

A New Biological Control Programme Against Thistles of the Genus *Onopordum* in Australia

D.T. Briese

CSIRO Biological Control Unit, 335 Avenue Abbé Paul Parguel, 34090 Montpellier France

Abstract

Four species of the thistle genus *Onopordum*, originating from the Mediterranean region, have become established as weeds in Australia. They are primarily competitors in pastures. *O. acanthium* and *O. illyricum*, in particular, cause substantial economic losses and are difficult to control with herbicides. *O. acaulon*, though more widespread, is only occasionally important as a weed, while *O. tauricum* is known only from two infestations in Victoria. Following submissions from CSIRO, the four species were declared targets for biological control in 1987, and a research programme aimed particularly at *O. acanthium* and *O. illyricum* commenced. The long-term purpose of this programme is to integrate biological control into the overall management of these thistles. To this end, investigations aimed at finding potential control agents form part of a larger series of studies designed to better understand the ecology of the host weeds both in Australia and Europe. The objectives of this research are to find agents which will reduce the number of achenes entering the soil seed pool, followed by those which can reduce the viability of existing plants. Populations of several reportedly quite specific capitula feeders (*Tephritis postica*, *Cerajocera lappae* and *Larinus* spp.) and of a stem-borer (*Lixus cardui*) have been located and long-term studies on their role in the population dynamics of *Onopordum* spp. commenced. Thus, with further surveys planned, prospects for finding suitable control agents seem quite good.

Introduction

The genus *Onopordum* (Asteraceae: Cynareae) comprises a group of carduine thistles that originated in Mediterranean Europe and central western Asia. By conservative estimates there are 20 to 25 species within the genus, although more than 100 have been described (Dress 1966). Of these, seven are listed by Holm *et al.* (1979) in their geographic atlas of world weeds and an eighth species is known as a weed in both western U.S.A. and Australia (Table 1). Four of these species, *O. acanthium* L., *O. acaulon* L., *O. illyricum* L. and *O. tauricum* Willd., have become weed problems following their introduction into new habitats. Australia is the only country where all four species have become established and where species of *Onopordum* (*O. acanthium*, *O. acaulon* and *O. illyricum*) are major weed problems (Table 1), the last two species apparently not occurring elsewhere outside their native range. Apart from an unsuccessful attempt to establish the *Carduus nutans* L. host race of *Rhinocyllus conicus* L. (Coleoptera: Curculionidae) on *Onopordum* sp. in the U.S.A. (Batra 1980), this genus has not previously been a target of a biological control project.

CSIRO has committed itself to a series of projects aimed at the eventual incorporation of biological control into the management of weedy thistle species in Australia (Wapshere 1984). This commenced in 1985 on nodding thistle (*C. nutans* L.) (Cynareae), and the slender thistles *C. pycnocephalus* L. and *C. tenuiflorus* L., aspects of which are discussed by Sheppard *et al.* (1989). The large economic losses caused by *Onopordum* spp. in Australia (mainly *O. acanthium* and *O. illyricum*) and the present inadequacy of chemical control (Keys *et al.* 1985) fully justify this biological control project. All four species of *Onopordum* have recently been approved as target organisms in Australia.

This paper provides some background information on the problem caused by *Onopordum* spp. in Australia, and describes the rationale of the biological control programme that has just commenced.

Table 1. Occurrence of *Onopordum* spp. considered to be weeds (adapted and extended from Holm *et al.* 1979).

Species	Importance as a weed species		
	Principal	Common	Present
<i>O. acanthium</i> L.	Australia ¹	Argentina ¹ England USSR Spain	Canada ¹ Chile ¹ New Zealand ¹ Turkey U.S.A. ¹
<i>O. acaulon</i> L.	Australia ¹		
<i>O. anisacanthum</i> Boiss.		Lebanon	
<i>O. heteracanthium</i> C.A. Mey		Iran Lebanon	
<i>O. illyricum</i> L.	Australia ¹		
<i>O. leptolepis</i> DC.		Iran	
<i>O. macracanthum</i> Schousb.		Morocco	
<i>O. tauricum</i> Willd.			Australia ¹ U.S.A. ¹

¹ Countries of recent introduction.

Onopordum Species in Australia

The species presenting the most important weed problems for Australia are scotch thistle, *O. acanthium*, and illyrian thistle, *O. illyricum*, vigorous biennials growing to over 2 m, which together infest almost 1,100,000 ha of land in the southeastern part of the country (Briese *et al.*, *in press*) (Fig. 1a). Generally populations of the two species are allopatric, though mixed infestations do occur. However, for practical control purposes the two species have been considered as one. They are primarily important competitors in soils of high fertility and in improved pastures. Although the species have been present in Australia for well over 100 years, probably as escaped garden ornamentals, pasture improvement programmes and increase soil fertility have led to a substantial increase in the importance of these nitrophilous weeds over the past 20-30 years.

The large rosette leaves can smother desirable vegetation and this, coupled with a tendency to form dense stands, can cause severe reductions in stocking capacity (Parsons 1973, Gammie 1972, Wheatley & Collett 1981). Secondary problems arise through contamination of wool from sheep reared on thistle-infested pastures, reduced quality of conserved fodder and reductions in property values (Wheatley & Collett 1981). Both species are declared noxious weeds in various regions where they occur, and chemical herbicides are the most commonly used form of control. However, the two *Onopordum* species are considered the most difficult thistles to kill with herbicides (Keys *et al.* 1985). Except at a very early growth stage, they are relatively resistant to cheap and mild hormonal herbicides, such as 2,4-D (2,4-dichlorophenoxy acetic acid) and MCPA ([4-chloro-*o*-tolyl oxy] acetic acid). This necessitates the use of expensive and potent herbicides such as Dicamba (3,6-dichloro-*o*-anisic acid) to obtain control. The use of these, however, may also lead to the destruction of the legume component of pastures (Wheatley & Collett 1981), and to marked losses in

pasture production. In addition, germination can occur throughout the year resulting in mixed-age stands which are even more difficult to control.

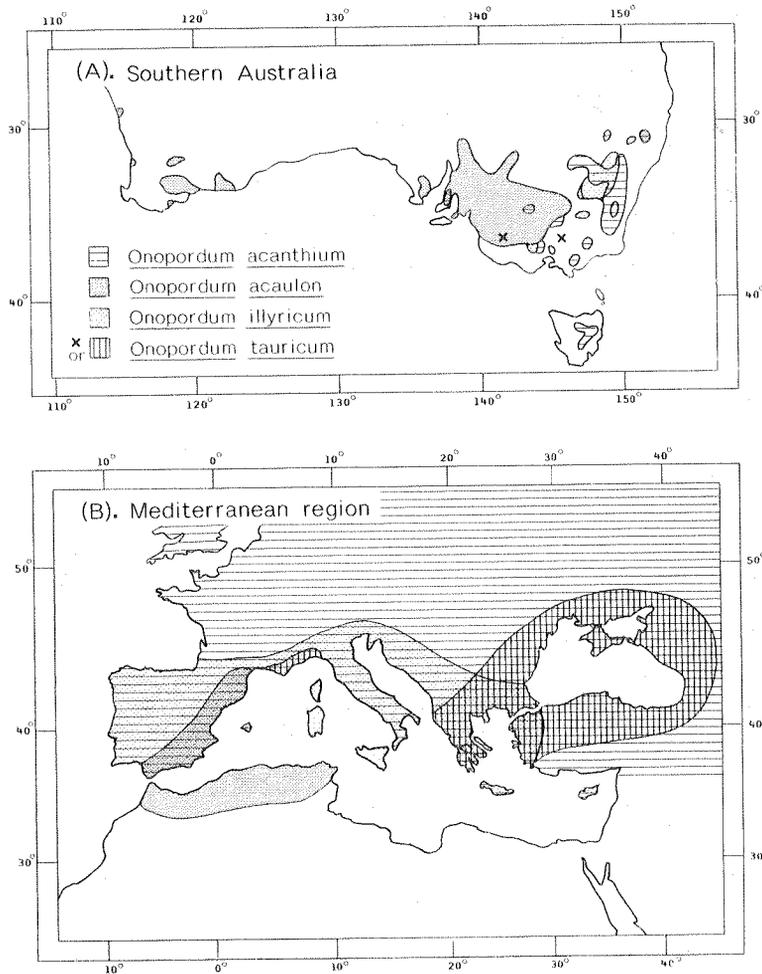


Figure 1. Distribution of four *Onopordum* species in: A) Southern Australia; and B) their Mediterranean area of origin.

Effective long-term control can at present only be achieved by proper pasture management, including the establishment and maintenance of competitive perennial pastures. Some perennial grasses, in particular *Phalaris aquatica* L. (Poaceae), can compete with Scotch thistles in the long-term, while others such as *Lolium perenne* L. (Poaceae) cannot (Michael 1968). However, in many infested areas, traditional practices favour mixed farming and permanent pastures are not acceptable (McGowen, I., pers. comm., 1986). It is hoped that biological control will provide a component of thistle management more suited to such practices.

To date, despite current control efforts, the weed problem posed by *O. acanthium* and *O. illyricum* is becoming more serious. In a recent survey (Briese *et al.*, *in press*), 18 of 35 shires in New South Wales seriously affected by the two weeds reported that infestations had increased in the past 3 yrs, 12 reported no change and only five indicated that a decline had occurred.

The stemless thistle, *O. acaulon*, which escaped as a garden ornamental in 1845 (Kloot 1983), is also primarily a competitor of pastures. It occupies a considerably larger geographic range than the two previous species (Fig. 1), but does not have the same economic importance as a weed. It occurs mainly on low-fertility soils in semi-arid areas and only occasionally reaches densities which seriously affect carrying capacity of the pasture (Kloot, P., pers. comm., 1986). However, it is still spreading and has recently invaded areas of Western Australia where a programme aimed at its eradication is in force. Successful biological control agents could reduce the capacity to spread of stemless thistle and reduce the frequency of population peaks that cause economic loss.

Taurian thistle, *O. tauricum*, is known only from two small infestations in Victoria (Fig. 1A), being first reported in 1913 and most recently in 1985. Fear of its potential as a weed, based on experience of Scotch and illyrian thistles, has led to intensive chemical and mechanical treatments aimed at eradication (Lane, D., pers. comm., 1986).

Structure of the Biological Control Programme

This programme consists of three phases, each having a number of specific research objectives.

Phase 1: Preliminary studies in Australia

1.1: Assessment of the distribution and perceived importance of Onopordum spp. Background information was needed, to decide whether the cost of a biological programme was warranted, and to establish priorities for studies on particular species. From the information obtained (summarised in the previous section) it became obvious that *O. acanthium* and *O. illyricum* should be the primary targets, while *O. acaulon* was sufficiently important to warrant a survey for potential control agents. The data were used to prepare the successful submissions to have these species declared as target organisms for biological control in early 1988. The study will also provide baseline data for assessing the overall impact of any control programme.

1.2: Ecological studies of Onopordum in Australia. The demography of *O. illyricum* and *O. acanthium*, including seed pool dynamics, is being studied by Dr R. Groves (CSIRO Division of Plant Industry) and his colleagues. Their aim is to obtain baseline ecological data and to understand the system that we hope to manipulate by the introduction of control agents - particularly those aimed at reducing the soil seed pool.

1.3: Surveys of existing natural enemies and quantification of their effects. These were undertaken in order to find out the structure of the phytophagous fauna into which new members would be added. The main aims were to identify any gaps in resource utilisation by existing natural enemies, to obtain some idea of the quantitative effects of this guild on the plants, and to detect possible interactions that might occur between existing and introduced species.

Phase 2: Studies in Mediterranean Europe

2.1: General surveys of the insect fauna. *Onopordum* spp. have not become widespread weeds outside Australia, and as a consequence their potential biological control agents have not yet been studied (Wapshere 1984). Zwölfer (1965) made some useful preliminary observations on the insect fauna of *O. acanthium* and *O. illyricum*, concentrating on central western Europe, with several samples from southern France. One important phase of the project, therefore, will be to undertake a detailed survey for potential control agents in the native range of these *Onopordum* species (Fig. 1B). Three regions are of specific interest - southern France, eastern Spain and Greece - because they contain areas that are ecoclimatically similar to infested areas of Australia, and because three of the four species of *Onopordum* concerned occur in each region (Fig. 1B), thereby enabling search efforts to be concentrated.

2.2: *Ecological studies of Onopordum in Europe.* The life-history of *O. acanthium* and *O. illyricum* will be investigated in their native ranges, to determine the role played by natural enemies in driving the population dynamics of these weeds. This study will parallel the work carried out in Australia by R. Groves and his colleagues, particularly as regards seed pool dynamics, in view of the absence of specialised capitula feeders in that country. The importance of separating the effects of biological control agents from other limiting factors has been stressed by Sheppard *et al.* (1989), and the data sought here should provide a more rational basis for selecting potential control agents and for predicting their likely effects. These studies commenced in autumn 1987 with the establishment of three study sites near Montpellier, France, which were selected for differences in habitat type and the phytophagous insect faunas present.

2.3: *Selection of agents and studies of their biology.* Promising potential agents will be screened against the two critical cultivated thistles, artichoke *Cynara scolymus* L. and safflower *Carthamus tinctorius* L. (Asteraceae), as agents attacking either or both species are unlikely to be given permission for release in Australia. It is intended to look more closely at the biology of agents that pass this preliminary host-specificity screen, to develop appropriate rearing techniques and to help assess their potential effectiveness.

Phase 3: Host-specificity testing and introduction in Australia

3.1 *Completion of host-specificity testing.* This will be carried out on agents that are safe for the two thistle crop plants, and will be done in the CSIRO quarantine facility in Canberra. It is hoped that work will have progressed sufficiently to commence testing in 1989.

3.2: *Release and evaluation of control agents.* Little can be said of this objective at this point as it depends on the outcome of activities not yet completed. However, it is planned to closely monitor the establishment of the biological control agents in Australia. Should they be successful, studies will be carried out to see how their effects can be incorporated into an integrated management plan for the control of *Onopordum* thistles. It is also intended to evaluate whether the effort involved in making detailed pre-release studies of the target weed and its fauna, in both the areas of origin and of introduction, has led to a greater efficiency in achieving control objectives.

Prospects for Biological Control

Types of Agents Required

It is particularly enlightening to compare the European insect fauna with that which has colonised *Onopordum* in Australia during its 150 year history there. Briese (1989) recently surveyed the natural enemies of thistles in parts of New South Wales, and identified important gaps in resource utilisation by the insect fauna - notably the virtual absence of attack on the roots or fruits (Table 2). Australia has only two native thistles, and hence insects which attack *Onopordum* spp. are mostly polyphagous foliage feeders (16/20 species), several having been accidentally introduced themselves (8/20 species). By contrast, only 15 of 40 species recorded by Zwölfer (1965) fed on plants outside the tribe Cynareae. Conspicuously absent from the insect fauna of *Onopordum* in Australia were specialist endophages which attack the fruit - only larvae of the two *Heliothis* spp. (Lepidoptera: Noctuidae) occasionally bored into the fruit, as well as feeding on leaf and stem tissue - whereas several species specialised on feeding the thistle heads in Europe (Table 2). These include *Larinus cynarae* F., *L. latus* Herbst and *L. onopordi* F. (Coleoptera: Curculionidae), and *Tephritis postica* Loew and *Cerajocera lappae* Ced. (Diptera: Tephritidae). As the primary aim of the biological control programme is to reduce the seed pool, these will be among the first species to be examined as potential control agents.

The other major gap in the *Onopordum* fauna in Australia is the absence of endophages that attack the roots and stems (Table 2). Although Zwölfer (1965) did not sample the roots of plants, he collected several species of stem-boring insect, including *Lixus cardui* Ol.

(Coleoptera: Curculionidae) which appears to be specific to the genus *Onopordum* (Petney and Zwölfer 1985).

Table 2. Comparison of the insect fauna of *Onopordum* in Europe (Zwölfer 1965) and Australia (Briese, unpubl. data, 1986).

Plant part attacked	Number of species attacking <i>O. acanthium</i> and/or <i>O. illyricum</i>		Australia	
	Europe Ectophage	Endophage ¹	Ectophage	Endophage
Root	not sampled		1	0
Stem	15	4	8	0
Leaf	22	6	14	1
Fruit	3	8	7	0
Total Species ²	22	18	19	1
	40		20	

¹ An endophage is defined as any insect passing its entire immature life feeding within the plant tissue.

² Columns are not additive as some species attacked more than one part of the plant.

To complement the reduction of the seed pool, it would be desirable to find a natural enemy able to kill or weaken young rosettes or even mature plants, thus reducing the existing densities of the weeds. The most likely insect candidates would be those which attack the root system and, as these were not surveyed by Zwölfer (1965), it will be an important aim of the general survey work to find potential agents capable of inflicting this type of damage. Existing plant densities could also be reduced by fungal attack, and although at present not a principal target of the surveys, the possibility of finding a suitable pathogen will not be overlooked. Three fungi, including the rust *Puccinia acanthii* Sydow (Uredinales) are recorded from various *Onopordum* species (Hasan, S., pers. comm., 1987).

Foliage feeders are unlikely to be considered as potential control agents. The foliage-feeding guild on *Onopordum* is already quite large in Australia (Table 2), and chemical-exclusion trials there showed that, even when relatively severe, this type of damage did not seriously reduce plant density or seed production (Leigh *et al.* 1990).

Preliminary Observations in Europe

Work on the European part of the project commenced in July 1987, early enough to locate populations of *O. acanthium*, *O. illyricum* and *O. tauricum* in the region around Montpellier, in the south of France, and to sample the levels of attack on capitula and stems of these 3 species. High levels of attack were found in all samples, particularly those of *O. illyricum* (Fig. 2).

Samples of thistle heads revealed that, as well as polyphagous feeders, such as *Lasioderma* sp. (Coleoptera: Anobiidae), *Cochylis posterana* Z. (Lepidoptera: Tortricidae) and *Pyroderces argyrogrammus* Z. (Lepidoptera: Momphidae), two important groups of relatively specific capitula feeders were represented, by the weevil *L. cynarae* and the seed-fly *T. postica* respectively (Fig. 2). Interestingly, *L. cynarae* showed high levels of attack on *O. illyricum*, but was absent from all except one sample of *O. acanthium*. This may reflect the climatic requirements of the weevil rather than illustrate any host-preference, as *O. illyricum* sites were situated in the warmer coastal plain, while the *O. acanthium* sites were

mainly in cooler inland areas. By contrast, the level of attack by *T. postica* was higher in the samples of *O. acanthium*, and the tephritid was absent from the single sample of *O. tauricum* (Fig. 2). Extensive sampling in the next few seasons should determine if these observations accurately reflect the phytophagous guild in this region.

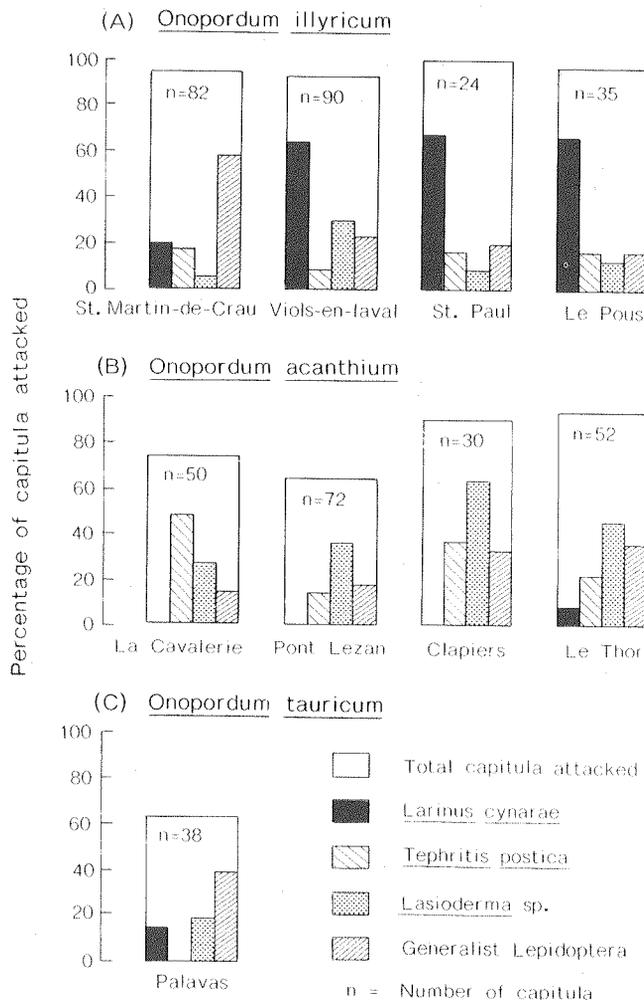


Figure 2. Level of insect attack on capitula of *Onopordum* species at different sites in southern France. Total attack is not necessarily the sum of percentages for individual species due to multiple attack on some capitulae.

L. cynarae was clearly the most spectacular in terms of observed damage, with single larvae being able to destroy virtually all achenes in capitula of 3 cm dia or smaller, and high damage levels occurring in larger capitula suffering multiple attack (Fig. 3). Unfortunately, *L. cynarae* is known as a pest of artichoke (Martelli 1948), while the other two *Larinus* species known to attack *Onopordum*, *L. latus* and *L. onopordi*, have also been recorded from the genus *Cynara* (Hoffmann 1954). However, it is quite possible that host-races of these species exist, as have been found for other members of the genus (Zwölfer *et al.* 1971). Interestingly, no attack was found on variegated thistle *Silybum marianum* L. (Cynareae), a known larval host of *L. cynarae* (Zwölfer *et al.* 1971), growing in the same field as *Larinus*-infested *O. illyricum* at St Martin-de-Crau. The primary hosts of these species appear to be *Onopordum* and it will be a priority to test the specificity of particular populations of these weevils to determine if they warrant further attention.

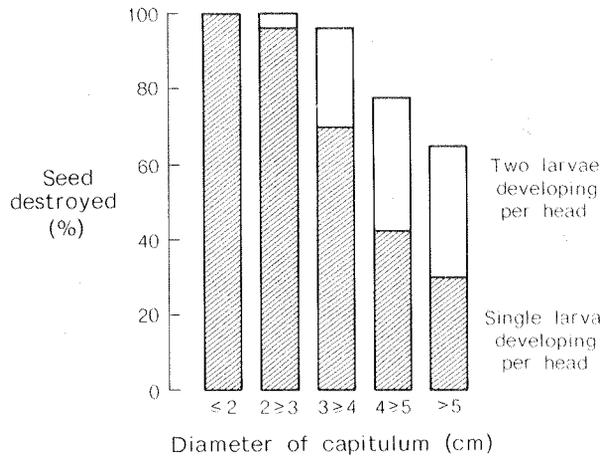


Figure 3. Effect of *Larinus cynarae* F. on seed production in individual capitulae of *Onopordum illyricum* L.

T. postica caused less damage, except at one site (La Cavalerie) where multiple attack on late flowers and buds destroyed ca. 40% and 100% of achenes respectively. Early flowers had been only lightly attacked, so seasonality of activity may be important for this species.

Finally, the stem-boring weevil *L. cardui*, was present at these sites, infesting up to 75% of stems at St Martin-de-Crau. This provides the opportunity to determine to what extent this form of attack on the target weeds can decrease the viability of plants and/or reduce overall seed production.

Conclusions

Previous studies and initial work in Europe suggest that the prospects of finding suitable biological control agents for *Onopordum* spp. in Australia are quite good. Since members of this genus reproduce by a once-only production of seed, and there are no natural enemies in Australia that exploit this resource, the primary aim will be to try and find sufficiently host-specific agents able to reduce the soil seed pool. Zwölfer (1985) considered that the most important trophic groups utilising thistle heads comprised those species forming structural or physiological galls combined with early aggregated attack, and those more solitary species that feed on achene and receptacle tissue. Representatives of both groups (tephritid seed-flies and *Larinus* spp., respectively) are major components of the *Onopordum* fauna in Europe.

The detailed studies of interactions between *Onopordum* spp. and their phytophagous faunas just commenced in the Montpellier region should clarify the role played by those groups of insects having different patterns of resource utilisation and determine whether they act in a competitive or complementary manner. For example, one should be able to determine whether a combination of compatible members of the two groups attacking the capitula would lead to more efficient biological control, as suggested by Zwölfer (1985). It should also indicate the likely effect that a large reduction in input to the seed pool might have on *Onopordum* population dynamics in Australia.

It is considered equally important to find answers to these more fundamental questions as to find a successful agent per se, in order to provide a broader ecological base underpinning the

practice of biological control, as well as satisfying the mission-oriented objectives of weed reduction.

Acknowledgments

This project is presently being supported jointly by the Wool Research and Development Fund of the Australian Wool Corporation, and the Australian Meat and Live-stock Research and Development Corporation.

References

- Batra, S.W.T. 1980. First establishment of *Rhinocyllus conicus* (Froelich) in Maryland and Pennsylvania for thistle control (Coleoptera: Curculionidae). *Proc. Ent. Soc. Wash.* 82:511.
- Briese, D.T. 1989. Natural enemies of *Onopordum* thistles in New South Wales. *J. Aust. Ent. Soc.* 28:125-34.
- Briese, D.T., D. Lane, B.H. Hyde-Wyatt, J. Crocker and R.G. Diver. 1989. Distribution of thistles of the genus *Onopordum* in Australia. *Plant Prot. Quart. (in press)*.
- Dress, W.J. 1966. Notes on the cultivated Compositae. *Onopordum*. *Baileya* 14:75-86.
- Gammie, R.L. 1972. Scotch thistles are spreading. *Agric. Gaz. N.S.W.* 83:79-81.
- Hoffmann, A. 1954. *Faune de France*. 59. Coleopteres Curculionides. Lechevalier, Paris, pp. 521-45.
- Holm, L., K.M. Pancho, K.P. Heberger and D.L. Plucknett. 1979. *A Geographic Atlas of World Weeds*. John Wiley, New York. 391 p.
- Keys, M., P. Simpson and J. Dymock. 1985. Pasture weeds of the southern tablelands. *Agdex No. 640*, 13 p.
- Kloot, P.M. 1983. Early records of alien plants naturalized in South Australia. *J. Adel. Bot. Gard.* 6:93-131.
- Leigh, J., D.T. Briese, M.L. Holgate and A.V. Slee. 1990. Seed production by five thistle species which were cut, goat-grazed, and attacked by insects. *Proc. Aust. Wool Corp. Conf. on "Weed, Invert. and Dis. Pests of Aust. Sheep Pastures"*, 1989. CSIRO-Aust. Wool Corp., Melbourne (*in press*).
- Martelli, M. 1948. Osservazioni sue due species del genere *Larinus* Germ. *Redia* 33:221-86.
- Michael, P.W. 1968. Control of the biennial thistle, *Onopordum*, by amitrole and five perennial grasses. *Aust. J. Exp. Agric. Anim. Husb.* 8:332-9.
- Parsons, W.T. 1973. *Noxious Weeds of Victoria*. Inkata Press, Melbourne, 300 p.
- Petney, T.M. and H. Zwölfer. 1985. Phytophagous insects associated with Cynareae hosts (Asteraceae) in Jordan. *Israel J. Ent.* 19:147-59.
- Sheppard, A.W., J.-P. Aeschlimann, J.M. Cullen, J.L. Saggiocco, J.-L. and J. Vitou. 1988. The relative importance of biological control agents to other limiting factors on weed population dynamics: a case study of *Carduus nutans* L. *Proc. VII Int. Symp. Biol. Contr. Weeds*, 6-11 March 1988, Rome, Italy. Delfosse, E.S. (ed.). 1st Sperm. Patol. Veg. (MAF) (*In Press*).
- Wapshere, A.J. 1984. The possibilities of biological control of thistles in Australia. *Proc. IV Aust. Appl. Ent. Res. Conf.*, September 1984. P. Bailey & D. Swincer (eds.). S.A. Dep. Agric., pp. 324-32.
- Wheatley, W.M. and I.J. Collett. 1981. Winning the thistle war. *Agric. Gaz. N.S.W.* 82:25-8.
- Zwölfer, H. 1965. Preliminary list of phytophagous insects attacking wild Cynareae (Compositae) in Europe. *Tech. Bull. Commonw. Inst. Biol. Contr.* 6:81-154.
- Zwölfer, H. 1985. Insects and thistle heads: resource utilization and guild structure. *Proc. VI Int. Symp. Biol. Contr. Weeds*, 19-25 August 1984, Vancouver, Canada. Delfosse, E.S. (ed.). Agric. Can., pp. 407-16.
- Zwölfer, H., K.E. Frick and L.A. Andres. 1971. A study of the host plant relationships of European members of the genus *Larinus* (Col: Curculionidae). *Tech. Bull. Commonw. Inst. Biol. Contr.* 14:97-143.