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Biology and management of *Melanagromyza obtusa* (Malloch) (Diptera:Agromyzidae)

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Melanagromyza obtusa (Malloch) (Diptera:Agromyzidae), the pigeonpea pod fly, is a key pest of pigeonpea [*Cajanus cajan* (L.) Millsp.] throughout south and south-east Asia. Females deposit eggs in the green pods of pigeonpea and other host plants, and the developing larva feeds on and destroys the unripe seed. Substantial yield losses have been attributed to this pest in several countries. Pest management strategies for the pigeonpea pod fly have emphasized chemical control and host-plant resistance. This paper reviews the literature on the distribution, host plants, biology, natural enemies and control strategies for this pest. Priorities for future research are also suggested. © 1998 Elsevier Science Ltd. All rights reserved

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Melanagromyza obtusa (Malloch) (Diptera:Agromyzidae), the pigeonpea [*Cajanus cajan* (L.) Millspaugh] pod fly, is one of the two most important pests of pigeonpea (Lal and Yadava, 1987; Lateef and Reed, 1990). Pigeonpea is grown throughout the tropics but most widely in south and south-east Asia, where it is a preferred source of vegetable protein (Nene and Sheila, 1990). It is also an important crop in eastern and southern Africa. The genus *Melanagromyza* includes 20 species some of which are pests of other legumes. Only two species, *M. obtusa* and *M. chalcosoma* Spencer, feed on pigeonpea (Spencer, 1973). *Melanagromyza chalcosoma*, which also feeds on cowpea (*Vigna unguiculata* Walp.) and is limited geographically to eastern and southern Africa (Spencer, 1973), is similar biologically to *M. obtusa*.

This paper reviews the literature on the biology, ecology and management of *M. obtusa*. The sources are widely scattered, frequently difficult to obtain, and include unpublished or limited distribution material. Much of the research has been conducted in India but will be of relevance to countries where *M. obtusa* is a pest. In addition, research on pest management strategies for *M. obtusa* may be relevant to the important but less well-studied *M. chalcosoma* (Minja et al., 1996). In the final section of this paper priority areas for future research are suggested.

Distribution and host plants

Melanagromyza obtusa has been reported from Asia and eastern Africa (*Table 1*), although its presence in the latter region is disputed. In Asia, it is recorded throughout the area bounded by Pakistan and Japan in the north, and Sri Lanka and Papua New Guinea in the south. In India, *M. obtusa* is widely distributed but is more prevalent in northern than in southern States (Sehgal, 1990). It has not been reported from several countries within the Australasian region (e.g.

Table 1. Geographic distribution of *M. obtusa*

Country	Reference
Bangladesh	Kabir, 1978
India	Maxwell-Lefroy, 1906
Indonesia	de Meijere, 1922 (in Spencer, 1973)
Japan	Singh and Ipe, 1973
Kenya*	Le Pelley, 1959
Malaysia	Sasakawa, 1963
Myanmar	Ahmad, 1938
Nepal	Neupane, 1993
Pakistan	Ahmad, 1982
Papua New	Singh and Ipe, 1973
Philippines	Litsinger, 1987 (pers. commun. in Talekar, 1990)
Sri Lanka	Thevasagayam and Canagasigham, 1960
Taiwan	Malloch, 1914
Thailand	Talekar, 1990
Uganda*	Le Pelley, 1959
Vietnam	Hong et al., 1992

*Doubtful, see text.

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Cambodia, China, Australia), perhaps due to the small areas under pigeonpea cultivation, although it is probably present since it is found in adjacent countries. The uncertainty regarding the presence of *M. obtusa* in eastern and southern Africa is complicated by the occurrence of the morphologically and ecologically similar *M. chalcosoma*. Spencer (1973) and Talekar (1990) both cite earlier reports of eastern and southern African locations (*Table 1*) as part of the authentic geographic range of *M. obtusa*. Reed and Lateef (1990) express strong doubt that *M. obtusa* is present in Africa and consider such reports to be misidentifications. Recent pigeonpea pest surveys in Kenya, Malawi, Tanzania and Uganda reported only *M. chalcosoma* infesting pigeonpea pods (Minja *et al.*, 1996) but this is a question which needs to be clarified.

Melanagromyza obtusa has a narrow host range and has only been recorded from five genera all in the Papilionaceae (*Table 2*). Pigeonpea and *Flemingia macrophylla* are the only commercially cultivated host plants. *Fleminga macrophylla*, used as a host plant in the production of lac, is heavily attacked by *M. obtusa* (Kulkarni, 1966). Reports of five other agriculturally important plant species as hosts for *M. obtusa* are questioned. Venugopal and Venkataramani (1954), Patel and Verma (1973) and Sharma and Singh (1984) have reported *M. obtusa* on okra [*Abelmoschus esculentus* (L.) Moench (= *Hibiscus esculentus* L.)] (Malvaceae). Sehgal (1987) believed that these authors had mistakenly identified *M. hibisci* Spencer (Agromyzidae) as *M. obtusa* and that okra is not a host for *M. obtusa*. This did not end the confusion and recent publications (e.g. Talekar, 1990) continue to report okra as a host plant for *M. obtusa*. Safflower (*Carthamus tinctorius* L.) (Asteraceae) and sesame (*Sesamum indicum* L.) (Pedaliaceae) have also been incorrectly reported as hosts for *M. obtusa* in India (Abraham *et al.*, 1973; David and Janagarajan, 1969; Husain and Khan, 1965). Neither plant is now considered to be an authentic host for *M. obtusa* (V.K. Sehgal, pers. commun.). There are also reports

of *M. obtusa* in pods of *Vigna radiata* (L.) R. Wilczek (Spencer, 1973) and *V. unguiculata* (Mehrotra *et al.*, 1989). Confirmation of the suitability of these hosts for *M. obtusa* survival and development is needed before they can be considered as host plants.

Growth and development

Ahmad (1938) provided a very detailed account of many aspects of *M. obtusa* biology. *Melanagromyza obtusa* females oviposit in the tender pods of the host plant. The eggs, glistening white when laid, are tear-shaped and measure approximately 1.0×0.2 mm (Ipe, 1974). Females lay between 30 and 40 eggs, although individuals may produce as many as 79 eggs (Ahmad, 1938; Bindra and Singh, 1972; Singh and Rai, 1984).

At constant temperatures under controlled conditions the egg stage requires 3 days at 27°C and 9 days at 18°C (Ahmad, 1938). Other workers have reported egg development times within this range (David, 1964; Singh and Rai, 1984). Newly hatched larvae (ca. 0.5 mm long) locate the developing seed and may feed on the exterior for a short time before boring through the seed coat. Larvae feed on the developing cotyledons and pass through three stadia before pupating (Ipe, 1974). A single pigeonpea seed is sufficient food for the larva to complete development, although occasionally more than one seed may be attacked (Ahmad, 1938). *Melanagromyza obtusa* larvae crawl out of the seed and cut a 'window' in the pod wall before pupating. The pupae are brown and ca. 2.5 mm in length. Pupation occurs in the open lumen of the locule. Spencer (1973) states that *M. obtusa* can be distinguished from *M. chalcosoma* because the latter pupates within the seed itself. There has been no other report of this. Pupae, brown and ca. 2.5 mm in length, require 9–23 days to complete development (Ahmad, 1938).

The total larval and pupal development period requires 6–11 and 9–23 days respectively (Ahmad, 1938). Slightly shorter development times have been

Table 2. Host plants of *Melanagromyza obtusa*

Host plant	Reference
Cajanus albicans (Wight and Arnott) van der Maeson	Sithanantham *et al.*, 1981
C. cajan (L.) Millspaugh	Maxwell-Lefroy, 1906
C. cajanifolius (Haines) van der Maeson	Jadhav *et al.*, 1983
C. platycarpus (Bentham) van der Maeson	Jadhav *et al.*, 1983
C. sericeus (Bentham ex Baker) van der Maeson	ICRISAT (unpublished)
C. volubilis (Blanco) Blanco	Jadhav *et al.*, 1983
Dunbaria spp.	ICRISAT, 1986
Flemingia macrophylla (Willdenow) Prain ex Merrill (= *F. congesta* Roxburgh)	Sehgal, 1965
F. stricta Roxburgh	ICRISAT, 1984
F. strobilifera (L.) Aiton	ICRISAT, 1984
Rhynchosia aurea de Candolle	Sithanantham *et al.*, 1981
R. bracteata Bentham ex Baker	ICRISAT, 1982
R. cana de Candolle	ICRISAT, 1982
R. minima (L.) de Candolle	Sithanantham *et al.*, 1981
R. rothii Bentham ex Aitchison	ICRISAT, 1982
R. rufescens de Candolle	ICRISAT, 1984
R. suaveolens de Candolle	ICRISAT, 1982
R. sublobata (Schumacher) Meikle	ICRISAT, 1984
Tephrosia purpurea (L.) Persoon	Sithanantham *et al.*, 1981

reported and may reflect higher temperatures experienced in the field (Bindra and Singh, 1972; Singh and Rai, 1984). Temperature-dependent growth rates (*Figure 1*) have been calculated for each of the immature stages of *M. obtusa* using data from Ahmad (1938), Ipe (1974) and Singh and Rai (1984). Linear regression analysis of egg development times at different temperatures ($y = 0.371 + 0.027x$; $r^2 = 0.97$) indicates that the threshold temperature for egg development is 13.7°C. Similar analyses for larval ($y = 0.114 + 0.010x$; $r^2 = 0.60$) and pupal ($y = 0.123 + 0.009x$; $r^2 = 0.97$) development rates produced the following developmental thresholds: larvae = 11.4°C and pupae = 13.7°C. These thresholds, and the developmental rates from which they are derived, need to be verified with a complete and independent data set.

The window cut by the fully grown larva, and covered only by translucent epidermal cells, serves as the adult fly's exit from the pod. It is likely that adults orient to the exit through a positive phototactic response (Ahmad, 1938). Adults are relatively short

lived. At low temperatures adults live for fewer than 12 days, while at higher temperatures longevity declines to 5–7 days (Ahmad, 1938). Adults maintained without food live about half as long as adults supplied with honey (Ahmad, 1938).

Oviposition

Adults mate 2–5 days after emergence and females select a site for oviposition. Females lay single eggs and require 2–4 min to deposit each egg (Ipe, 1974). Generally, a single egg is laid per locule, although as many as 22 eggs have been found in a single pod (Ipe, 1974). It is not known whether females 'mark' oviposition sites to prevent subsequent females from depositing eggs in the same locule. Ipe (1974) reports that an average of four eggs per pigeonpea pod were found in a heavily infested field.

Sithanantham *et al.* (1981) reported a slight but non-significant tendency for more *M. obtusa* eggs to be found in pods in the upper third of pigeonpea
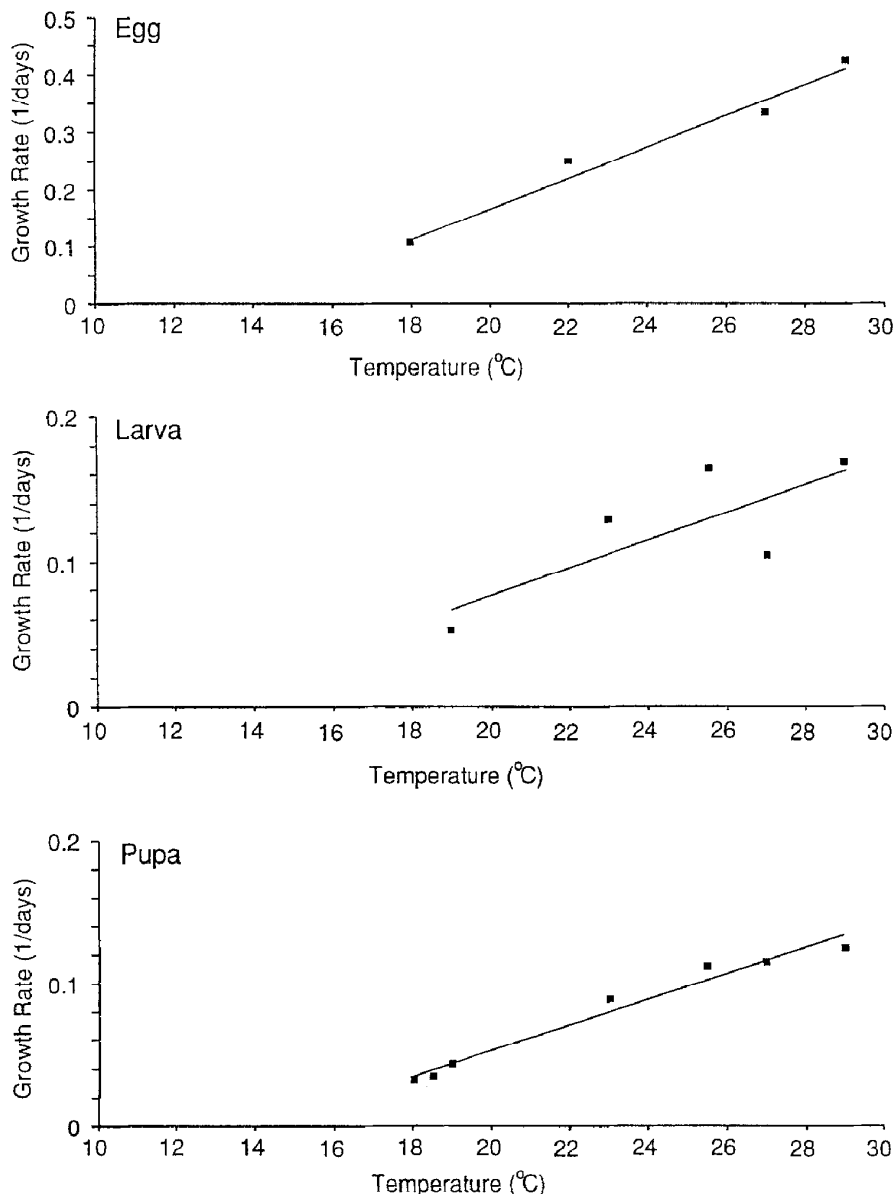

Figure 1. Growth rates for *Melanagromyza obtusa* eggs, larvae and pupae (data from Ahmad, 1938; Ipe, 1974; Singh and Rai, 1984).

plants compared to the middle or lower portions. Kaushik *et al.* (1988) divided plants into four areas: upper, upper–middle, lower–middle and lower. They found 70% of eggs in pods from the middle two regions of the plant, and fewest eggs in pods from the upper portion. These authors noted that the middle portion of the plant bears the majority of the pods but did not account for the difference in pod number between areas. It may be that the number of available pods is a more important ovipositional cue for females than the location of pods on the plant. The preference for pods located in different areas of the plant probably does not reflect a preference for pods of specific ages (see below). The most commonly cultivated pigeonpea cultivars are indeterminate in growth and have pods of different ages simultaneously available in upper, middle and lower portions of the plant.

The 'within-pod' distribution of pod fly eggs has also been investigated. Several workers have noted that more eggs are placed near the ventral suture than either lateral areas or near the dorsal suture of pods (Sithanantham *et al.*, 1981; Singh *et al.*, 1982; Lal *et al.*, 1988). In this position eggs are furthest from the developing seed and may be less likely to be crushed (Sithanantham *et al.*, 1981). This position, on the underside of the pod, may also be less accessible to some natural enemies. Females also select locules for oviposition in a non-random manner. Singh *et al.* (1982) found that the fewest eggs were placed in the basal locule, with equal numbers in the middle and apical locules. Other workers reported that middle locules are favoured, and that fewest eggs are found in apical locules (Lal *et al.*, 1988).

Pod age and size have been shown to influence the selection of oviposition sites by *M. obtusa*. Singh *et al.* (1982) reported that younger ('green') pods are preferred to older pods for oviposition. Lal *et al.* (1988) found that as the season progressed, females selected younger pods for oviposition. In January, females preferred 30–35-day-old pods while in April, females preferred 10–20-day-old pods (Lal *et al.*, 1988). These workers believed that as daily mean temperatures increased from January to April, pod growth and, hence suitability to pod fly, changed. It may also be that pod fly populations increase during this same period, forcing females to select younger pods for oviposition.

Veda *et al.* (1975) were the first to note a positive correlation ($r = 0.24$) between pod width and the percentage of infested grain. Strong correlations have been recorded between both pod width ($r = 0.98$) and pod length ($r = 0.99$), and per cent grain damage in another study (Thakur *et al.*, 1989). Lal *et al.* (1988) noted that small pods had less pod fly damage than larger pods while Tripathi and Prohit (1983) found that small pods were more heavily damaged. All of these reports assume that greater damage levels reflect preferential selection by females.

Seasonality

The seasonal population dynamics of *M. obtusa* are governed by its restricted host range and feeding niche. In India, pigeonpea pods are available in the field from approximately October to April. Pod fly infestations can increase rapidly over a relatively short period (Rangaiah and Sehgal, 1986). As temperatures decline in December and January, *M. obtusa* ovipositional activity also declines (Ahmad, 1938; Srivastava *et al.*, 1991). However, infestations increase along with temperatures and pigeonpea which matures in March or April is often heavily damaged (Lal *et al.*, 1981; Yadava *et al.*, 1983a).

The population dynamics of *M. obtusa* on host plants other than pigeonpea have not been well studied. Kulkarni (1966) found pods of *F. macrophylla* infested from mid-November through to mid-February. This plant supports *M. obtusa* in uncultivated areas and can produce flowers and pods in the summer (Sithanantham and Sehgal, 1985). Khokhar *et al.* (1987) found up to 19% of pods of *Rhyncosia minima* infested with eggs, larvae and/or pupae of *M. obtusa* between April and November. Thus, it appears that *M. obtusa* survives in the off-season on alternative host plants.

Damage, yield loss and monitoring

Melanagromyza obtusa is of economic importance only in the larval stage. Larvae damage pigeonpea and reduce yield by feeding on and destroying the developing seed. Damaged seeds do not germinate (Singh and Singh, 1986), and may or may not be consumed, depending on the level of damage. Even slightly damaged seed receives a lower price in the market. Damage and yield losses vary across locations, seasons and cultivars, and it is difficult to estimate losses due to this pest. A large number of reports of damage to pigeonpea by *M. obtusa* is available. Insect damage to pigeonpea is often reported in terms of pod damage. For *M. obtusa* this is not a useful indication of damage or yield loss since there may be five or more seeds per pod and *M. obtusa* rarely damages all of the seeds in a pod. For this reason Bindra and Jokhmola (1967) suggested that pod fly damage be reported in terms of grain or seed damage.

Two methods have been suggested for computing yield loss in pigeonpea from information on *M. obtusa* damage. The difference in the methods depends on the suitability of damaged grains for human consumption. If infested grains are not fit for consumption, as Gangrade (1965) stated, then yield loss is equal to the percentage of damaged seeds (e.g. 16% damaged seeds would equal 16% yield loss). This figure would represent the maximum yield loss as each seed damaged would be considered unusable. Gangrade (1965) used this reasoning but underestimated yield losses by using the weight rather than the number of damaged seeds and dividing by the total weight, including damaged seeds, in a sample.

Bindra and Jokhmola (1967) noted the problem in Gangrade's method and suggested that damaged seeds were not a total loss. They calculated that yield loss is equal to the reduction in weight of damaged seeds divided by the proportion of *M. obtusa*

damaged seeds:yield loss (%) = [(wt of undamaged seeds – wt of damaged seeds)/wt of undamaged seeds]/proportion of seeds damaged by *M. obtusa*. The reduction in seed mass due to *M. obtusa* is calculated using an equivalent number of damaged and undamaged seeds.

It is unclear which method is more accurate although many authors have followed the latter methodology to express yield loss (see below). The first method is calculated more easily since pest incidence (percentage of damaged seeds) equals yield loss. It may also be more accurate if, as is likely, damaged seeds are discarded during the harvesting and milling process. If damaged seeds are in fact utilized for human or animal consumption then the second method will be more accurate. The second method requires the additional step of calculating the reduction in seed mass due to *M. obtusa*.

Most of the data on *M. obtusa* damage and yield loss has been obtained from trials on research stations. *Table 3* provides a selected list of published reports of seed damage by *M. obtusa* at research stations in India, Taiwan and Vietnam. Results in this table indicate seed damage of between 2% and more than 90%, with large variations across locations, seasons and genotypes. While useful, research stations rarely provide conditions similar to farmers' fields. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and ICAR (Indian Council of Agricultural Research) entomologists surveyed pigeonpea fields in India for insect pest damage from 1975 to 1981. It was observed that *M. obtusa* was a more serious pest in the northern and central areas of India than in the southern or north-western areas. Nonetheless, seed damage of more than 30% was reported from some districts of the southern state of Andhra Pradesh (Lateef and Reed, 1983). Several other publications have also reported *M. obtusa* damage levels in farmers' fields. Extensive surveys carried out in the northern state of Uttar Pradesh revealed that pod fly damage in farmers' fields ranged from 14 to 46% of pigeonpea seeds (Lal

et al., 1992). In Madhya Pradesh, *M. obtusa* was recorded damaging up to 20% of pigeonpea seeds in farmers' fields (Odak *et al.*, 1976; Sithanantham and Singh, 1986). Seed damage due to pod fly ranged from 2.6 to 11% in 11 districts of Gujarat over a 2 year period (Kabaria *et al.*, 1988). Pod fly is the most destructive pest of pigeonpea in northern Vietnam, causing extensive losses in pigeonpea yields in four Provinces (Hong *et al.*, 1992). The conclusion from both on-farm and on-station observations (*Table 3*) is that *M. obtusa* regularly causes substantial but highly variable yield losses in pigeonpea.

Because all of the immature stages of *M. obtusa* occur within the developing pod it is difficult to monitor populations in a non-destructive manner. Several workers have tried to develop methods to monitor adult populations. Sithanantham *et al.* (1988) evaluated a wide variety of trap designs, colours, attractants and even virgin male and female flies. Although they recorded positive attraction to ethanol and ammonium sulphide, the response was too weak to be considered useful for monitoring field populations. More recently, Mohan *et al.* (1994) developed a simple sticky trap for monitoring pod fly in the field, and reported catching up to 60 flies per week. The trap developed by Mohan *et al.* caught more than 6 × the number of adult flies caught in the traps developed by Sithanantham *et al.*, but whether these traps will monitor field populations accurately is unknown. Placing traps in different fields at different times of the year and correlating the number of adults caught with the density of *M. obtusa* eggs would provide an indication of the traps usefulness as a monitoring tool.

Natural enemies

The only natural enemies of *M. obtusa* reported thus far are parasitic Hymenoptera. No predators, pathogens or non-hymenopterous parasitoids are known. At least 14 species of Hymenoptera have been

Table 3. Selected reports of pigeonpea (Cajanus cajan) seed yield losses due to *Melanagromyza obtusa*

Reference	Year of research	Location[1]	Loss attributable to *M. obtusa*
Bindra and Jokhmola, 1967	1955–56 and 1957–58	Jabalpur, Madhya Pradesh	4–43% grain damage in 43 genotypes
Gangrade, 1963	1959–60 and 1960–61	Jabalpur, Madhya Pradesh	13–87% grain damage in different flushes of 4 cultivars
Rawat and Jakhmola, 1967	1966	Jabalpur, Madhya Pradesh	2–11% grain yield loss in 8 cultivars
Patel and Patel, 1983	1975–76	Anand, Gujarat	7–23% grain damage in 14 genotypes
Reddy *et al.*, 1981	1978–79	Varanasi, Uttar Pradesh	20–46% seed damage in 16 long duration cultivars
Bhosale and Nawale, 1985	1978–79	Rahuri, Maharashtra	5–15%, 8–20% and 12–31% grain damage in early (11 lines), medium (22 lines) and late (7 lines) genotypes
Naresh *et al.*, 1983	1980	Hisar, Haryana	4–12% grain damage in 8 cultivars
Naresh and Singh, 1984	1980	Hisar, Haryana	<2% grain damage in cultivar Prabhat (early)
Pandey *et al.*, 1984	?	Navgaon, Rajasthan	16–45% grain infestation in 18 cultivars
Patnaik and Patnaik, 1985	1983–84	Sambalpur, Orissa	13–30% grain damage in 7 early genotypes
Bhalani and Parsana, 1992	1984 and 1986	Junagadh, Gujarat	2–12% and 4–10% grain damage in extra-short (33 lines) and short (12 lines) genotypes
Yadava *et al.*, 1988	1984–85 and 1985–86	Kanpur, Uttar Pradesh	9–30% grain damage in 4 cultivars
Veda and Shaw, 1992	1988–89	Jhabua, Madhya Pradesh	0–3% grain loss in ICPL 87
Borad *et al.*, 1991	1988–89 and 1989–90	Anand, Gujarat	24–40% grain damage in 15 genotypes
Talekar, 1988	1985–86	Shanhua, Taiwan	43% seed damage
Hong *et al.*, 1992	1990	Hanoi, Vietnam	88–99% seed damage in 6 cultivars

[1]India, unless otherwise noted.

recorded as parasitoids of *M. obtusa* (*Table 4*). Most of the studies on *M. obtusa*'s natural enemies have focused on three groups of parasitoids: *Euderus* spp. (Eulophidae), *Eurytoma* sp. (Eurytomidae) and *Ormyrus* spp. (Ormyridae). *Euderus lividus* (Ashmead) (Eulophidae) was the first parasitoid of *M. obtusa* reported (Ahmad, 1938). Mani (1939) studied a series reared by Ahmad and noted a wide range in adult size and coloration. *Euderus* spp. are ectoparasitoids. Females of *E. agromyzae* Gangrade (Eulophidae) usually deposit one egg per host, although up to five have been observed (Gangrade, 1962) while *E. lividus* females deposit up to nine eggs per host (Ahmad, 1940). It was earlier thought that females oviposited through the exit hole cut by the last instar *M. obtusa* larva. This would restrict these parasitoids to attacking final instar larvae. Singh (1991) however, found that second instars collected from the field had already been parasitized by *E. lividus*. The immature stages of both *Euderus* spp. last for 25–45 days depending on temperature (Ahmad, 1940; Gangrade, 1962; Singh *et al.*, 1991). Gangrade (1962) and Singh *et al.* (1991) give detailed accounts of the biology and development of *E. agromyzae* and *E. lividus* respectively. *Euderus* spp. are widespread in India, occuring in 10 of the 11 states surveyed, and are the first or second most common parasitoid of *M. obtusa* (Sithanantham *et al.*, 1987). Parasitism rates of more than 25% have been reported for this group (Ahmad, 1940; Thakur and Odak, 1982). In Sri Lanka, *Euderus* sp. is less common, emerging from only 2% of hosts (Fellowes and Amarasena, 1977). *Euderus* sp. has also been reared from *M. obtusa* on pigeonpea in the Philippines (Litsinger, pers. commun. in Talekar, 1990).

Both *Ormyrus orientalis* (Walker) and *O. fredricki* Narendran (Ormyridae) emerge from pod fly puparia and most authors consider them primary parasitoids,

although this has not been confirmed. Singh and Singh (1991) reported *O. orientalis* ovipositing in host pupae while Singh (1991) observed *O. orientalis* attacking third instar larvae. The developmental biology and immature stages have been described by Singh and Singh (1991). *Ormyrus orientalis* is widespread in India but generally <6% parasitism is reported (Sithanantham *et al.*, 1983; Sebastian, 1993). Parasitism levels of 12.5% have been recorded in central India (Thakur and Odak, 1982) and 30% from Sri Lanka (Fellowes and Amarasena, 1977). *Ormyrus fredricki* has recently been reported from India, but no information on its biology is available (Peter, 1992).

Eurytoma sp. females oviposit on final instar *M. obtusa* larvae or between the host body and the puparium and emerge from the pupal stage (Singh, 1994). The immature stages are completed in approximately 35 days under laboratory conditions (Singh *et al.*, 1991). This parasitoid is less widespread in India, recorded from 7 of 11 states surveyed, and is of relatively minor importance, occuring in <2% of samples in both India and Sri Lanka (Sithanantham *et al.*, 1983; Fellowes and Amarasena, 1977). It has also been reported from the Philippines (Litsinger, pers. commun., in Talekar, 1990).

The other parasitoids of *M. obtusa* have been less well studied. Two *Bracon* spp. (Braconidae) have been obtained from *M. obtusa* on *F. macrophylla* (Sah and Mehra, 1986) but not on pigeonpea. No information on the biology, ecology or incidence has been reported for *Plutarchia*. Sithanantham *et al.* (1987) indicate that *Antistrophoplex* (Torymidae) may be a hyperparasitoid. The genus *Antistrophoplex* has been synonomized with the valid genus *Microdontomerus* (Grissell, pers. commun., 1997). There are no other species of *Microdontomerus* reported from India and Grissell suggests that the record of *Antistrophoplex*

Table 4. Parasitoids reared from *Melanagromyza obtusa*

Family	Species	Reference
Braconidae		
	Bracon sp.	Sah and Mehra, 1986
	B. fletcheri Silvestri	Sah and Mehra, 1986
Diapriidae		
	Trichopria sp.	Thakur and Odak, 1982
Eulophidae		
	Euderus sp.	Sithanantham *et al.*, 1987
	E. agromyzae Gangrade	Gangrade, 1960
	E. lividus (Ashmead)	Ahmad, 1938
	Diglyphus funicularis Khan	Khan, 1985
	D. mandibularis Khan	Khan, 1985
	Tetrastichus atomella Khan	Ipe, 1987
Eupelmidae		
	Eupelmus sp.	Thakur and Odak, 1982
	E. urozonus Datman	Fellowes and Amarasena, 1977
Eurytomidae		
	Eurytoma sp. *robusta* Mayr group	Sithanantham *et al.*, 1987
	Plutarchia sp. nr. *indefensa* (Walker)	Sithanantham *et al.*, 1987
Ormyridae		
	Ormyrus fredricki Narendran	Peter, 1992
	O. orientalis (Walker)	Fellowes and Amarasena, 1977
Torymidae		
	Microdontomerus (= *Antistrophoplex*) sp.*	Sithanantham *et al.*, 1983
	Pseudotorymus (= *Senegalella*) sp.	Singh *et al.*, 1991

*Possible mis-identification of *Pseudotorymus* sp. (Grissell, pers. commun., 1997).

could be a misidentification of a species of *Pseudo-torymus* (Torymidae), a genus reliably known from India. *Senegalella* sp. is a larval–pupal ecto-parasitoid which attacks third instar *M. obtusa* larvae (Singh, 1994). This genus has recently been synonomized and is now correctly referred to as *Pseudotorymus* (Torymidae) (Grissell, 1995). The immature stages and adult have been described by Singh and Manwani (1993). Total immature development time requires 15–35 days (Singh, 1994). Thakur and Odak (1982) reported that *Trichopria* sp. (Diapriidae), *Eupelmus* sp. and *E. urozonus* Datman (Eupelmidae) parasitized 18%, 12.5% and 9.5%, of available hosts in central India, respectively. They provide no information about the size or frequency of samples collected in this study. The high parasitism levels reported for *Trichopria* sp. are questionable, especially as this parasitoid has not been reported in any other study. *Eupelmus urozonus* is also present in Sri Lanka, where 2% parasitism was reported in the only available study (Fellowes and Amarasena, 1977).

The seasonal abundance and/or impact of *M. obtusa* parasitoids may be related to environmental temperatures. Ahmad (1940) observed that *E. lividus* was rare during the winter and found that its high developmental threshold made it less effective at low temperatures. Singh (1992) reported less activity in December, when temperatures are lower, for three parasitoids on long duration pigeonpea. Other authors have reported parasitism levels of 3–21% in December in different Indian states (Sebastian, 1993; Sithanantham *et al.*, 1983). Research at ICRISAT over 5 years showed combined parasitism levels of 7–18% in December, but the mean was only slightly lower than in November and January (Sithanantham *et al.*, 1987).

It is difficult to evaluate the effectiveness of the parasitoids which attack *M. obtusa* because in most reports the number of hosts collected have not been given. Although parasitism levels may reach 50% by the end of the pigeonpea season (Ahmad, 1940), the guild of parasitoids which attack *M. obtusa* are reportedly not effective in minimizing damage and yield losses. Detailed life-table studies would establish the importance of natural enemies in pod fly population dynamics.

Host-plant resistance

Host-plant resistance is one of the most important and widely used components in integrated pest management. Pest resistant cultivars, when available, provide a sustainable solution at relatively low cost to a wide variety of farmers. Host-plant resistance has significant advantages over other pest control strategies in situations where:

1. an insect is exposed for only a brief period of its life cycle;
2. the crop is of low economic value;
3. the pest is continuously present and is the single most limiting factor in successful cultivation of a crop in a wide area;

4. other controls are not available (Ortman and Peters, 1980).

These four conditions apply to *M. obtusa* on pigeonpea throughout much of its range.

Host evasion

Host evasion is one of several phenomena which results in apparent resistance by some genotypes relative to others. Asynchrony between insect pest and host-plant phenologies results in plants or genotypes which escape or avoid peak pest attack and damage. Yadava *et al.* (1983a) found that the relative time of maturity in pigeonpea greatly influences the quality and quantity of damage by *M. obtusa*. They observed that pigeonpea cultivars which matured at the end of November in India exhibited only 4% seed damage due to pod fly while cultivars harvested in mid-February suffered 11% seed damage, and those harvested in the last week of April had 35% seed damage. Lal *et al.* (1988) confirmed that in northern India early maturing varieties showed low pod fly damage (13% seed damage) in comparison to late maturing varieties (27–35% seed damage). Pigeonpea cultivars which mature early can avoid substantial damage from *M. obtusa*.

The use of determinate versus indeterminate pigeonpea genotypes also acts as a host evasion strategy. Determinate type pigeonpea genotypes suffer less pod fly damage than in indeterminate plant types. Seed damage in a determinate genotype was 9–13% lower than in an indeterminate genotype of similar duration over a 3 year period (Lal *et al.*, 1986). Gupta *et al.* (1991), using data from a number of trials conducted over 5 years at Hisar in northern India, reported a similar result. The reason for the higher pod fly damage in the indeterminate genotype was because of the continuous availability of immature pods, the preferred stage for pod fly oviposition and development, in these genotypes (Lal *et al.*, 1986). The relatively high levels of natural out-crossing in pigeonpea has produced a mixture of highly heterogeneous, asynchronous and indeterminate plant types in farmers fields, particularly in medium- and long-duration genotypes (Laxman Singh *et al.*, 1990). The consequence of this is an extended reproductive phase with immature pods being available for as long as 4 months, allowing many generations of pod fly to develop resulting in high populations (DPR, 1987). Unpublished results from the Indian Institute of Pulses Research (IIPR) suggest that by synchronizing and restricting the reproductive phase of pigeonpea, damage from pod fly can be reduced.

Genetic resistance

Pigeonpea is a self-pollinated crop, although out-crossing is common (Bhatia *et al.*, 1981; Prasad *et al.*, 1972). Segregation therefore has been a major hurdle to incorporating resistance into preferred plant types. The identification and development of promising and

reliable sources of resistance to pod fly in pigeonpea has progressed by advancing single plant selections for 5–7 years (Dias *et al.*, 1981; Reed and Lateef, 1990). Much of this work has been conducted over the past 20 years at ICRISAT, IIPR and collaborating centers of the All India Coordinated Pulse Improvement Project (AICPIP).

Evaluation of pigeonpea germplasm for reduced susceptibility to pod fly was initiated at ICRISAT in 1975 (Davies and Lateef, 1978; Lateef, 1977). A methodology for open field screening was developed in which material was compared with check cultivars of similar maturity under pesticide free conditions. Promising selections were advanced through selfed seeds for up to 4 years in replicated trials. In these trials selections are grouped into narrow maturity ranges and evaluated under sprayed and unsprayed conditions (Lateef and Reed, 1981; Reed and Lateef, 1990). The large plant size (2 m and above), long growing season (140–300 days), ability to compensate for damage with multiple flushes of flowers and high incidence of out-crossing have all posed problems and slowed progress. A method of grading test materials based on pod damage relative to standard controls and converted to a scale of 1–9 was developed to deal with the problem of seasonal and yearly variations in the intensity of infestations and confusing relative performance across localities and years (Lateef and Reed, 1985).

ICRISAT screened more than 10,000 germplasm accessions and breeding lines for resistance to *M. obtusa* under pesticide-free open field plots over a period of 6–11 years per selection (Lateef and Pimbert, 1990). Several lines, including material in short, medium and long duration maturity groups, have shown consistent resistance to *M. obtusa* (*Table* 5). Some of this material has also been evaluated in multi-location trials in the Indian national programme through the AICPIP network (*Table* 6). The Indian Institute of Pulses Research (IIPR) has worked extensively on host plant resistance to pod fly in medium- and long-duration pigeonpea. After identifying tolerant/resistant single plant selections, progeny were advanced through selfed seeds for 6–8 years. In addition, more than 3000 lines were screened between 1978 and 1990 and another 2033 pigeonpea accessions were screened from 1991 to 1994. Among the latter, 8.3% suffered less than 5% pod damage and were considered promising for further evaluation. Ten pigeonpea selections (ICRISAT 16, 166-2-1, ICP 7946-1-3-3, ICP 127, SL 12-3-1, 41-3-3, PDA 88-2E-3-1, ICP 3401, ICP 7950 and ICP 12304) were identified as highly promising after extensive testing (Lal, 1996). Many of these selections have been evaluated in multi-location and multi-year testing through the AICPIP network and have shown stable and consistent performance (*Tables* 6 and 7). Two selections, PDA 88-2E and PDA 89-2E, have been used as donors in the pod fly resistance breeding programme (Lal, 1996).

The genus *Cajanus* has been reorganized to incorporate the genus *Atylosia* (van der Maesen, 1985). One wild species, *C. scarabaeoides* (formerly *A. scarabaeoides*), is considered highly resistant to *M. obtusa*

Table 5. Pigeonpea genotypes with resistance to pod fly, *Melanagromyza obtusa*, ICRISAT Asia Center, 1979-91

Genotype	Mean resistance rating[2]	Range of pod fly damage (%)
Short duration		
ICP 909-E3	4.2 (11)[3]	1-25
Control (T-21)	6.0 (11)	1-15
Medium duration		
ICP 7050-E1	2.6 (7)	1-14
ICP 10531-E1	3.8 (11)	1-26
ICP 7941-E1	3.7 (9)	2-22
ICP 7946-E1	3.6 (11)	2-14
ICP 6977-E1	3.5 (6)	1-22
ICP 7194-S4	4.2 (9)	3-24
Controls		
BDN 1	6.0 (10)	1-31
C 11	6.0 (11)	3-30
Long duration		
ICP 8102-5-S1	5.3 (11)	7-27
ICP 8094-2-S2	5.3 (11)	11-30
ICP 7176-5	4.6 (11)	6-23
Controls		
Bahar	6.0 (2)	34
ICP 6443	6.0 (11)	13-32
PPE 36-2	7.7 (7)	17-44

[1]Source: ICRISAT, 1991.
[2]Relative resistance rating in comparison with controls scored on a scale of 1–9, where 1 = resistant, 9 = susceptible.
[3]Figures in parentheses indicate number of years tested.

(Saxena *et al.*, 1990). Observations over 5 years at ICRISAT-Patancheru revealed that <1% of *C. scarabaeoides* pods were infested by *M. obtusa* (Crop Protection Division, unpublished data). Although this wild species appears to be a good source of resistance there is little knowledge of the mechanism of resistance and there have been no attempts to transfer resistance to pigeonpea. Reed and Lateef (1990) considered this approach to be less productive than searching for resistance within the *C. cajan* germplasm.

Table 6. Results of multilocation evaluation of pigeonpea genotypes with resistance to pod fly, *Melanagromyza obtusa*, by the All India Coordinated Pulses Improvement Project (AICPIP), 1988-95[1]

Genotype	Mean resistance rating[2]	Range of pod fly damage (%)
PDA 92-3E	3.7 (5/4)[3]	5.8-37.0
PDA 89-2E	3.7 (5/5)	4.8-37.5
PDA 92-1E	5.0 (5/2)	6.6-54.0
PDA 92-2E	4.0 (5/3)	8.1-49.7
PDA 88-2E	3.5 (6/5)	3.0-37.7
PDA 93-2E	4.4 (5/5)	14.2-42.3
PDA 88-1E	4.0 (4/4)	8.9-39.0
PDA 93-1E	4.4 (2/2)	27.7-44.3
PDA 91-2E	5.5 (2/1)	12.7-21.3
PDA 88-3E	4.4 (3/3)	13.9-37.0
PDA 89-3E	3.8 (3/3)	8.0-28.5
Bahar (Ch.)	5.8 (6/6)	12.9-64.0
NP(WR)-15	5.0 (5/5)	8.5-53.8
MA-2	4.6 (4/6)	11.5-40.3

[1]Source: AICPIP Annual Reports (1988–89 to 1994–95).
[2]Relative resistance rating in comparison with controls scored on a scale of 1–9, where 1 = resistant, 9 = susceptible.
[3]Figures in parentheses indicate number of locations and years tested.

Table 7. Per cent pod damage due to *Melanagromyza obtusa* and relative resistance rating of nine pigeonpea genotypes at four locations in India, 1994/95[1]

Genotype	ICRISAT[2]	BHU	IIPR	NDUAT	Mean
SL 21-1-3	5.5 (2)[3]	17.9 (3)	11.7 (2)	1.5 (2)	9.15 (2.25)
SL 22-2-3	1.0 (2)	2.6 (2)	3.5 (2)	2.0 (2)	2.27 (2.00)
SL 21-9-3	1.7 (2)	4.9 (2)	5.0 (2)	0.0 (1)	2.90 (1.75)
SL 21-6-2	4.8 (2)	16.5 (3)	13.0 (2)	1.5 (2)	3.95 (2.25)
SL 12-3-1	1.5 (2)	5.2 (2)	4.0 (2)	2.0 (2)	3.17 (2.00)
PDA 88-2E	3.0 (2)	7.2 (2)	9.3 (2)	2.0 (2)	5.37 (2.00)
PDA 89-2E	3.5 (2)	6.8 (2)	8.9 (2)	1.0 (2)	5.05 (2.00)
PDA 92-3E	4.1 (2)	14.2 (3)	11.8 (2)	2.0 (2)	5.03 (2.25)
PDA 93-1E	6.3 (2)	7.7 (3)	17.6 (3)	0.0 (1)	7.90 (2.25)
Controls					
Bahar	17.7 (4)	34.5 (5)	49.8 (5)	21.0 (6)	38.80 (5.00)
T-7	27.8 (6)	42.4 (6)	58.5 (6)	13.0 (4)	33.42 (5.50)

[1]Source: Lal, 1996.
[2]Locations: ICRISAT Asia Center, Patancheru, Andhra Pradesh; BHU = Banares Hindu University, Varanasi, Uttar Pradesh; IIPR = Indian Insitute of Pulses Research, Kanpur, Uttar Pradesh; NDUAT = Narender Dev University of Agriculture and Technology, Faizabad, Uttar Pradesh.
[3]Figure in parentheses are relative resistance ratings in comparison with controls scored on a scale of 1–9, where 1 = resistant, 9 = susceptible.

Mechanisms of resistance

Both ovipositional non-preference and antibiosis have been suggested as modes of resistance for *M. obtusa* (Reed and Lateef, 1990). Several plant characters have been implicated in pod fly ovipositional preference including pod trichomes, the concentrations of tannin-like substances beneath the outer epidermis, and the thickness of the fibrous cell layer above the inner epidermis (Sithanantham *et al.*, 1981). Lal and Yadava (1994) observed that resistant pigeonpea selections had fewer pod fly eggs than susceptible selections, indicating that ovipositional non-preference may be an important character in pod fly resistance.

As noted earlier a positive correlation between seed damage and both pod width and pod length has been observed in several studies (Lal *et al.*, 1988; Thakur *et al.*, 1989; Veda *et al.*, 1975). Lal *et al.* (1988) also noted that black- or brown mottled seeds showed lower pod fly damage (4.2–4.3%) than white or yellow seeds (20.6–23.5%). Similarly, sickle shaped pods with deep constrictions between seed locules were less preferred for pod fly oviposition than cultivars with shallow constrictions. The conclusion drawn from these studies is that cultivars with small pods, small, dark-coloured seeds and deep constrictions between locules would be less preferred by *M. obtusa* females and would suffer less pod fly damage. It has not been reported whether a pigeonpea cultivar with these characteristics would be acceptable to farmers.

Dass and Odak (1987) reported correlations between several biochemical characters of pigeonpea pod walls and damage by *M. obtusa*. Among the relationships they observed were negative correlations between the amount of wax, phenols, total amino acids, proline, crude fibres and ascorbic acid and pod fly incidence. They also reported a positive correlation between the amount of nitrogen and pod fly infestation. An unpublished study at IIPR compared some biochemical constituents in the pods of a resistant and a susceptible pigeonpea genotype. The resistant genotype had higher levels of phenols, triacontane and hentriacontane compared to the susceptible genotype. It is not know whether these differences are consistent among the large number of resistant genotypes which have been identified and what the role of these compounds is in resistance to pod fly.

Inheritance

Little information on the genetics and inheritance of resistance to *M. obtusa* in pigeonpea is available. The following preliminary evidence, reported by Lal (1996), indicates that inheritance of resistance appears to be additive. Studies on the general combining ability of selected pigeonpea genotypes has shown that genotypes PDA 89-5E, PDA 88-2E and PDA 89-7E, which are highly resistant to *M. obtusa*, should produce the most promising and desirable segregants. The specific combining ability represents the dominance and epistatic effects which are nonfixable in nature. Seven out of 15 crosses made in 1992–1993 (Bahar × PDA 89-5E, Bahar × BDA 88-2E, Bahar × PDA 89-7E, T-7 × PDA 89-5E, T-7 × PDA 88-2E, T-7 × PDA 89-7E and PDA 89-5E × PDA 88-2E) were good specific combiners for pod fly resistance.

The estimates of general combining ability effects were negative and significant for PDA 88-2E and PDA 89-2E for pod fly, and thus were expected to offer the most promise in breeding for useful and desirable segregants. Nine of 27 crosses evaluated during 1993-1994 (Bahar × DPPA 85-15, Bahar × PDA 88-2E, Bahar × PDA 89-2E, DPPA 8515 × ICP 8860, DPPA 85-15 × NP (WR) 15, ICP 8860 × PDA 88-2E, KPBR 80-2-1 × PDA 88-2E, KPBR 80-2-1 × PDA 89-2E and NP (WR) 15 × PDA 88-2E) were found to be good specific combiners for pod fly resistance.

Cultural control

Several cultural control practices have been investigated for their effect either in modifying pod fly

population levels or in reducing pod fly damage. Veeraswamy (1959) was the first to study the effect of sowing time on pod fly damage. In a 1 year trial, grain damage was five times lower when the crop was sown 6 weeks earlier than normal. More recently, sowing time was shown to have no effect on *M. obtusa* damage in a 2-year study in Gujarat (Kabaria *et al.*, 1990). Differences in pod damage were noted among genotypes but this was not associated with sowing time. Yadav *et al.* (1992) reported 50% less pod and grain damage when pigeonpea was sown 5 weeks early relative to normal sowing time in a 2-year study.

Intercropping with blackgram [*Vigna mungo* (L.) Hepper], mung bean (*V. radiata*), cowpea (*V. unguiculata*), sorghum [*Sorghum bicolor* (L.) Moench] or pearl millet [*Pennisetum glaucum* (L.) R.Br.] did not significantly reduce the incidence of *M. obtusa* relative to a pigeonpea monocrop (Singh and Singh, 1978). A 2-year study showed a consistent trend of lower levels of seed damage by *M. obtusa* in three short duration pigeonpea cultivars intercropped with mung bean than in monocropped pigeonpea plots (Dahiya and Chauhan, 1992). Yadav *et al.* (1992) also observed a lower incidence of *M. obtusa* and less grain damage when pigeonpea was intercropped with mung bean relative to sole pigeonpea. Plot size in both of these experiments was very small ($\leq 10 \, m^2$) and it is questionable whether a mobile insect would recognize inter-plot differences at such a small scale. Large plot evaluations are needed to confirm the benefit of reduced pod fly damage in pigeonpea by intercropping with mung bean.

The effect of fertilizer and intercultivation operations on pod fly were studied by Badaya *et al.* (1990). They found that the recommended fertilizer dose (18 kg N_2+46 kg P_2O_5 ha^{-1}) and two hand weedings+ one interrow cultivation both singly and in combination, resulted in significantly less grain damage due to podfly than the control. Yadav *et al.* (1992) noted small and inconsistent differences in the effect of phosphorus fertilizer on *M. obtusa* incidence and damage.

Chemical control

There is a voluminous and often confusing array of reports on chemical control of *M. obtusa* in pigeonpea. A wide range of chemical insecticides has been tested, most frequently as liquid formulations. All of the insecticides which have been evaluated have been found to reduce grain damage and/or increase yields relative to untreated control plots in one or more studies. The first insecticides were tested in the early 1960s and included BHC, DDT, dipterex, endrin, parathion, dieldrin and methyl demeton. Among these DDT, dipterex and endrin provided the best control (David, 1964; Srivastava and Srivastava, 1966). More recently organophosphate, carbamate and synthetic pyrethroid insecticides have been evaluated for pod fly control. The insecticides most frequently reported as providing effective control against pod fly in pigeonpea are endosulfan, quin-

alphos, monocrotophos, dimethoate, methamidophos, fenavalerate, cypermethrin and decamethrin (Bhalani and Parsana, 1991; Lal and Yadava, 1988; Patil *et al.*, 1990; Prasad and Singh, 1992; Sahu *et al.*, 1991; Singh *et al.*, 1988; Sontakke and Mishra, 1991).

Several formulations of neem (*Azadirachta indica* A. Juss.) extracts and karanj [*Pongamia pinnata* (L.)] oil have been evaluated for control of pod fly. Five and eight per cent neem seed kernel extracts (Dhanorkar and Daware, 1979; Pandao *et al.*, 1993; Srivastava *et al.*, 1984; Thakre *et al.*, 1981), 2% ethanolic extract of neem seed kernels and 10% neem oil (Singh *et al.*, 1985) treatments resulted in less pod fly damage and/or higher yields than untreated control treatments. Many commercial formulations of azadiractin are now available and this may increase interest in using neem to control pod fly. Two per cent karanj oil (Sundara Babu and Rajasekaran, 1984) and 0.2% karanj oil+1% soap (Degaonkar *et al.*, 1988) were also found to be effective in reducing levels of pod fly damage relative to untreated control plots.

Because the immature stages of the pod fly are concealed within the pigeonpea pod, systemic insecticides provide more effective control than contact insecticides. Several systemic insecticides, including thiometon and formothion, have produced high levels of egg and larval mortality in field tests (Singh *et al.*, 1984). Lal and Yadava (1988) compared the effectiveness of granular systemic insecticides applied at planting with foliar applications at podding stage. They found that two applications of 0.05% dimethoate gave better control than soil applications of carbofuran, disulfoton and phorate at planting, although all treatments suffered less damage than control plots. *Melanagromyza obtusa* attacks pigeonpea in the reproductive phase (40 or more days after sowing) and it is unlikely that the effect of the soil applied systemic insecticides remain for more than 30 days after application.

Several studies have shown that two and three applications are more effective in reducing pod fly infestations than single applications of the same insecticide (Bhadauria *et al.*, 1991; Singh and Rai, 1985; Sinha and Srivastava, 1989). Typical of these reports is the data presented by Yadava *et al.* (1983b) who reported 14% grain damage in untreated plots, 7% damage with one, 5% damage with two and 3% damage with three sprays of monocrotophos (0.04%). The superior performance of two and three sprays is due partly to the 'calendar spray' approach which is used to time insecticide applications in pigeonpea. The first application is made at the flowering stage and the second and third sprays are applied 1 and 2 weeks later. *Melanagromyza obtusa* prefers to oviposit in tender green pods and pesticide application timed to coincide with this stage will be more effective than sprays at either earlier or later stages (Bhadauria *et al.*, 1991).

The current control recommendations for *M. obtusa* on pigeonpea in India are three sprays of monocrotophos 36EC 0.04%, endosulfan 35EC 0.07% or ekalux 25EC 0.05%, all applied at 500-1000 water ha^{-1}. The first application is made at

pod initiation stage and the second and third sprays at 10-day intervals (Sachan, 1995). There has been no report of insecticide resistance in *M. obtusa* but this has not been investigated. The impact of chemical pesticides on natural enemies and their interaction with host-plant resistance has also not been investigated.

Future research needs

Research over the past 50 years has provided a good understanding of the biology, ecology and management of *M. obtusa*. There are however, several areas in which further research is needed. Detailed studies of pod fly population dynamics, including the role of alternate host plants and interactions with natural enemies, are lacking. These studies will clarify the seasonal dynamics of pod fly populations and provide a better understanding of the influence of natural enemies in regulating population fluctuations. These studies will also answer questions about whether *M. obtusa* uses diapause or aestivation to survive the dry season.

The potential for developing pigeonpea cultivars with high levels of resistance to pod fly appears to be good. Several genotypes within the pigeonpea germplasm have already been identified. It would be useful to identify the mechanisms which provide resistance to *M. obtusa* so that pigeonpea and wild species germplasm could be utilized more effectively. The resistant genotypes need to be combined with high yield and consumer-preferred agronomic characteristics before they will be accepted by farmers. The identification of resistance mechanisms and the development of resistant pigeonpea cultivars would be greatly enhanced by techniques to artificially rear *M. obtusa*. This would permit rapid evaluation of specific mechanisms under controlled conditions.

Two other management strategies, intercropping and insecticides, have shown promise in research station trials. Intercropping pigeonpea with mung bean needs to be tested in large plots to verify its efficacy before this strategy can be recommended to farmers. The economics of chemical control should be calculated and a simple but effective set of recommendations developed. The longer term goal of pigeonpea entomologists must be to improve host-plant resistance and the effectiveness of pod fly natural enemies in order to make pesticide application unnecessary.

Acknowledgements

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