Vine mealybug, *Planococcusficus* (Signoret) (Hemiptera: Pseudococcidae), a Key Pest in South African vineyards. A Review

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Vine mealybug, *Planococcus ficus* **(Signoret), is a key pest in vineyards in the Western Cape and North-West Provinces of South Africa and more recently in the USA. This pest was first reported in the Western Cape Province in 1943. The taxonomy and identification of this species are made difficult by complex slide-mounting techniques and the lack of qualitative characteristics. Vine mealybug is polyphagous with a wide range of host plants. *P. ficus* causes direct crop loss due to desiccation of bunches in the case of wine grapes and unsightly honeydew excretion on bunches in the case of table grapes. High infestations of *P. ficus* can cause early leaf loss and resultant weakening of vines. Vine mealybug also vectors the vine leaf roll virus. This pest is currently controlled using chemical, biological and cultural control techniques in an integrated pest-management system. This system relies on the use of pheromone and physical monitoring techniques, which provide information on infestation levels.**

INTRODUCTION AND HISTORY OF THE PEST IN SOUTH AFRICA

Planococcus ficus (Signoret) was initially identified in the Western Cape Province as *Planococcus citri* (Risso) by Joubert (1943), Kriegler (1954) and Whitehead (1957) after introduction to the area, probably with plant material. De Lotto (1975) subsequently identified it as *Planococcus ficus.* The most recent samples of the insect collected during 1999/2000 were identified as *Planococcus ficus* (Walton 2003) by I.M. Millar, Plant Protection Research Institute in Pretoria.

P. ficus was first recorded as a pest in the Western Cape Province during 1930 (Joubert 1943). By 1935 *P. ficus* had spread to the Hex River Valley and subsequently to all other major grape-producing areas (Joubert 1943) in this Province. Kriegler (1954) regarded it as one of the most important pests of the grape industry in South Africa. Other pseudococcid species recorded from vines in the Western Cape Province included *Pseudococcus longispinus* (Targioni) and *Ferrisia malvastra* (McDaniel), which were also identified by I.M. Millar (Walton 2003), Plant Protection Research Institute in Pretoria. These have, however, not yet attained pest status on grapes locally.

TAXONOMY

Current Status

The most recent classification was done by Ben-Dov (1994) who placed *P. ficus* in the Order Hemiptera, Suborder Homoptera, Superfamily Coccoidea and Family Pseudococcidae. The species was well described by De Lotto (1975), Cox (1981, 1989), and Williams & Granara de Willink (1992). Keys for the adult female of this species were given in Williams & Moghaddam (1999) (Iran), Williams & Granara de Willink (1992) (Central and South America), Cox (1989) (World), Cox & Ben-Dov (1986) (Mediterranean basin), and Cox & Wetton (1988) (West Indies). *P. ficus* was initially described as *Coccus vitis* by Nedzilskii (1869) (Cox & Ben-Dov, 1986). Lichtenstein (1870) subsequently placed this species in the genus *Dactylopius* (Cox 1989). Signoret (1875) described it as *Planococcus ficus.* Thereafter various synonyms were used, many of which were the result of misidentification (Ben-Dov, 1994) (Table 1).

Vernacular names

Vernacular names given by Balachowsky & Mesnil (1935) include 'cocciniglia farinosa della vite', 'cochonilha algodeo da vinha', 'cotonet de la vid', 'grapevine mealybug' and 'la cochenille farineuse de la vigne'. Berlinger (1977) described *P. ficus* as the 'Mediterranean vine mealybug', Bodenheimer (1924) as 'subterranean vine mealy bug' and De Lotto (1975) as 'vine mealybug'.

BIOLOGY

Morphometrics

Criteria for age distinction of the different developmental stages of *P. ficus* were described by Kriegler (1954). This information was used in studies on the developmental biology of this pest (Walton, 2003). Kriegler (1954) made use of a combination of colour, size, and other characteristics to distinguish between the different stages. Certain criteria were selected and are presented in Table 2.

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TABLE 1

Synonyms used for *Planococcus ficus* (Ben-Dov 1994).

Synonym	Author	Comment
Coccus vitis	Nedzilskii (1869), Lindinger(1912), Borchsenius(1949)	Incorrect due to misidentification (Cox & Ben-Dov, 1986). True identity unknown.
Dactylopius vitis	Lichtenstein(1870), Signoret(1895)	Misidentification (Cox, 1989)
Dactylopius ficus	Signoret (1875), Borchsenius (1949)	Type material lost (Ben-Dov & Matile-Ferrero, 1995).
Dactylopius subterraneus	Hempel(1901)	On roots of cultivated grapes
Pseudococcus ficus	Fernald (1903)	Change of combination
Pseudococcus vitis	Fernald (1903), Leonard! (1920), Bodenheimer (1924)	
Pseudococcus citriodes	Ferris(1922)	New name
Pseudococcus citri	Balachowsky & Mesnil (1935)	Misidentification
Dactylopius ficus	Borchsenius (1949)	Synonymous with *Pseudococcus citri* (Risso)
Planococcus citroides	Ferris (1950)	Change of combination
Planococcus vitis	Ezzat & McConnell (1956), Matile-Ferrero(1984)	
Planococcus ficus	Ezzat & McConnell (1956)	Change of combination
Pseudococcus praetermissus	Ezzat (1962)	Synonym

In a recent survey (Walton, 2003), *P. ficus* was found to be the dominant mealybug species in vineyards in the Western Cape Province of South Africa. Adult female mealybugs were approximately 4 mm in length, slightly more than 2 mm wide and about 1.5 mm thick. The adult female and immature stages were ovate, humpbacked, light slate- to flesh-coloured and covered by a fine, white powdery wax secretion, which was more evident on the later stages. The body of the adult female was clearly segmented and had a fringe of short, finger-like wax filaments around its edge (Kriegler, 1954) (Fig. 1). After mating, egg sacs covered with waxy threads started to appear.

This species was easily distinguished from *Ps. longispinus*, which was about 3 mm long, 1 mm wide, ovate, and yellowish grey in colour. Adult females and younger stages of this species had exceptionally long posterior filaments and no egg sacs, as this species was ovoviviparous (El-Minshawy, *et al.* 1974). A single adult female *Ferrisia malvastra* (McDaniel), 7 mm long and 4 mm wide with a light orange colour was recorded for the first time from a vineyard in Stellenbosch (Walton, 2003) and clearly differed in morphology from *P. ficus.*

P. ficus is closely related to *P. citri.* Separation of these two species is based on minor differences in the number and arrangement of glandular ducts of the dermis. *P. ficus* has fewer groups of and smaller ducts than *P. citri* (De Lotto, 1975). However, *P. citri* has not yet been found on vines in South Africa.

Life cycle

Kriegler (1954) studied the lifecycle of *P. ficus* in detail. Developmental stages studied were eggs and first, second and third nymphal instars. It was found that the male characteristics appeared after the third nymphal instar and, during subsequent development, differentiation between the sexes occurred. In the case of the male, the prepupa was followed by the pupa from which the winged male emerged (Fig. 1). Males were characterised by having long filamentous anal setae and no mouthparts (Kriegler 1954). The adult female started releasing pheromones at sexual maturity, attracting adult males for copulation (Hinkens *et al.,* 2001). Subsequent to copulation there was a pre-oviposition period, after which the female laid eggs in an egg sac made up of

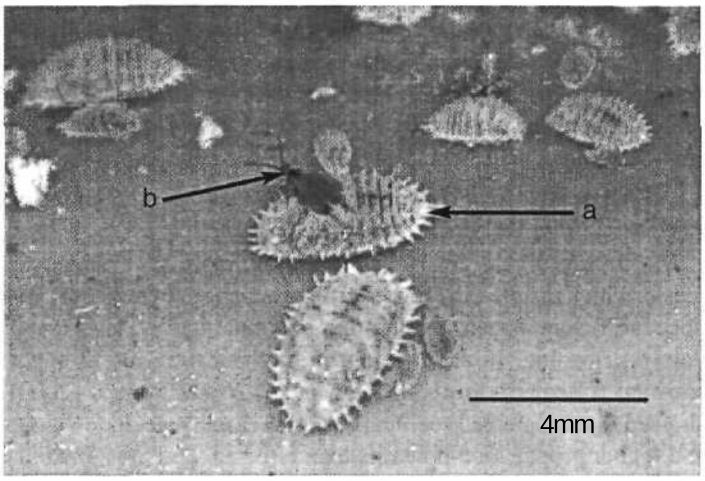

FIGURE 1
Adult female (indicated by arrow a) and male (indicated by arrow b) *Planococcus ficus.*

TABLE 2
Morphometric characters for distinguishing life stages of *Planococcus ficus* (Kriegler, 1954) in developmental biology studies.

Stage	Average length (mm)	Average width (mm)	Characteristics/Colour
Egg	0.41	0.21	Light straw
First nymphal instar	0.46	0.22	Light to dark yellow, six antennal segments
Second nymphal instar	0.68	0.35	Yellowish brown
Third nymphal instar	1.13	0.66	Seven antennal segments
Male prepupa	0.95		One pair of lateral ocelli. Visible wingbuds
Male pupa	1.05		Three pairs of lateral ocelli. Wingbuds reaching to third abdominal segment
Adult male	1.05		Wings fully developed
Adult female	1.69	0.99	Wingless, eight antennal segments

filamentous waxy hairs. Kriegler (1954) recorded an average of 362 eggs per female. Life-table studies were done at constant temperatures by Walton (2003) whereby the lower and upper threshold temperatures for development of *P. ficus* were estimated at 16.59 and 35.61°C, respectively. These results were similar to those of Duso *et al.* (1985), who indicated that the optimum temperatures ranged from 23°C to 27°C.

Hosts

P. ficus is a polyphagous insect and, apart from the economic damage it can cause to *Vitis vinifera* Linn., it has been found on various other host plants (Table 3).

None of the above host plants were found in close proximity to the vineyards sampled in the study by Walton (2003). A variety of weeds were, however, sampled for mealybugs in vineyards during the current study, but no *P. ficus* were found on any of them (Walton 2003).

GEOGRAPHICAL DISTRIBUTION AND ECONOMIC IMPORTANCE

P. ficus has been found in most grape-production areas throughout the world (Table 4). It is of particular economic importance on grapevines in the Mediterranean region, South Africa, Pakistan and Argentina (Ben-Dov, 1994).

Engelbrecht & Kasdorf (1984) and Cabaleiro & Segura (1997) found that *P. ficus* transmitted the grapevine leafroll associated virus 3 (GLRa V-3). Initially, the mealybug specimens studied by Cabaleiro & Segura (1997) were identified as *Planococcus citri* (Risso), but later identified by Ben-Dov as *P. ficus* (Signoret) (Yair Ben-Dov, unpublished data, July 1998). Transmission of GLRa V-3 by *P. ficus* and positive identification of GLRa V-3 were further confirmed using PCR methods by Acheche *et al.* (1999).

The transfer of the leafroll virus caused inefficient photosynthesis, which resulted in reduced fruit production, inability to produce sufficient sugar, higher than normal acidity levels and delayed ripening. In addition, infested vines were less drought resistant (Cabaleiro *et al.*, 1999; Manini, 2000). Manini (2000) showed that uninfected seedlings had increased vegetative vigour and higher propagation potential than infected seedlings. In addition, *P. ficus* has been found to be a virus vector of corky-bark disease (Engelbrecht & Kasdorf, 1985; Tanne *et al*, 1989), and Shiraz disease (Engelbrecht & Kasdorf, 1984) in vines.

Apart from being a vector of GLRa V-3, high infestations of *P. ficus* in table grape bunches result in direct crop loss and progressive weakening of vines through early leaf loss (Kriegler, 1954; Whitehead, 1957; Berlinger, 1977; Charles, 1982; Walton, 2003).

Seasonal population dynamics and phenology

In South Africa Kriegler (1954) recorded six generations per year, while Walton (2003) found between five and six generations. In Italy Duso (1990) recorded only three generations per year. These differences could be attributed to temperature differences between the two countries.

Upward movement on the trunk began from spring or early summer (October in South Africa, March/April in Israel and Italy) (Kriegler, 1954; Berlinger, 1977; Duso, 1990; Walton, 2003). Populations started to develop on new growth and the population peak was recorded between the end of January and the beginning of February, after which numbers declined (Kriegler, 1954; Whitehead, 1957; Walton, 2003). Mealybugs found in the vine canopy after harvest formed the nuclei of winter colonies (Whitehead, 1957). Similar observations were made in Israel and Italy (Berlinger, 1977; Duso, 1990). Berlinger (1977) noted that winter population levels were low in Israel and consisted mainly of non-ovipositing adult females. Walton (2003) found populations of this pest on roots of vines.

Kriegler (1954) studied the influence of temperature on the development of *P. ficus* under fluctuating temperatures on potatoes in an outdoor greenhouse. Duso *et al.* (1985) and Berlinger (1977) studied the development of *P. ficus* in the field. Berlinger (1977) found that cool early summer temperatures delayed upward migration, which delayed the population peak.

MONITORING SYSTEMS FOR VINE MEALYBUG

The low tolerance for *P. ficus* and the importance of timely insecticide applications necessitated the use of a species-specific monitoring programme for rapidly determining the pest population density. Two monitoring systems are currently in use: labour-intensive (Geiger & Daane, 2001) physical sampling of vines infested with *P. ficus* (Walton 2003) and pheromone monitoring (Millar *et al.*, 2002; Walton *et al.*, 2003).

Physical sampling can be used by producers in South Africa to provide an estimate of *P. ficus* population levels in commercial vineyards with known levels of error, enabling producers to

TABLE 3

Recorded findings of *P. ficus* on host plants other than *V vinifera.*

Family	Genus/Species	Reference
Anacardiaceae	*Mangifera indica* Biume	Ezzat & McConnel (1956), Cox (1989), Ben-Dov (1994)
Apocynaceae	*Nerium oleander* Linn.	Ezzat&McConnel(1956)
Asteraceae	*Dahlia* spp.	Ezzat & McConnel (1956)
Juglandaceae	*Juglans* spp.	Ezzat & McConnel (1956)
Lauraceae	*Persea americana* Mill.	Cox (1989), Ben-Dov (1994)
Labiaceae	*Dichrostachys glomerata* Linn.	Cox (1989), Ben-Dov (1994)
	Prosopis farcata Linn.	Cox (1989), Ben-Dov (1994)
	Tephrosia purpurea Pers.	Cox (1989), Ben-Dov (1994)
Moraceae	***Ficus*** *benjamina* Linn.	Williams & Granara de Willink (1992), Ben-Dov (1994)
Palmae	*Phoenix dactylifera* Linn.	Cox (1989), Ben-Dov (1994)
Platanaceae	*Platanus orientalis* Linn.	Martin-Mateo (1985), Williams & Moghaddam (1999)
Poaceae	*Bambusa* spp.	Ezzat & McConnel (1956)
Rhamnaceae	*Zizyphus spina-christi* Georgi	Cox (1989), Ben-Dov (1994)
Rosaceae	*Cydonia oblonga* Mill.	Granara de Willink *et al.* (1997)
Rosaceae	*Malus domestica* Baumg.	Granara de Willink *et al.* (1997)
	Malus pumila Mill.	Cox (1989), Ben-Dov (1994)
Salicaceae	*Salix spp.*	Cox (1989), Ben-Dov (1994)
Sterculiaceae	*Theobroma cacao* Linn.	Ezzat & McConnel (1956)
Styracaceae	*Styrax officinalis* Walt.	Cox (1989), Ben-Dov (1994)

decide on the necessity for and correct timing of intervention (Walton, 2003). Physical monitoring methods are most effective later in the summer, when mealybugs are in exposed locations (e.g. new canes and leaves) and when the population densities are relatively high (Geiger *et al,* 2001; Walton 2003). In practice, this period occurs only after crop damage has taken place.

Pheromone-based monitoring programmes are less time consuming, simpler and more sensitive than physical inspections (Millar *et al,* 2002; Walton *et al,* 2003). Pheromone-baited lures were found to be attractive to male *P. ficus* for up to 12 weeks, with an effective range of 50 m (Hinkens *et al,* 2001). The number of *P. ficus* males caught in pheromone-baited traps was positively correlated to female mealybug infestation levels, determined using physical sampling methods (Walton *et al,* 2003).

CONTROL STRATEGIES

Chemical control

Chemical control of *P. ficus* in South Africa is currently based on either two treatments of chlorpyrifos two weeks apart, or prothiophos just before bud burst. These treatments are applied during the dormant period. An additional supplementary treatment of a chemical with a short residual period, such as dichlorvos or methidathion, is sometimes applied prior to harvest from January to April (Nel *et al,* 1999). However, *P. ficus* colonies are protected by wax threads and are not easily controlled by these routine sprays. Populations usually occur under bark and in crevices on the main stem as well as on roots, making it difficult to target this pest with insecticides (Berlinger, 1977). Kriegler (1954) and Whitehead (1957) recommended the application of spot treatments with chemicals when high mealybug infestations occur. However, they emphasised the integrated use of chemical and biological control. The systemic pesticide Imidacloprid SC (350g/L) (http://www.ipw.co.za) was recently registered for use on vine mealybug in South Africa. This chemical may be a useful alternative to the chemicals mentioned above. However, there are indications that pesticide resistance to this compound can develop (Prabhaker *et al,* 1997; Zhao *et al,* 2000). Therefore, resistance-management measures should be employed to delay or prevent the development of resistance.

Biological control

Many natural enemies associated with *P. ficus* have been reported, some of which were hyperparasitoids (Table 5).

From the list it is clear that *P. ficus* populations are attacked by a range of natural enemies, many of which commonly occur in the Western Cape Province (Whitehead, 1957; Urban, 1985; Walton, 2003). The most common natural enemies in this area include, in descending order of abundance,

- Parasitoids: *Anagyrus* spp., *Coccidoxenoides perminutus, Leptomastix dactylopii.*
- Predatory beetles: *Nephus bineavatus, N. angustus* and *N. quadrivittatus.*

TABLE 4
Geographical areas where *Planococcus ficus* has been recorded on vines (Ben-Dov 1994).

Geographical area	Reference
Afrotropical: South Africa	Ezzat & McConnel (1956), De Lotto (1975), Cox (1989), Ben-Dov (1994)
Mauritius	Ezzat & McConnel (1956)
Nearctic: United States of America	Ezzat & McConnel (1956)
Neotropical: Argentina	Hempel (1901), Ezzat & McConnel (1956),, Granara de Willink (1991), Williams & Granara de Willink (1992), Ben-Dov (1994), Trjapitzyn & Trjapitzyn (1999)
Brazil	Williams & Granara de Willink (1992), Ben-Dov (1994)
Chile	Ezzat & McConnel (1956)
Dominican Republic	Ezzat & McConnel (1956)
Trinidad and Tobago	Ezzat & McConnel (1956)
Uruguay	Granara de Willink *et al*, (1997)
Oriental: India	Varshney (1992), Ben-Dov (1994)
Pakistan	Cox (1989), Ben-Dov (1994)
Palearctic: Afghanistan	Kozár, Fowjhan & Zarrabi (1996)
Azerbaijan	Rzaeva (1985), Ben-Dov (1994)
Azores	Ezzat & McConnel (1956)
Canary Islands	Camera Hernandez & Pérez Guera (1986), Perez Guerra & Carnero Hernandez (1987), Ben-Dov (1994)
Palearctic: Crete	Argyriou (1983), Cox (1989), Ben-Dov (1994)
Cyprus	Cox (1989), Ben-Dov (1994)
Egypt	Ezzat & McConnel (1956), Ezzat & Nada (1987), Cox (1989), Ben-Dov (1994)
France	Signoret (1875), Ben-Dov (1994)
Greece	Ezzat & McConnel (1956)
Hyeres Islands	Foldi (2000)
Iran	Cox (1989), Ben-Dov (1994), Kozar, Fowjhan & Zarrabi (1996), Williams & Moghaddam (1999)
Iraq	Cox (1989), Ben-Dov (1994)
Israel	Bodenheimer (1924), Avidov (1961), Avidov & Harpaz 1969), Cox & Ben-Dov (1986), Ben-Dov (1994)
Italy	Leonardi (1920), Tranfaglia (1976), Marotta (1987), Rosciglione & Castellano (1985), Duso (1990), Ben-Dov (1994)
Lebanon	Cox (1989), Ben-Dov (1994)
Libya	Ferris (1922), Ben-Dov (1994)
Portugal	Ezzat & McConnel (1956)
Sardinia	Melis (1930), Ben-Dov (1994), Longo *et al.* (1995), Pellizzari-Scaltriti & Fontana (1996)
Saudi Arabia	Beccari (1971), Matiie-Ferrero (1984), Ben-Dov (1994)
Sicily	Longo *etal.* (1995), Russo & Mazzeo (1997)
Spain	G6mez-Menor Ortega (1937), Ezzat & McConnel (1956), Martin-Malteo (1985), Ben-Dov (1994)
Syria	Ezzat & McConnel (1956)
Tunisia	Cox (1989), Ben-Dov (1994)
Turkmenistan	Achangelskaya (1930), Ben-Dov (1994)

Berlinger (1977) also found that the parasitoids and predators mentioned above were dominant in Israel. Whitehead (1957) believed that predatory beetles played a major part in biological control and that the parasitoids were of lesser importance. Predatory beetle population levels peaked early in the season (from September to November) and declined after this (Walton, 2003; Whitehead, 1957). However, mealybug population levels did not decrease while the predators were present (Berlinger,

TABLE 5

Natural enemies associated with *P. ficus.*

Order and Family	Species	Reference	Comment
Diptera: Chamameyidae	*Leucopis* sp.	Rzaeva(1985)	
Hymenoptera: Encyrtidae	*Pachyneuron concolor* Forster	Rzaeva(1985)	Possible hyperparasitoid
	Allotropa mecrida Walker	Rzaeva(1985J	
	Anagyrus pseudococci (Girault)	Rzaeva (1985), Urban (1985), Trjapitzyn & Trjapitzyn(1999)	
	Chartocerus subaeneus Forster	Rzaeva (1985)	Possible hyperparasitoid
	Clausenia josefi Rosen	Rosen (1965), Berlinger (1977), Trjapitzyn (1989)	
	Coccidoxenoides perminutus (Timberlake)	Berlinger (1977), Urban (1985), Trjapitzyn (1989)	Synonym: *Pauridia peregrina*
Hymenoptera: Encyrtidae	*Leptomastix flavus* Mercet	Berlinger (1977)	
	Leptomastidea abnormis (Girault)	Berlinger (1977), Urban (1985), Trjapitzyn (1989), Trjapitzyn & Trjapitzyn (1999)	
	Prochiloneurus bolivari (Mercet)	Trjapitzyn (1989)	Possible hyperparasitoid
	Prochiloneurus pulchellus (Silvestri)	Trjapitzyn (1989)	Possible hyperparasitoid
	Chrysoplatycerus splendens (Howard)	Walton (2003)	
Neuroptera: Chrysopidae	*Chrysoperla camea* (Stephens)	Rzaeva (1985)	
Coleoptera: Coccinellidae	*Nephus reunioni* Fiirsch	Rzaeva(1985)	
	Cryptolaemus montrouzieri Mulsant	Orlinskii *et at.* (1989)	
	Hyperaspis felixi Mulsant	Whitehead (1957), Urban (1985)	
	Nephus angustus Casey	Whitehead (1957), Urban (1985)	
	Nephus binaevatus Mulsant	Whitehead (1957), Urban (1985)	
Coleoptera: Coccinellidae	*Nephus quadrivittatus* Mulsant	Whitehead (1957), Urban (1985)	
	Rhizobiellus sp.	Whitehead (1957)	
	Cydonia lunata F.	Whitehead (1957)	
	Scymnus nubilis Mulsant	Walton (2003)	

1977; Urban, 1985; Walton, 2003) both in the Western Cape and in Israel. The lack of density-dependence documented between vine mealybugs and predatory beetles led Walton (2003) to assume that this group of beneficials were of lesser importance. Parasitoid numbers reached a peak later in the season (from November), which resulted in the destruction of most of the mealybug colonies (Berlinger, 1977; Urban, 1985; Walton, 2003) towards the end of the season (February to March). This suggested that the parasitoid complex played a major role in reducing *P. ficus* numbers.

Biological control was severely hampered by the presence of a variety of ant species (Kriegler, 1954; Whitehead, 1957; Addison & Samways, 2000) in vineyards in the Western Cape Province. This was also reported in Israel (Berlinger, 1977). Ant control has been achieved using chemical stem-barrier treatments (Addison, 2002). Walton (2003) did a two-year field study of mass releases of *C. perminutus*, a parasitoid of the first, second and third instars of *P. ficus*. This method of control was at least as effective as the currently used chemical control programme.

Cultural control

Bugg & Waddington (1994), Whitehead (1957) and Urban (1985) suggested that the preservation of surrounding vegetation was important for optimising conditions for natural enemies. Cover crops were effective only if they attracted Coccinellidae and Neuroptera (Bugg & Waddington, 1994). These authors also noted that common vetch *{Vicia saliva)* had stipular extra-floral nectaries that attracted parasitic wasps. Work done on the effects of cover crops on natural enemy populations of mealybugs by P. Addison (Personal communication) and Costello & Daane (2003) indicated that cover cropping had no significant effect on their occurrence in vineyards.

Providing pollen, nectar, suitable habitats, sprays of sucrose or a yeast product plus sucrose led to an increase in local populations of predatory coccinellids, chrysopids, and hemerobiids. These food sources increased the longevity not only of predators, but also of adult encyrtid wasps and enhanced biocontrol of mealybugs in the field (Neuenschwander & Hagen, 1980; Urban, 1985).

Kriegler (1954) and Flaherty *et al.* (1982) found that leaf removal and correct summer pruning reduced the number of leaves that predators and parasitoids had to cover in search of prey, thereby increasing their effectiveness. This also reduced mealybug populations by removing them with the surplus stems and leaves, and contributed to better aeration of vines. Road dust and inert carriers of fungicides should be kept to a minimum as these adversely affected natural enemies (Searle, 1965). Mealybugs overwintering on old wood and under loose bark readily infested bunches that touched the woody parts of the vine. However, bunches that hung free from old wood were less susceptible to cosmetic damage. Therefore, bunches touching the old wood should be thinned so as to avoid contact (Kriegler, 1954; Flaherty *et al.,* 1982). The use of chemical and sticky trunk barriers to keep ants from the vine canopy could further aid in biological control *of P. ficus* (Whitehead, 1957; Addison, 2002).

The spread of *P. ficus* pest populations can further be limited by co-ordinating on-farm movement of implements and labourers.

Integrated control

Whitehead (1957), Berlinger (1977) and Urban (1985) believed that an integrated approach should be followed, which would enhance biological control. In addition, ant exclusion by trunk barriers was considered an important element of the integrated system (Whitehead, 1957). If biological control was not adequate, limited chemical intervention using spot treatments of short residual pesticides should be considered.

Information on the development rate of *P. ficus* (Walton, 2003) was used to estimate the number of degree-days required by *P. ficus* to complete its development and to estimate the rate of development of the *P. ficus* population through the season (Walton, 2003). This information was used as input for a *P. ficus* pest-management model. Data from monitoring *P. ficus* and ant activity were used as components to construct a decision chart. This chart can be used by producers to optimise the control of *P. ficus* populations using either chemical control or mass releases of *C. perminutus*.

Presently, integrated production of wine (IPW) is encouraged by the wine industry in South Africa (Tromp & Marais, 2000). This system includes sound integrated pest-management strategies for suppressing pests such as *P. ficus.* Strategies include monitoring pest activity, pest-control practices such as trunk barriers, optimised use of biological control and limited use of chemicals during the growing season. In addition, an AgChem Environmental Work Group codes all registered pesticides for acceptability in integrated production systems for use against insect pests, including those for *P. ficus* control. This coding system is based on the environmental impact of products (Walton & Pringle, 1999; Tromp & Marais, 2000; Walton & Pringle, 2001). Producers are encouraged to implement these guidelines (www.ipw.co.za) and random audits are conducted to determine compliance.

CONCLUSIONS

The taxonomic status of *P. ficus* has been uncertain due to the difficulty of the slide-mounting techniques used for preparing specimens for identification and the lack of qualitative physical differences to other closely related species (De Lotto, 1975; Ben-Dov, 1994). A recent survey of mealybugs in the Western Cape Province indicated that *P. ficus* is dominant locally (Walton, 2003). This has important implications for the grape-growing industry in South Africa, because vine mealybug is an important vector of the vine leafroll virus. The spread of this virus can only be controlled by limiting the development of *P. ficus* infestations in vineyards.

The majority of producers currently control this pest using commercially registered pesticides. The recent registration of the chloro-nicotinyl compound, imidacloprid, and possible registration of similar chemical compounds in the future may aid in alleviating the limited range of available chemical compounds for vine mealybug control. The optimal application rate, timing, cost effectiveness and efficacy of these compounds, however, need to be determined.

The current global trend of antagonism towards pesticide use, the evidence of pesticide resistance and the difficulty of controlling this pest with conventional pesticides, however, serve as an incentive for using alternative pest-control strategies. An integrated control programme is seen as the only sustainable alternative to the currently used chemical control regime. Tools available for integrated control include physical and pheromone-baited monitoring, temperature-driven models, biological control through mass releases of natural enemies and optimally timed chemical sprays. The isolation and commercial synthesis of the vine mealybug pheromone have provided an opportunity to investigate mating disruption as a further alternative pest-management strategy for the control of *P. ficus.*

The lower and upper developmental temperatures of *P. ficus* and *C. perminutus,* an important parasitic wasp, have been determined (Walton, 2003). These parameters were used to estimate the number of degree days required for both insects to complete their entire lifecycles. This information can be used in temeperature-driven models for optimising the timing of control measures.

Pesticide failures have necessitated the development of alternative pest-management measures such as mass releases of natural enemies for *P. ficus* control in South Africa (Walton, 2003). A review of the published information on mass rearing parasitoids has been produced by Etzel & Legner (1999), but no literature was available on the mass rearing of *C. perminutus* on *P. ficus.* To promote biological control as an alternative to chemical control, *C. perminutus* was produced and released on *P. ficus* pest populations and methods for mass release and the effectiveness of *C. perminutus* for controlling *P. ficus* populations were investigated (Walton, 2003).

To time control actions such as mass releases or chemical control of *P. ficus* pest populations correctly, accurate information on field infestation levels was needed and a system for monitoring *P. ficus* population levels with known levels of error was developed using pheromone and physical monitoring (Walton, 2003). With the above information, action thresholds could be determined and used as a basis for *P. ficus* management.

Information gathered on the above aspects was combined to construct a decision model for integrated *P. ficus* management (Walton, 2003). This decision model should be verified in **the** field. Future work will include the use of *P. ficus* pheromones for mating disruption.

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