising from the use of herbicides are not great and those which exist are fairly well identified. It is probably appropriate for non-commercial research to ensure that its resources are available to prevent the creation of major problems.

Development of Selective Weed Control

Selective weed control before 1950 was practised but required high rates of herbicide, or the use of chemicals which were difficult to handle or had high mammalian toxicity. Kerosene of fairly high aromatic content was and, is still used, at 40-80 gallons per acre to control weeds in carrots but sulphuric acid is rarely, if ever used now, to control weeds in wheat.

Non-commercial research groups were interested in chemical weed control before 1950 but this interest became more apparent with the advent of 2,4-D and 2,4,5-T. Initially, it seems that they undertook limited research themselves, but preferred to develop close liaisons with chemical companies undertaking development work.

It was perhaps fortuitous that the first two of the new herbicides were suitable for use in large area situations in which well identified weed problems existed. 2,4-D was recommended for control of skeleton weed in wheat and 2,4,5-T for blackberry and other woody weeds (Green, 1953). Expansion of the use of herbicides to other crops and other situations developed gradually with non-commercial research running parallel to or behind commercial development. At times non-commercial groups have become interested in problems which occurred in the use of herbicides and not forecast by commercial development. Rylands and Mears (1967), for instance, found that barban used at selective rates damaged some commercial wheat varieties.

Economics of Weed Control

In a recent review, Moore (1971) discussed the wide range of situations in which herbicides are used. He defined the major problems requiring resolution to be: effective herbicidal control of nut grass; post-emergence herbicides for vegetable crops; safe and effective overall sprays for some woody weed species; and pre-emergence chemicals for use in *Pinus radiata* plantations.

In his review, Moore did not discuss, or identify, the economics of weed control in crops. In fact this is an area in which far too little work has been undertaken. This has been highlighted by Mears (1971) in respect to tobacco.

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Some authors have reported on the economics of weed control which are useful for cost-benefit studies. Reeves and Tuohey (1971) report that di-allate or tri-allate at 0·6 kg/ha gave the most economic control of Wimmera rye grass in wheat. Rylands (1967) reported an almost 100% increase in carrot yields by the use of herbicides. McDiarmid (1967) discussed the cost of herbicides and calculated the returns to growers from the use of 2,4-D to control skeleton weed, and other herbicides to control amsinckia in wheat. His overall conclusion was that chemical control was profitable.

Fisher and Schulze (1967) have reported on costs of chemical weed control in cotton and Cuthbertson (1967) has estimated likely community gains from herbicide use in wheat. These estimates are of little use in cost benefit analyses for a farm situation.

There can be little doubt that more attention must be given to this area of research and it is one in which non-commercial groups can play a major part.

Development of Chemical Weed Control

The progress of chemical weed control since 1950 has been from the control of broad-leaved weeds in wheat and pastures, to grass weeds in wheat and pastures and to all weeds in horticultural crops as well as the use of herbicides for chemical ploughing. This pattern has been partly possible because of an increasing sophistication of herbicides and methods of use. A second factor has been that growers of high return investment per hectare horticultural crops have become convinced of herbicide safety. High costs of traditional methods of weed control also played an important part in this development. Mears and Green (1968) made reference to problems of the use of herbicides in horticulture.

Individual Crops

Wheat

Weed problems in wheat received attention, particularly control of skeleton weed, shortly after 2,4-D and similar herbicides became available. Tindale (1954, 1955) reported on the efficacy and safety of 2,4-D and MCPA in this regard. As new chemicals became available and other weeds became important, research continued. Amsinckia control has been reported by Lumb (1968) and capeweed control by Reeves and Lumb (1972). Molnar, Donaldson and Parsons (1967) discussed the use of picloram to control skeleton weed. In recent years interest has developed in the control of wild oats in wheat and progress in this field has been reported by McNamara (1972).

Pastures

Green (1951) reported on the use of 2,4-D to control St. John's wort in pastures. Hall (1961c) reviewed the use of TCA, 2,2-DPA, MCPA, 2,4-D and 2,4-DB and Campbell (1961a) reported on the control of barley grass in burr medic pastures. Cuthbertson (1961) found diquat at low rates useful to control capeweed in improved pastures. Squires (1963) controlled barley grass in irrigated clover pastures with 2,2-DPA, diquat and paraquat and found 2,2-DPA at 2·2 kg/ha the least acceptable. Pearce (1964) found that spiny emex could be controlled with dicamba if legume preservation was not important. McGowan (1970) studied effects of 2.4-D, 2,2-DPA, paraquat and diquat on weed competition and pasture yield. He concluded all were useful in improved pastures but time of spraying affected yield and proportion of pasture species. An important effect of picloram on pasture establishment following wheat spraying has been reported by Welsh (1966) who found the chemical could prevent legume growth for at least seven months in a sandy soil.

Vegetables

Work in N.S.W. was under way by the late 1950's and Hall (1958) reported on the use of several chemicals including CDAA, CDEC over a range of vegetables. Herbicides useful in controlling weeds in onions were reported as being CDAA, CDEC by Hall (1961a), who also reported on the usefulness of these two chemicals for vegetables and maize (Hall, 1961b). Hall (1962) reported CDEC was also useful in lettuce and beetroot. Morgans (1968) briefly reviewed the range of herbicides useful in vegetable crops.

Maize and Sorghum

The use of 2,4-D to control weeds in maize led to damage if applied when maize was more than 30 cm. high (Kavanagh, 1958). Walls (1961) outlined recommendations for the use of 2,4-D, atrazine, simazine and CDAA in maize. Both atrazine and 2,4-D are now widely used in maize and sorghum.

Horticulture

An early report by Gregory and Hall (1961) of work on vines with several chemicals including 2,2-DPA and amitrole discussed a balance between herbicides and cultural operations. Baxter and Newman (1971) reported that contact herbicides or simazine are useful in narrow strips to control grass and maintain nitrogen supply to young apples. Campbell and Mears (unpublished data) have evidence on the tolerance of mature apples to diuron, atrazine, amitrole and 2,2-DPA. At normally applied rates no ill effects occurred from several years' application. However, in one dry year even 11·2 kg/ha of 2,2-DPA caused damage and higher rates of diuron and atrazine had severe effects after several years.

Other Crops

Rice

The main weed in rice is *Echinochloa* spp. and until reports on the use of propanil by Boerema and McDonald (1962) and Boerema (1963), cultural methods of control were used. In the Ord area, van Rijn (1964) also found propanil useful. Fischer, Swain and Boerema (1966) demonstrated that molinate was also useful to control barnyard grass in rice over a greater range of conditions but was more reliable in cooler years.

Cotton

This crop was not grown in N.S.W. in any significant amount until the early 1960's, and has been of considerable interest to both commercial and non-commercial workers.

Fischer (1966) demonstrated that trifluralin, used in the crop to control grasses, must be correctly placed in the soil. Van Rijn (1964, 1967) tested diuron and other chemicals under Ord River conditions. He found diuron to be a successful pre-emergence herbicide.

Situational Weed Control

Control of weeds in irrigation channels, along lines of communication and in storage areas has been practised for many years. Most work since 1950 has been undertaken by commercial interests. However, van Rijn (1963) reported on the use of monuron and simazine in irrigation ditches. Levi

(1959) used amitrole for the control of water couch in channels. Toth (1971) reviewed the use of chemicals for total vegetation control and indicated that a large number of chemicals have a place.

Seedbed Preparation

While not initially aiming to provide a chemical seedbed by killing the dominant existing species, Campbell (1961b) laid a basis for later work. His demonstration that serrated tussock could be killed by the application of 28·0 kg/ha of 2,2-DPA, applied either from ground or air, allowed later work in pasture establishment. Campbell and Annard (1962) also reported that burning assisted in control of serrated tussock by allowing a reduced rate of herbicide. Cocks (1965) reported that diquat assisted establishment of pastures by controlling capeweed. Colman (1966) used 2,2-DPA at 7 kg/ha to incorporate an annual component into a perennial grass pasture. Other authors have also reported on this technique for establishment of crops or pasture species into an existing pasture. Murtagh (1972) demonstrated that 11 kg/ha of 2,2-DPA reduced the grass competition to *Dolichos lablab* and that the nitrogen available as a result of reduced paspalum growth compensated for low nitrogen fixation by poor strains of Rhizobia.

Control of Woody Weeds

A considerable amount of research has been undertaken in regard to the control of woody weeds. This interest has developed from three points of view; to clear and maintain lines of communication, in land development and to remove pest harbours.

Only three chemicals, 2,4,5-T, ammate and picloram have engendered much interest and 2,4,5-T is fairly widely reported in the literature: Bissett and Shaw (1954); Robertson (1961); Parsons and Amor (1968). Mears (1966) reported on the use of picloram for timber killing.

General

In recent years some research has been undertaken on aspects of herbicide use other than those directly related to a weed or crop reaction. Greenham (1962) investigated the translocation of herbicides in skeleton weed. Bowmer (1971) discusses the adsorption of atrazine on some soils and the effect this has on grass control. Pillay and Tchan (1971) found that the effectiveness of diuron is reduced by increasing amounts of organic carbon in the soil.

Conclusion

Research activities of non-commercial Australian workers have generally been concerned with similar aspects to those of commercial workers. In the main, they were commenced after those of commercial workers and results did not appear until a chemical was being used. This is unavoidable as companies are required for their own purpose, and by law, to thoroughly test a chemical before sale.

Over the period under review it can be seen that as the number and sophistication of herbicides increased, so did the broadness of their use. In general herbicides useful in controlling weeds in annual crops developed first and gradually were moved into perennial crops. The use of herbicides in high value per hectare crops, either in terms of returns or of capital investment, was slower to develop.

The later interest of non-commerciál groups in other aspects of herbicide usage is welcome and must be continued. There is urgent need to evolve weed control systems using herbicides to do what is required without leaving any legacy of toxic residues. As well, it is important to establish the mode of action of herbicides both in soil and plant more clearly and to give greater attention to methods of application of herbicides. An area of great concern is that of the "on farm" economics of herbicide use.

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CHEMICALS AFTER 1950 — INDUSTRY

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The discovery that the organic chemicals 2,4-D and 2,4,5-T had phytotoxic properties was the first major breakthrough in the field of weed control. Their introduction to Australia in the late 1940's led to the establishment of a new industry group, the manufacturers and distributors of agricultural chemicals.

It is fortunate that 2,4-D and 2,4,5-T, the first organic herbicides available for development in Australia, were such spectacular products. Coupled with this was the fact that 2,4-D was suitable for introduction to wheat and low-return agricultural industry which at that time was seriously threatened by skeleton weed and cruciferous weeds.

The new industry was motivated because it saw a business opportunity which would result from the establishment of a research, development and commercial team, and thus this industry grew. This may not have occurred if the first organic herbicides had been only suitable to an intensive high-return agricultural industry.

Industry has always played a very important role in the weed control field. In an address at the 6th National Convention of the Agricultural and Veterinary Chemicals Association of Australia Mr. L. Campbell-Smith (1968) discussed the type of work industry has done and will continue to do in Australia:

> "During my occasional wanderings in other countries, I have been impressed by the benefit which chemical and rural industry derives from our research being conducted in a thinly populated continent such as Australia. Here, Government departments and universities cannot cope with the rural research requirements of industry, as is largely the case in the United States. Our companies cannot afford too many specialists and our research and development staff must, of necessity, appreciate our consumers' problems. Like the farmer himself, research staff need to be scientists, long-distance travellers and labourers. They must know the practical problems of the man on the land. A large proportion of the research staff of rural chemical industry were attracted from Government departments to environments where they can give more free rein to their creative talents and energies. Consequently, I claim that the 200-odd research and development staff employed by industry in Australia, can on a pro-rata basis, probably contribute more useful applied information than any other research group in the world."

Since 1950 there have been many dramatic changes in the field of weed research in Australia. There are now new chemicals available for almost every market situation.

In some countries the major role of industry was in providing herbicides to government workers who then developed sophisticated weed control

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methods. However, as was pointed out by Mr. Campbell-Smith, much of the development responsibility in Australia fell to industry. Therefore we have seen that the agricultural chemical industry not only provided the herbicides but also, because of their own work and that in co-operation with Government departments, developed chemicals, markets and new techniques.

If industry had not accepted the challenge and established their own research and development organization, Australia would not now lead the world in weed control (e.g., industrial weed control and early season weed control in cereals). Their work and contribution to weed control has led to the acceptance of the agricultural chemical industry as an equal partner with the Government groups in the fields of weed research, development and education in Australia.

However, this was not the case in the early 1950's as is evidenced by the number of delegates attending the weed control conference held at Roseworthy Agricultural College in 1954. At that time, out of 44 delegates, only five came from industry, compared with 60 out of 143 delegates who attended the 1970 Australian Weeds Conference at Hobart. This was the first instance where weed control had received any recognition as a science and of the part played by an industry group in this development.

Industry and Government have had somewhat different approaches to their fields of investigation in weed control. The interests of industry are created largely by markets, i.e., the size and capacity to pay (for obvious reasons), whilst the interests of the Government people has led to investigations being carried out in fields of weed control which are of interest to smaller groups. This statement could raise criticism because of the activities of the Government bodies in many large development projects, e.g., brigalow control in Queensland, but in the main the statement is correct. This is not meant to be a criticism of the Government's activities but rather indicates how a symbiotic relationship developed between the two groups right from the outset and has continued to work over the years.

However, the object of this paper is not to grind an axe on industry's behalf but rather to show from an overall point of view the way industry has contributed to the history of weed control in Australia.

On looking through the literature and other sources of information it is obvious that over the years there has been close co-operation between industry and both State and Commonwealth Departments. There are too many examples of this to cite particular cases but it is evident this occurred from the outset and will continue in the future.

However, this work was of importance in the early 1950's and in October 1953 the then Timbrol Company produced a Technical Information Sheet titled "Chemical Weed Control with 2,4-D and 2,4,5-T" which provided a summary of the information on the results and practical suggested usage of these chemicals in Australia. In the acknowledgement section it is stated that the co-operative field work and interchange of weeds research results with the various Commonwealth and State departments had enabled Timbrol to produce this bulletin indicating that close co-operation had existed. Industry undertook to compile that information and disseminate it by way of such technical bulletins, etc., a practice which has continued.

It is interesting to compare the recommendations given in that Technical Information Bulletin in 1953 with a recommendation chart prepared in 1972 and note the many recommendations which still remain valid. This surely indicates that the phenoxy herbicides heralded the birth of sophisticated weed control.

The hormones 2,4-D and 2,4,5-T certainly dominated the selective weed control scene for the period 1950 to 1954/5. In 1954 reference is made in papers by Levi and Robinson to "CMU", developed by Dupont as a soil sterilizer, a compound which could be applied at much lower rates than chlorates and borates which were then available.

The development of 2,2-DPA as a systemic grass killer for control of industrial vegetation was reported in 1954. The discovery of 2,2-DPA was a similar milestone from an historical point of view to that of 2,4-D and 2,4,5-T. Applied as a post emergent spray, 2,2-DPA provided a method of controlling grassy weeds and of young annual grasses at relatively low rates.

"CMU" (monuron), closely followed by diuron, was the first of the pre-emergent herbicides to be developed. It was followed in 1957 by simazine and atrazine from the Geigy laboratories. Soon the substituted ureas and triazine chemical groups were established in the fields of weed control in Australia. The two chemical groups introduced the concept of pre-emergent weed control for general use (although 2,4-D had been used pre-emergent for weed control in sugar cane in Queensland since 1952). The mode of action of these new pre-emergent chemicals made it essential for all weed workers to study the influence of soil type, soil moisture, etc., as well as performance as a herbicide.

In 1958 a discovery of Amchem Products, Inc. U.S.A., amitrole, was introduced to the Australian market. Combined industry and Government work established amitrole in the non-crop weed control field, with particular reference to control of irrigation weeds.

In 1957/58 a derivative of the phenoxy group (2,4-DB) was introduced to the Australian market by May and Baker. This product opened up the field of weed control in lucerne and legume crops.

Thus during the period 1955-1960 Australian weed research workers had available to them herbicides with a wide range of activity. These were being exploited as was evident by the range of papers delivered at the 2nd Australian Weed Control Conference in Canberra in 1960. At this conference the major contribution of industry in new fields of research was evident. The only paper dealing with the use of pre-emergent herbicides in maize was delivered by industry representatives. This technique is now established practice in this crop.

The introduction of triazines to the maize/sorghum market was not as spectacular as 2,4-D to the cereal industry. Prior to this practice becoming accepted, techniques such as band spraying had to be adopted to bring the economics of the triazine products in line with the production output of the crop. The need for weed control was not as great in these crops as it was in cereal crops in the 1950's and it was not until extensive irrigation areas were opened up in N.S.W. that atrazine was accepted as a management tool in the growth of maize and sorghum crops.

If the triazines had been introduced before the phenoxy herbicides then the history of weed control may have been changed in Australia.

Industry workers pioneered the subject of control of unwanted vegetation with mixtures of knockdown and residual herbicides. Its continued use has enabled Australia to lead the world in total vegetation control.

Until the introduction of diquat in 1960 the organic herbicides available were mostly of the translocated type. This product (and paraquat which was introduced later) had the unique properties of rapid contact and desiccating action. It was active at low rates when compared with desiccants such as sodium chlorate.

As a result of the introduction of diquat/paraquat herbicides work commenced in the horticultural fields for the first time. These products have not continued as the only compounds available but have led to the introduction and use of combinations of knockdown and residual herbicides including amitrole, triazines, ureas, 2,2-DPA and others.

During the period 1960/1965 the agricultural chemical industry was largely responsible for the development and introduction of early season weed control in cereals with the preliminary development of prometryne and linuron, for control of phenoxy-resistant weeds. Final development work was carried out in co-operation with the various Departments of Agriculture.

As a result of this work compounds such as bromoxynil (Amchem), methabenzthiazuron (Bayer) were introduced in the Australian market with their subsequent development into other fields. Had not industry opened up the field of early season weed control in cereal crops these latter two compounds may not have been developed.

During this period also as a result of research in the Monsanto Laboratories, di-allate and tri-allate were developed for the control of wild oats and rye grass in wheat and barley. This was another example of a co-operative project between industry and Government departments resulting in an answer to a major problem in an extensive agricultural market.

The use of products other than 2,4-D necessitated a change in attitude and approach to cereal spraying and as a result required an extensive educational programme which largely became the responsibility of the companies selling the various products.

During this period trifluralin—the first of the aniline groups of compounds—was introduced to Australia for development by Eli-Lilly. This allowed effective grass control in many crops to be obtained where it was not previously possible. Trifluralin was introduced to Australia at about the same time as cotton was developing as an industry. Cotton, being a high-cost agricultural product, allowed the introduction and development of a sophisticated group of products like trifluralin. If these products had been introduced prior to the establishment of the cotton-growing industry it is doubtful if they would have generated the interest that they have to-day.

Industry does not always back winners as evidenced by the amount of money some companies spent in the sugar-cane industry. Some excellent products have been developed specifically for this crop for weed control but because of poor farmer acceptance they have disappeared from the Australian weed control scene. Thus we see that industry has to have a major market available to allow it to exploit the potential of a product. This probably explains why, in general, industry activity in weed control in vegetables has not been exploited to the same extent. The introduction of products such as chlorthal, CDEC and CDAA are largely due to Government work, again an example of the symbiotic relationship which has been established in Australian agriculture.

Since 1950 and the introduction of 2,4,5-T and 2,4-D, no major breakthroughs occurred in the field of scrub and brush control until approximately 1963/64 when picloram was developed by Dow Chemicals.

The techniques developed for the uses of 2,4,5-T and mixtures of 2,4,5-T with 2,4-D (i.e., overall spray, basal spray, frilling, etc.) were largely a result of work carried out by industry groups, but the adoption of this work and its application for the control of scrub and brush species on non-arable land was carried out largely by Government workers and here we refer to the use of 2,4,5-T on eucalypts (regrowth control) and the control of brigalow scrub in Queensland.

A similar approach has followed with the development of picloram by Dow Chemicals who developed the concept of stem injection for scrub control using this chemical. This has been adopted and modified by other workers particularly Government workers.

In the field of non-crop weed control, it is considered that Australia leads the world because of the use of mixtures of herbicides. This field has been dominated by amitrole, 2,2-DPA and the triazines. However, these products are not effective against summer growing perennial grasses and the development of bromacil by Dupont followed lately by karbutilate from F.M.C. has allowed further development in market and maintained Australia's leadership in this field. The progress in this sector has been mainly due to industry's efforts because of the realization of the potential and needs of this market situation.

Industry has also played a major role in the important development of application equipment in the weed control field and as a result of their work we have seen the introduction of low volume equipment, i.e., boom sprayers, misting machines and the development of the aerial spray industry. This development was necessary by industry to ensure acceptance and application of the herbicides that were available.

Industry has also been responsible for formulation development including the introduction of surfactants. The formulation chemist has played an important role in the history of weed control in Australia.

Industry thus has played a major role in the two decades that weed control has been practised in this country. The role of industry in Australia has been different to the role played in other countries and if industry had not accepted the challenge in the early period then this responsibility would have remained with the Government and universities which would have increased the overall burden on the Australian tax payer. Industry has played a big role in the past and will continue to play a big role in the future, although it is evident that if it is going to survive it will have to introduce new concepts of weed control.

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