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BIOLOGICAL CONTROL OF PESTS:
ITS POTENTIAL IN WEST AFRICA

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BIOLOGICAL CONTROL OF INSECT PESTS OF SORGHUM AND PEARL MILLET IN WEST AFRICA*

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Abstract

Present situation of insect pests of sorghum and pearl millet in West Africa is summarized. Notes on distribution and host range of parasites, predators and pathogens are presented and the scope of biological control is discussed. Among parasites reported from West Africa : Apanteles sesamiae Cam., Tetrastichus atriclavus Wts., Pediobius furvus Gah., Hyperchalcidia soudanensis Stef., Sturmiopsis parasitica Curr. are major parasites of stemborers and Tetrastichus diplosidis Crawf. and Eupelmus popa Gir. are of grain midges. Ants, coccinellids, syrphids and bugs may prove useful as potential predators. Surveys and further studies on insect pests and natural enemies are suggested.

I - Introduction

In West Africa, sorghum (Sorghum bicolor (L.) Moench) and pearl millet (Pennisetum typhoides Stapf. & Hubb.) are the major food crops occupying an area of about 17 million hectares. These crops are damaged by a range of insect pests. Efforts have been made to evolve suitable control strategies in order to reduce the pest populations and thus the crop losses; viz. stemborers (Harris, 1962); grain midges (Harris, 1961; Coutin, 1970 a,b); millet earhead caterpillars (Vercambre, 1978) and shootfly (Adesiyun, 1978).

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At present, few cultural practices (partial burning of stems, dates of planting etc.) are being evaluated for the control of stemborers. Similarly, work on varietal resistance to the pests of sorghum and pearl millet is underway through ICRISAT's regional programme. It is proposed that the surveys and biological and ecological studies on insect pests and their natural enemies should be undertaken. This would help in future to plan an integrated control where all suitable techniques could be used in a compatible manner to maintain the pest populations below economic injury levels.

The objective of the present paper is to review the biocontrol research in West Africa and to discuss its scope in controlling the major insect pests of sorghum and millets.

II - Major pest species on sorghum and millets

The insect pests attacking sorghum and millets have been surveyed by Risbec (1950) and Appert (1957) in Senegal and Mali; Forsyth (1960) in Ghana; Ajayi (1978) in Nigeria, Bridge et al. (1978) in the Gambia; Ndoye (1979 a) and Gahukar (1981 a) in Senegal; Bonzi (1980) in Upper Volta and Doumbia (1980) in Mali. Only the pests of economic importance are discussed here.

(i) Seedling pests : Leaf feeding beetles and shootflies (Chloropidae, Muscidae) attack these crops at seedling stage. Of the shootflies identified in West Africa, only Atherigona soccata Rond. is a major pest attacking sorghum, specially the late planted crops (Deeming, 1971; Adesiyun, 1978; Gahukar 1981 b).

(ii) Foliage pests : Young as well as old leaves are eaten, throughout plant growth, by a number of lepidopterous pests. Some are sporadic pests and complete defoliation may occur in case of early attack; viz. Spodoptera exempta Wlk., S. exigua Hb., Mythimna loreyi Dup., M. separata Wlk., Amsacta moloneyi Drc. During the prolonged droughts, aphids (Rhopalosiphum maïdis Fit.) invade young plants of sorghum and cause some reduction in yield.

(iii) Stemborers : The following stemborers have been recorded on graminaceous crops; some of them are important pests (Risbec, 1950, 1960; Harris, 1962; Brenière, 1971; Bonzi, 1977; Ndoye, 1977; Doumbia, 1980).

Busseola fusca Fuller
Sesamia calamistis Hmps.
S. penniseti Tams and Bowd.
S. poephaga Tams and Bowd.
S. cretica Led.
S. nonagrioides botenphaga Tams and Bowd.
Manga basilinea Bowd.
Acigona ignefusalis Hmps.
Eldana saccharina Wlk.

A description of life history of major borers and host plants has been given by Harris (1962). B. fusca is a major pest of sorghum and maize in most parts of tropical Africa. Whereas, S. calamistis is a polyphagous pest distributed throughout East and West Africa. Another important borer, A. ignefusalis prefers millet but also attacks sorghum and other cereals in West Africa.

(iv) Earhead pests : The sorghum midge (Contarinia sorghicola Coq.) and millet midge (Geromyia penniseti Felt.) attack flowering heads and can cause up to 100% yield loss. Biology of these pests has been studied in Senegal and Nigeria (Harris, 1961; Coutin and Harris, 1968; Coutin, 1970 a). Since 1972, a complex of species including Masalia spp., Raghuva albipunctella De Joannis; Raghuva spp., has been noticed attacking millet (Vercambre, 1978). Recent studies in Senegal confirmed that only R. albipunctella is a major pest in sahelian countries (Ndoye, 1979 b). The developing grains are devoured by Heliothis armigera Hbn., Eublemma gayneri Roths. and Pyroderces simplex Wsm. which sometimes may cause some losses.

Various species of bugs, blister beetles, thrips, jassids, earwigs, grasshoppers attack the crops during vegetative and flowering stages. Detail studies are necessary on these insects to assess the yield loss and economic injury levels.

III - Parasites, predators and pathogens on major pests

(i) Parasites : A range of hymenopterous and dipterous parasites have been reported from West Africa (Table 1). The families of these parasites are as follows :

Hymenoptera	: Braconidae
	Bethylidae
	Chalcidae
	Encyrtidae
	Eulophidae
	Eupelmidae
	Eurytomidae
	Ichneumonidae
	Platygasteridae
	Pteromalidae
	Scelionidae
Diptera	: Sarcophagidae
	Tachinidae
	Chloropidae
	Phoridae

The review of literature indicates that very little information is available on the estimation of efficacy of these parasites in the control of insect pests in West Africa. In Nigeria, Harris (1962) reported that 3 parasites (Apanteles sesamiae Cam., Tetrastichus atriclavus Wts., Pediobius furvus Gah.) were effective in controlling the larval population of B. fusca while Syzeuctus sp. was effective against A. ignefusalis; even though the level of parasitism was only 10%. Furthermore, their population varied from year to year and from

one species to another.

Recently, Ndoye (1980) studied the biology of a bethylid, Goniozus procerae Risb. which attacked less than 2% of the diapausing larvae of A. ignefusalis in Senegal.

Coutin and Harris (1968) observed considerable reduction in millet midge populations due to parasites. On sorghum midge, Eupelmus popa Gin. was predominent in Senegal and Nigeria (Harris, 1961; Coutin, 1970 a). Our observations during the last 3 years show that Tetrastichus spp. and Eupelmus spp. are important in controlling sorghum midge, but parasitism is usually low during the peak of pest incidence. Their populations increase only at the end of crop season when the pest incidence is decreasing and crop is already damaged. Moreover, favourable climatic conditions and availability of flowering heads play an important role in the fluctuations of parasite populations.

In case of dipterous parasites, they are comparatively rare in West Africa. One potential parasite is a tachinid, Sturmiopsis parasitica Curr. which attacks stemborers. The role of sarcophagids, chloropids and phorids as parasites is problematical since they are saprophagous.

(ii) Predators : Predators like ants, beetles, bugs, syrphids and mites attacking stemborers, grain midges, aphids and Amsacta larvae have been reported from West Africa (Table 2). Among vertebrates, birds are obviously important as insect predators; although their effectiveness has not been studied yet. Similarly, behaviour of spiders and chrysopids should be studied and perhaps their potentiality can be measured.

(iii) Pathogens : The most common diseases of insects are caused by bacteria, fungi, viruses, protozoa and nematodes. Bacteria and fungi have been identified from larvae/pupae of stemborers in West Africa (Table 3).

IV - Advantages and requirements of biological control

The development of pest management systems should be based on ecological conditions (Huffaker, 1974; Pimentel and Goodman, 1978). Natural enemies play an important role in these systems (Delucchi, 1971; Hurpin, 1975).

In biological control, establishment, multiplication and dispersal on wide area of natural enemies are important steps. Such projects need high initial inputs but can prove to be economical on long term basis; since the control is self perpetuating. Using biological control, risks of environmental pollution, development of resistance by pests to pesticides, toxic effects in food chains, dangerous effects on pollinators and natural enemies etc. are avoided and natural balance is not disturbed. It is true that 100% pest control is not achieved but the pest populations are maintained below economic thresholds. The biological control is successful, particularly in the situations where repeated applications of pesticides are required. Moreover, it can be made more effective by predicting the pest outbreaks.

For successful biological control, correct identification of pest species and their parasites/predators and recognition of cryptic species or intraspecific entities are of utmost importance (Rosen and Debach, 1973). As far as possible, surveys should be made for local parasites since the relationships pests - parasites are stable. These collections may also show distinct races or ecotypes which may be suited to particular host or environment. After having confirmed the absence of local parasites, potential parasites can be introduced if they are (i) pest specific, (ii) non plant breeder, (iii) not attacking other primary parasites. In case of predators and parasites of introduced pests, they are to be searched in the country of pest origin.

V - Possibilities of biocontrol in West Africa

Chemicals were tested against shootflies (Adesiyun, 1978); millet earhead caterpillars (Vercambre, 1978) and grain midges (Coutin, 1970, a, b). However, cost of pesticides, phytotoxicity, application techniques, residues in grains and stalks are some of the problems which require further studies. Cultural practices were suggested for the control of stemborers (Harris, 1962; Adesiyun and Ajayi, 1980); midges (Harris, 1961) and millet earhead caterpillars (Vercambre, 1978); but socio economic problems may hinder the practicability of some of these recommendations. For example, destruction of borer infested stalks which are generally used for hut construction and fencing by villagers. These few examples illustrate the scope for biological control in West Africa.

(a) Transfer of parasites/predators within Africa

There is a urgent need to survey the parasitic fauna and to study their biology, seasonal population fluctuations, potentiality in pest control etc. Then the transfer of selected parasites/predators can be implemented in the same ecological zones within West African countries. In West Africa, parasites suffer in dry season due to climatic conditions and the diapause of host insect. This breaks the synchronisation between host and parasite. Few parasites attack diapausing larvae/pupae, but parasitism is generally at a low level. Thus, there is a scope for introducing few parasites which should be able to undergo a resting stage along with host insects and should be able to multiply quickly and produce a large population when insects become active.

In case of midge parasites, potential parasites exist in West Africa, but they appear late in the season. Suitable conditions should be investigated so that they multiply during high pest incidence. This can probably be done by growing early flowering varieties or alternate host plants as one of the parasites, T. diplosidis is strongly attracted to sorghum heads rather than to host insect, C. sorghicola (McMillan and Wiseman, 1979).

The major midge parasites are :

(i) Tetrastichus diplosidis Crawf. - It is a larval-pupal endoparasite recorded in Senegal and other West African countries.

(ii) Eupelmus popa Gir. - It is larval-pupal ectoparasite and probably a hyperparasite through T. atriclavus. The first instar larvae feed upon larvae whereas later instars attack pupae. Few larvae, after feeding upon one host, complete their growth upon plant sap.

The following stemborer parasites are important in East Africa (Mohyaddin and Greathead, 1970) and are reported from West Africa; their use can therefore be suggested.

(i) Apanteles sesamiae Cam. - It is a gregarious larval endoparasite, widely distributed in Africa. Even though it is attacked by hyperparasites : Ceraphron sp., Eurytoma sp., Platyerizotes soudanensis Ferr., Pediobius homoeus Wtrst., it is quite successful in wet areas. It produces a large number of adults from a single host.

(ii) Sturmiopsis parasitica Curr. - It is primarily a larval and occasionally a larval-pupal endoparasite. Although few hyerparasites have been reported (Epiencyrtus sp.) from Nigeria, it remains as an efficient parasite due to synchronization of its life history with that of B. fusca.

(iii) Dentichasmias busseolae Hein. - It is a solitary pupal endoparasite, widely distributed in East Africa, and well adapted to dry areas. In West Africa it was found only in Nigeria on A. ignefusalis.

(iv) Pediobius furvus Gah. - It is a gregarious pupal endoparasite, widely distributed in West Africa. It gets adapted to a wide range of ecological conditions and produces many adults from one host insect.

(v) Hyperchalcidia soudanensis Stef. - It is a solitary pupal endoparasite, adapted to drier areas. It has been reported from Nigeria, Senegal, Mali, Kenya, Uganda and Cameroun.

Two West African stemborer parasites, G. procerae, T. atriclavus have been reared in laboratory and were released in African countries (Bordat et al., 1977.

In West Africa, little information is available on egg parasites. Five parasites of family Scelionidae were recovered from lepidopterous pests. Recently, one unidentified species of Trichogramma (Trichogrammatidae) has been reported from Senegal attacking eggs of Raghuva sp. (Bournier J.P. Pers. Commun.). The egg parasites are rare in East Africa; the possibility of their transfer is therefore very less. In Uganda, ants (Tetramorium guineense Fab., Pheidole megacephala Fab., Carciocondyla badonci Arnold and C.emeryi Forel) were found responsible for more than 90% mortality of eggs and early instar larvae of B. fusca and Chilo partellus Swin. (Mohyuddin and Greathead, 1970) and of Eldana saccharina Wlk. (Girling, 1978). However, this may hinder the host availability to egg parasites. Ants also attack larvae and pupae of stemborers harbouring in old stalks; therefore, their potentiality may be explored in borer control.

(b) Introduction of natural enemies

Effective enemies may be imported in West Africa to control either target pest or species related to it or for the same type of micro habitat. These parasites should possess the qualities such as (i) high host searching ability, (ii) high degree of host specificity or preference, (iii) high biotic potential related to host, (iv) good adaptation to wide range of environmental conditions.

Information on a range of parasites of some of the graminaceous stemborers from Asia is available (Bennett, 1965; Sharma et al. 1966; Rao et al. 1971). Mohyuddin and Greathead (1970) discussed the potentiality of some of these parasites and suggested introduction of following parasites in East Africa due to their wide distribution, high biotic potential and

wide host range. If satisfactory results are obtained, these parasites can be recommended in West Africa.

(i) Apanteles flavipes Cam.
(ii) A. chilonis Munak.
(iii) Bracon chinensis Szep.
(iv) B. onukii Watanabe
(v) Sturmiopsis inferens Towns.

Subsequently, first 2 parasites were bred on laboratory host insects and released in Reunion and Madagascar Islands (Bordat et al., 1977).

Other introduced parasites tried in East and West Africa are :

(i) Tetrastichus israeli Mani
(ii) Trichospilus diatraeae Cher. & Margh
(iii) Itoplectis narangae Ashm.

The eulophids, T. israeli and T. diatraeae may not be effective since they are potential hyperparasites of tachinid parasites (Bennett, 1965).

The effective parasites/predators, particularly Trichogramma egg parasites, may be imported from other continents and tried in West Africa. The pathogens whose commercial preparations are available (for example, Bacillus thuringiensis Berl), may be used against lepidopterous pests.

Multiplication of parasites for a large scale release may pose a problem in present situations. Importation of parasites needs high cost. Furthermore, development of simple and less expensive breeding techniques and training of staff in handling the parasites may be necessary. The shipments take a long time to reach the place of field release and sometimes the parasites may be found dead. Thus multiple shipments are required for establishment of natural enemy and to study its performance in the given environment. It is suggested that the studies on population ecology and genetics of natural enemies, importation policies and training of personnel should find a place in forthcoming projects on biological control of insect pests.

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References

ADESIYUN, A.A., 1978. Evaluation of some insecticides for the control of sorghum shootfly in Nigeria. Paper presented at the 8th Nigeria Society of Plant Prot., 19pp.

ADESIYUN, A.A. and AJAYI, O. 1980. Control of the sorghum stemborer, Busseola fusca, by partial burning of the stalks. Trop. Pest Manag. 26 : 113-117.

AJAYI, O. 1978. Control of sorghum, millet and wheat field insect pests. Paper presented at second national sorghum, millet and wheat Conference, Zaria, Nigeria; 13pp.

APPERT, J. 1957. Les parasites animaux des plantes cultivées au Sénégal et au Soudan Français. Gouvernement Général de l'Afrique Occidentale Française, Dakar, 292 pp.

BARNES, H.F. 1958. Progress in the biological testing of sorghum midge (Contarinia spp.) Bull. Entomol. Res. 49 : 555-558.

BENNETT, F.D. 1965. Tests with parasites of asian graminaceous moth borers on Diatraea and allied genera in Trinidad. Tech. Bull. Commonw. Inst. Biol. Control N° 5 : 101-116.

BONZI, M. 1977. La situation des foreurs des graminées en Haute-Volta. Présenté à la réunion sur les foreurs des graminées, Bouaké, Côte d'Ivoire, 6pp.

BONZI, M. 1980. Rapport annuel 1979. Défense des cultures, IRAT, Haute-Volta, 50pp.

BORDAT, D., BRENIERE, J. et COQUARD, J. 1977. Foreurs de graminées africaines : parasitisme et technique d'élevage. Agron. Trop. 32 : 391-399.

BRENIERE, J. 1971. Les problèmes des lépidoptères foreurs des graminées en Afrique de l'Ouest. Ann. Zool. Ecol. anim. 3 : 287-296.

BRIDGE, J., TERRY, P.J. and TUNSTALL, J.M. 1978. A survey of crop pests, diseases and weeds of the Gambia. U.K. Ministry of Overseas Development, London. 45pp.

COUTIN, R. 1970 a. Biologie de la cécidomy du sorgho (Contarinia sorghicola Coq.) et lutte chimique. Phyt. phytopharm. 19 : 65 - 83.

COUTIN,,R. 1970 b. Influence de deux insecticides sur la biocénose de Geromyia penniseti Felt. au Sénégal Commun. VII Congrès Intern. Prot. Plantes, Paris. p. 600-601.

COUTIN, R. and HARRIS, K.M. 1968. The taxonomy, distribution, biology and economic importance of the millet grain midge, Geromyia penniseti (Felt.) gen. n. comb. n. (Dipt., Cecidomyiidae). Bull. Entomol. Res. 59 : 259-273.

DEEMING, J.C. 1971. Some species of Atherigona Rondani (Diptera, Muscidae) from northern Nigeria, with special reference to those injurious to cereal crops. Bull. Entomol. Res. 61 : 133-190.

DELUCCHI, V. 1971. L'impact des entomophages en protection phyto-sanitaire. Meded. Facult. Landbouw. Rijk. Gent (Belgique) 36 : 831-837.

DOUMBIA, Y.O. 1980. Entomologie du mil et sorgho : Résultats de la campagne 1979. SRCVO, Sotuba; Mali, 68pp.

FORSYTH, J. 1966. Agricultural insects of Ghana, Ghana Academy of Sciences, Accra, 163 pp.

GAHUKAR, R.T. 1980. Rapport annuel du programme d'entomologie du sorgho (année 1979), Multigr. CNRA, Bambey, Sénégal, 77pp.

GAHUKAR, R.T. 1981a. Inventaire des insectes nuisibles du sorgho au Sénégal (en préparation).

GAHUKAR, R.T. 1981 b. Species of Atherigona in West Africa with particular reference to sorghum shootfly (in preparation).

GAHUKAR, R.T. 1981 c. Rapport annuel du programme d'entomologie du sorgho (année 1980) (en préparation).

GIRLING, D.J. 1978. The distribution and biology of Eldana saccharina Walker (Lepidoptera : Pyralidae) and its relationship to other stemborers in Uganda. Bull. Entomol. Res. 68 : 471 - 488.

HARRIS, K.M. 1961. The sorghum midge, Contarinia sorghicola (Coq) in Nigeria. Bull. Entomol. Res. 52 :129-146.

HARRIS, K.M. 1962. Lepidopterous stemborers of cereals in Nigeria. Bull. Entomol. Res. 53 : 139 - 172.

HUFFAKER, C.B. 1974. Some ecological roots of pest control. Entomophaga 19 : 371-389.

HURPIN, B. 1975. Perspectivité et contraintes de la lutte microbiologique. Z. ang. Entomol. 77 : 377 - 381.

JERATH, M.L. 1968. Parasites of sugarcane stemborers in Nigeria. J. Econ. Entomol. 61 : 435-436.

JORDAN, F.J. 1966. Report on an investigation into the presence and prevalence of rice stemborers and their parasites in Sierra Leone, 1964-1965. West African Rice Res. Stn. Rokupr. 47pp.

McMILLAN, W.W. and WISEMAN, B.R. 1979. Attraction of sorghum midge parasites to sorghum heads. Florida Entomol. 62 : 281-282.

MOHYUDDIN, A.I. and GREATHEAD, D.J. 1970. An annotated list of the parasites of graminaceous stemborers in East Africa, with a discussion on their potential in biological control. Entomophaga 15 : 241 - 274.

NDOYE, M. 1977. Synthèse de quelques résultats sur les insectes foreurs des mils et sorgho au Sénégal, CNRA, Bambey, Multigr. 15pp.

NDOYE, M. 1979 a. L'entomofaune nuisible au mil à chandelle (Pennisetum typhoïdes) au Sénégal. Présenté au Congrès sur la lutte contre les insectes au milieu tropical, Marseille, France, Multigr. 17 pp.

NDOYE, M. 1979 b. New millet spike pests in Senegal and the sahelian zone. Plant Prot. Bull (FAO) 27 : 7-8.

NDOYE, M. 1980. Goniozus procerae Risbec (Hymenoptera, Bethylidae) ectoparasite larvaire d'Acigona ignefusalis (Lepid., Pyralidae, Crambinae), CNRA, Bambey, Multigr., 6pp.

PIMENTEL, D. and GOODMAN, N. 1978. Ecological basis for the management of insect populations. Oikos 30 : 422-437.

RAO, V.P., GHANI, N.A., SANKARAN, T., and MATHUR. R.C. 1971. A review of the biological control of insects and stem pests in South East Asia and the Pacific region. Tech. Bull. Commonw. Inst. Biol. Control N° 6.

RISBEC, J. 1950. La faune entomologique des cultures au Sénégal et au Soudan Français. Gouvernement Général de l'Afrique Occidentale Française, Dakar, 639 pp.

RISBEC, J. 1960; Les parasites des insectes d'importance économique en Afrique Tropicale et à Madagascar. Agron. Trop. 15 : 624 - 656.

ROSEN, D. and DEBACH, P. 1973. Systematics, morphology and biological control. Entomophaga 18 : 215-222.

SHARMA, A.K., SAXENA, J.D. and SUBBA RAO, B.R. 1966. A catalogue of the hymenopterous and dipterous parasites of Chilo zonellus Swinhoe (Crambidae : Lepidoptera) Indian J. Entomol. 28 : 510 - 542.

VERCAMBRE, B. 1978. Raghuva spp., Masalia sp., chenilles des chandelles du mil en zone sahélienne. Agron. Trop. 33 : 62 - 79.

TABLE 1 : Parasites of major insect pests of sorghum and pearl millet reported from West Africa

Order and Family	Species	Host insect and life stage attacked	Distribution	Reference
Order : Hymenoptera				
1. Braconidae	Apanteles sesamiae Cam.	B. fusca (larva)	Nigeria	Harris, 1962
		Sesamia sp. (larva)	Nigeria	Harris, 1962
		S. nonagrioides botenphaga (larva)	Sierra Leone	Jordan, 1966
		A. ignefusalis (larva)	West Africa	Risbec, 1960
	Apanteles syleptae Ferr.	S. exigua (larva)	Senegal	Risbec, 1950
				Gahukar, 1981
	Apanteles sagax Wikn.	M. loreyi (larva	Senegal	Risbec, 1960
	Apanteles ghesquieri Saeg.	E. gayneri (larva)	Senegal	Risbec, 1960
	Apanteles aroxys Saeg.	E. gayneri (larva)	Senegal	Risbec, 1960
	Apanteles sp.	S. cretica (pupa)	Senegal	Risbec, 1960
	Apanteles sp.	C. sorghicola (larva/pupa)	Senegal	Gahukar, 1980
	Rhogas mimeuri Ferr.	H. armigera (larva)	Mali	Doumbia, 1980
		M. separata (larva)	Mali	Doumbia, 1980
	Euvipio rufa Szepl.	A. ignefusalis (larva)	Nigeria	Harris, 1962
	Euvipio fascialis Szepl.		Senegal	Risbec, 1960
	Rhaconotus soudanensis Wilkn.	A. ignefusalis (larva)	Senegal	Risbec, 1960
	Rhaconotus sp.	E. gayneri (larva)	Senegal	Risbec, 1960
	Habrobracon hebetor Say.	Raghuva spp. Masalia sp. (larva)	Senegal	Vercambre, 1978
		M. loreyi (larva)	Senegal	Risbec, 1960

	Glyptomorpha sp.	A. ignefusalis (pupa)	Nigeria	Harris, 1962
	Microdus sp.	M. loreyi (larva)	Senegal	Risbec, 1960
	Phanerotoma sp.	S. cretica (pupa)	Senegal	Risbec, 1960
	Bracon praecepter Brues.	E. gayneri (larva)	Senegal	Risbec, 1960
	Disophrys iridipennis Cam.	S. exigua (larva)	Senegal	Risbec, 1950
	Cardiochiles sp.	"	Senegal	Risbec, 1950
2. Bethylidae	Goniozus procerae Risb.	A. ignefusalis (larva)	Senegal	Risbec, 1950; Ndoye, 1980
	Goniozus sp.	"	Nigeria	Harris, 1962
3. Chalcididae	Hyperchalcidia soudanensis	A. ignefusalis (pupa)	Nigeria	Harris, 1962
			Senegal	Risbec, 1950
		E. saccharina (pupa)	Mali	Risbec, 1960
	Brachymeria feae Mas.	S. calamistis? (pupa)	Nigeria	Harris, 1962
		M. loreyi (pupa)	Senegal	Risbec, 1950
	Brachymeria eublemmae Stef.	E. gayneri (pupa)	Senegal	Risbec, 1950
	Euchalcidia eutlemmae Stef.		Senegal	Risbec, 1950
	Paroxycoryphiscus signifer Stef.	E. gayneri (larva)	Mali	Doumbia, 1980
4. Encyrtidae	Paraphaenodisus risbeci Guesq.	S. cretica (pupa)	Senegal	Risbec, 1950
	Euzkadia sp. (? integralis Merc.)	A. ignefusalis (larva)	"	"

5. Eulophidae	Pediobius furvus Gah.	S. cretica (larva)	Senegal	Risbec, 1950
		A. ignefusalis (pupa)	Nigeria	Jerath, 1966
		S. penniseti ? (pupa)	Sierra Leone	Jordan, 1966
			Ghana	Forsyth, 1966
		B. fusca (pupa)	Nigeria	Harris, 1962
	Pediobius hirtellus Mas.	S. poephaga (pupa)	"	"
	Tetrastichus diplosidis Craw.	C. sorghicola (larva-pupa)	Senegal	Coutin, 1970; Gahukar, 1980
	Tetrastichus atriclavus Wtrst.	B. fusca (pupa)	Nigeria	Harris, 1962
		A. ignefusalis (pupa)	"	Gahukar, 1981
		Sesamia sp. (pupa)	Nigeria	Harris, 1962
	Tetrastichus celamae Risb.	E. gayneri (pupa)	Senegal	Risbec, 1950
	Tetrastichus spp.	C. sorghicola (larva-pupa)	Nigeria	Harris, 1961
			Ghana	Barnes, 1958
		G. penniseti (larva-pupa)	Senegal	Coutin & Harris, 1968
	Pleurotropis braconivora Risb.	E. gayneri (larva)	Senegal	Risbec, 1950
	Aprostocetus sp.	C. sorghicola (larva-pupa)	Nigeria	Harris, 1961
			Senegal	Coutin, 1970a; Gahukar, 1980
	Euplectrus laphygmae Ferr.	A. moloneyi (larva)	Senegal	Risbec, 1950
		S. exigua (larva)	"	"
		S. exempta (larva)	"	"

6. Eupelmidae	Eupelmus popa Gir.	C. sorghicola (larva-pupa)	Nigeria	Harris, 1961
			Senegal	Coutin, 1970; Gahukar, 1980.
		B. fusca	Nigeria	Harris, 1962
	Eupelmus australicus Gir.	C. sorghicola (larva-pupa)	Senegal	Gahukar, 1980.
	Eupelmus spp.	C. sorghicola (larva-pupa)	Nigeria	Harris, 1961
		G. penniseti (larva-pupa)	Senegal	Coutin & Harris, 1968
7. Eurytomidae	Eurytoma verbenae Ferr.	E. gayneri (pupa)	Senegal	Risbec, 1950
	Systole sp.	E. gayneri (larva)	"	"
8. Ichneumonidae	Dentichasmias busseolae Hein.	A. ignefusalis (pupa)	Nigeria	Harris, 1962
	Isotima sp.	B. fusca (?)	Sierra Leone	Jordan, 1966
	Syzeuctus spp.	A. ignefusalis (larva)	Nigeria	Harris, 1962
			Senegal	Risbec, 1960
	Chasmias sp.	A. ignefusalis (pupa)	Nigeria	Harris, 1962
	Trathala flavo-orbitalis Cam.	M. loreyi (larva)	Senegal	Gahukar, 1981c
	Pristomerus sp.	S. exigua (larva)	Senegal	Risbec, 1950
		H.armigera (larva)		Gahukar, 1981c
		E. gayneri (larva)	"	"
	Scenocharops spp.	Sesamia spp. (larva)	Sierra Leone	Jordan, 1966
	Charops tegularis Szepl.	A. moloneyi (larva)	Senegal	Risbec, 1950

	Charops sp.	S. exigua (larva)	Senegal	Risbec, 1950
9. Platygasteridae	Platygastor sp.	G. penniseti (larva-pupa)	Senegal	Coutin & Harris, 1968
	Aphanogmus sp.	"	"	"
10. Pteromalidae	Norbanus sp.	Sesamia sp. (larva-pupa)	Nigeria	Harris, 1962
	Spalangia pennisetae Risb.	A. soccata (pupa)	Senegal	Risbec, 1950
	Spalangia atherigonae Risb.	"	"	"
11. Scelionidae	Platyteleromus busseolae Gah.	B. fusca (eggs)	Nigeria	Harris, 1962
	Platyteleromus hylas Nixon	A. ignefusalis (eggs)	Senegal	Risbec, 1950
	Telenomus thestor Nixon	A. moloneyi (eggs)	"	"
	Telenomus sp.	S. calamistis (eggs)	Ghana	Forsyth, 1966
	Hadronotus pisus Nixon	E. gayneri (eggs)	Senegal	Risbec, 1950
Order : Diptera				
1. Tachinidae	Sturmiopsis parasitica Curr.	Eldana sp. (larva-pupa)	Nigeria	Jerath, 1968
		A. ignefusalis (larva-pupa)	Nigeria	Harris, 1962
		Sesamia sp. (pupa)	"	"
		B. fusca (pupa)	"	"
	Sturnia inconspicuella Bar.	A. moloneyi (larva)	Senegal	Risbec, 1950

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	Sturmia inconopicua Mg.	S. exigua (larva)	Senegal	Risbec, 1950
	Sturmia sp.	"	"	"
	Palexorista laxa Curr.	H. armigera (larva)	Mali	Doumbia, 1980
		M. separata (larva)	"	"
	Linnaemya angulicornis Speis.	M. loreyi (larva)	Senegal	Gahukar, 1981c
	Goniophthalmus halli Mes.	R. albipunctella (larva)	"	"
2. Sarcophagidae	Sarcophaga villa Curr.	A. soccata (larva)	Senegal	Gahukar, 1981c
	Helicobia destructor Mall.	H. armigera (larva)	"	"
3. Chloropidae	Oscinosoma risbeci Seguy	S. cretica (larva)	Senegal	Risbec, 1950
	Ceratopogon risbeci Seguy	A. ignefusalis (larva)	"	"
	Epimadiza sp.	A. ignefusalis (pupa)	"	"
4. Phoridae	Aphiochaeta xanthina Speis.	S. cretica (larva)	Senegal	Risbec, 1950
	Aphiochaeta sp.	A. ignefusalis (larva)	"	"
	Megaselia sp.	S. exempta (larva)	"	"

TABLE 2 : Predators of major insect pests of sorghum and pearl millet reported from West Africa

Order and Family	Species	Host insect & life stage attacked	Distribution	Reference
Order : Hymenoptera				
1. Formicidae	Dorylus affinis Sch.	B. fusca (larva)	Nigeria	Harris, 1962
Order : Coleoptera				
1. Carabidae	Distichus gagatinus Dej.	A. moloneyi (larva)	Senegal	Risbec, 1950
2. Coccinellidae	Micraspis striata F.	R. maidis (nymph-adult)	Gambia	Bridge et al., 1978
Order Hemiptera				
1. Anthocoridae	Orius punctaticollis Reu.	C. sorghicola (ovipositing females)	Senegal	Coutin, 1970a
	Orius sp.	G. penniseti (ovipositing females)	"	Coutin & Harris, 1968
Order : Diptera				
1. Syrphidae	Ischiodon aegyptium Wied.	R. maidis (nymph-adult)	Gambia	Bridge et al., 1978
Class : Arachnida	Pyemotes ventricesus Newfs.	A. ignefusalis (larva)	Nigeria	Harris, 1962
	Thomisus sp.	C. sorghicola (ovipositing females)	Nigeria	Harris, 1961
	Diaca sp.	"	"	"

TABLE 3 : Pathogens on major insect pests of sorghum and pearl millet reported from West Africa

Group	Pathogen	Host insect and life stage attacked	Distribution	Reference
Bacteria	*Bacillus thuriengiensis* Berl.	*B. fusca* (larva)	Nigeria	Harris, 1962
Fungi	*Metarrhizium anisopliae* (Metsch.) Sorok.	*A. ignefusalis* (larva)	"	"
	Aspergillus flavus Link.	*Raghuva* spp. *Masalia* sp. (larva)	Senegal	Vercambre, 1978
		B. fusca (larva - pupa)	Nigeria	Harris, 1962
	Aspergillus sydowi Thom & Church	*B. fusca* (pupa)	"	"