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Article *in* International Journal of Pest Management · October 2010

DOI: 10.1080/09670874.2010.500406

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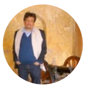

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International Journal of Pest Management
Vol. 56, No. 4, October–December 2010, 337–349

Insect pests and their management in yam production and storage: a world review

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(*Received 17 September 2009; final version received 8 June 2010*)

Yam (*Dioscorea* spp.) is a tropical tuber crop produced for food and medicinal purposes. Yams are infested by a broad taxonomic diversity of insect pests. We reviewed a total of 73 insect species associated with *Dioscorea* species in different parts of the world. Yam is infested by 48 species when the crop is in the field, and after harvest (i.e. in storage) the tubers are attacked by 27 species. The majority of these insects belong to the order Coleoptera (35 species) followed by the orders Hemiptera (15), Lepidoptera (13), Isoptera (5), Hymenoptera (2), Diptera (1), and Thysanoptera (1). Yam scales, mealybugs, and a few beetles cause significant losses to tubers both in the field and in storage. We review various methods of management for these insect pests. An integrated approach towards managing these pests, both in the field and in storage, is essential. Post-harvest losses in storage of yam can be reduced, partly, by using biocontrol agents for mealybugs and scales. Alternative strategies for the management of insect pests of tubers in storage are discussed.

Keywords: yam; *Dioscorea* species; pest insects; insect-transmitted viruses; biological control; host plant resistance; cultural practices; post-harvest management

1. Introduction

Yams (*Dioscorea* sp., family Dioscoreacea) are annual or perennial tuber-bearing and climbing plants. Of the 600 or so species of *Dioscorea* recognized worldwide, only 10 are grown for food in various tropical and subtropical parts of the world. A few species are grown on a small-scale for extraction of the pharmaceutical compounds dioscorin and diosgenin. The tubers have organoleptic qualities that can make them the preferred carbohydrate staple and can contribute up to 350 dietary calories per person each day (Asiedu et al. 2001).

Yams are produced over 5 million hectares in 47 countries in tropical and subtropical regions of the world. More than 95% of the world's 47 million metric tonnes of yam produced annually comes from Sub Saharan Africa (IITA 2007). Yams, including some other tuber crops such as sweet potato and colocasia, are the staple food crops for some ethnic groups in Papua and New Guinea (Meyer Rochow 1973). Yam is also one of the important components of the diet of tribes in the Andaman and Nicobar islands in the Bay of Bengal; it is interesting to note that, of all the population groups so far surveyed in the Indian Union, the Nicobarese of Great Nicobar are considered to have the best diet (Roy and Roy 1969). According to the World Health Organization, growing yams is helpful in the maintenance of public health (Arata 1977). Clearing of forests in Nigeria with subsequent planting of yams, cassava and other field crops and eventual replanting with teak 2–3 years later, was found to result in the elimination or reduction of *Aedes* vectors of yellow fever and other arboviruses without resorting to the use of chemicals, which was helpful in minimising the amount of pesticide applied against peridomestic mosquito species (Arata 1977). Dweck (2002) reviewed *Dioscorea* spp. and their uses in different industries. Some species of *Dioscorea, D. sylvatica* and *D. dregeana* show antibacterial activity against gram-positive bacteria and gram-negative *Escherichia coli* (Kelmanson et al. 2000). Widely prescribed cortisones and hydrocortisones are indirect products of the genus *Dioscorea*. They are used for the treatment of Addison's disease, some allergies, bursitis, contact dermatitis, psoriasis, rheumatoid arthritis, sciatica, Brown Recluse Spider bites, insect stings, and other diseases and ailments (Foster and Duke 1990). Water Yam or Greater Yam, *D. alata*, is widely cultivated in north eastern India and is intercropped or mixed cropped with maize, sweetpotato, ginger and vegetables (Rajasekhara Rao 2005; Rajasekhara Rao et al. 2006).

The productivity of yam cultivation has been severely constrained by reduction in soil fertility, increases in infestation of coleopteran pests and increases in production costs. Increasing pressure from a range of insect pests (e.g. leaf and tuber beetles, mealybugs, scales), fungi (anthracnose, leaf spot, leaf blight, tuber rots) and viruses, as well as nematodes,

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ISSN 0967-0874 print/ISSN 1366-5863 online

DOI: 10.1080/09670874.2010.500406
http://www.informaworld.com

contribute to sub-optimal yields and the deterioration of tuber quality in storage. The high-risk area for nematode infestation is estimated to be 45% in yam-growing regions of West Africa (Manyong and Oyewole 1997). In addition to these problems, dried yam chips are also reported to contain mycotoxins (Bankole and Adebanjo 2003).

Here, we review the yam arthropod fauna, management practices, to identify the strategies required for successful insect pest control in field and storage settings.

2. Yam insect pests

Of the 73 species of insects that are associated with *Dioscorea* spp. in different parts of the world, 49 species attack the field crop (Table 1), and 27 infest yam after harvest (i.e. in storage) (Table 2). The majority of the insects belong to the order Coleoptera (35 species) followed by the orders Hemiptera (15), Lepidoptera (13), Isoptera (5), Hymenoptera (2), Diptera (1), and Thysanoptera (1). The scales, mealybugs and few Coleoptera are economically important because they can reduce field crop growth and cause severe losses of the tubers during storage.

2.1. Pre-harvest insect pests

Yam is attacked by several species of foliage-feeding and stem-boring insects (Table 1). Yam production is affected by a leaf-feeding beetle *Crioceris livida* Dalman (=*Lilioceris livida*) (Coleoptera: Chrysomelidae) (Asiedu et al. 2001). The population density of *C. livida* reaches a peak during June, and by August the numbers decline considerably in yams in Nigeria (Echendu and Emehute 1992). *Lasioptera* sp. (Diptera: Cecidomyiidae) (Emehute 1998) induces galls on leaves (Emehute 1998). Grubs of *Galerucida bicolour* Hope (Coleoptera: Chrysomelidae) feed on tender leaves and shoot tips. The adults live for 10–13 d and feed on mature leaves, perforating the leaf lamina (Kumar 2007). *Polyphylla laticollis* Lewis (Coleoptera: Scarabaeidae) is an important insect pest of yam in Fuxin Prefecture, Liaoning Province, China, despite completing one generation in 4 years. Adults, which are abundant in late July, live for approximately 17 d, and feed on the leaves of maize, poplar, elm and the needles of *Pinus thunbergii* and the larvae feed on the foliage of yam (Li 1984). Palaniswami and Pillai (1982) and Kumar (2007) reported that grubs and adults of *Lema lacordairei* Baly (Coleoptera: Chrysomelidae) feed on the leaves and cause defoliation in *D. alata* and *D. rotundata*. This pest was found during August but is more abundant in September–November.

Larvae of the Asian sawfly *Ansioarthra coerulea* Cameron (Hymenoptera: Tenthredinidae) larvae cause economic damage to *D. alata* in the state of Meghalaya, India (Vasu et al. 2000; Shylesha et al. 2006). The early instars of *A. coerulea* were found to cause extensive defoliation (as much as 90%) leading to significant yield reduction (Rajasekhara Rao et al. 2006). The larval stages of another *Senoclidia purpurata* F. Smith tenthredinid sawfly, have been recorded as foliage-feeders on yam in Nigeria (Szent Ivany 1974), China (Xiao 1993) and Papua New Guinea (Risimeri 2001). *Thrips crawfordi* Nakahara (Thysanoptera: Thripidae) infests *Smilacina* sp., *Smilax* sp. and wild yam in the USA and Canada (Nakahara 1994). Another leaf feeder, *Acrolepiopsis nagaimo* Yasuda (Lepidoptera: Acrolepiidae), which infests *D. opposita*, is reported from Japan (Yasuda 2000). Yam leafminers (*Acrolepiopsis* spp.) have been reported damaging Chinese yam and its relatives in Aomori Prefecture in China (Oikawa et al. 2004). In Cuba, eight species of whitefly (Hemiptera: Aleyrodidae) were collected from different crops, of which yam was infested with *Dialeurodes* sp. (Vazquez et al. 1995). Palaniswami and Pillai (1982) reported foliage-feeding by *Dasychira mendosa* Hub. (Lepidoptera: Lymantridae) in India. They also reported feeding by stem-boring beetles, *Clytocera chinospila* Gahan and *Apomecyna saltator* Fab. (Coleoptera: Cerambycidae). In Brazil, the main foliage-feeding insects associated with *Dioscorea* spp. are *Pseudoplusia* sp. (Lepidoptera: Noctuidae) and *Xystus arnoldi* Kirby (Curculionidae) (Ritzinger et al. 2003). *Stenocrates cultor* Burmeister (Coleoptera: Scarabaeidae) was found feeding on tubers when yams cultivated with a high quantity of organic matter in Minas Gerais, Brazil (Venzon and Pallini Filho 1995).

Two major insect pests of yam, *Aspidiella hartii* Cockerell (Hemiptera: Diaspididae) and *Heteroligus meles* (Billberger) (Coleoptera: Dynastidae), infest the foliage and tubers when the crop is in stand. *A. hartii*-infested plants show wilting due to continuous removal of plant sap. During January to April, pests multiply considerably and cover the entire tuber. The infested tubers shrivel, so reducing their quality, viability and marketability. Severe infestation of yam tubers by *A. hartii* kills the whole plant (Ritchie 1918). *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae), which usually attacks coconut in Hawaii, was found infesting *Dioscorea* sp. in Pearl City on the Island of Oahu (USDA 1978). In India, yams are infested by 12 insect pest species of which *A. hartii* is the most important (Pillai et al. 1993). The mealybug, *Ferrisia virgata* Cockerell (Hemiptera: Pseudococcidae) was observed on *D. dumatorum* only (Nair et al. 1982). *Quadraspidiotus perniciosus* (Comstock) (Hemiptera: Diaspididae) is a cosmopolitan pest and infests yam foliage in many countries of South East Asia (Hill 2008). In Papua New Guinea (PNG) *Planococcus dioscoreae* Williams (Hemiptera: Pseudococcidae), found infesting the leaves and tubers, is reported to be the only major pest of yam (Szent Ivany 1974), followed by the minor pests *Blastobasis* sp. (Lepidoptera: Blastobasidae),

Table 1. List of insects of yam: field/pre-harvest.

Order	Family	Species	Damage	Geographical distribution	References
Coleoptera	Cerambycidae	*Apomecyna dioscorea* Pierce	Root, tuber	Jamaica, Cuba	Hill (2008)
		Apomecyna saltator Fab.	Vine borer	India	Palaniswami and Pillai (1982)
		Clytocera chinospila Gahan	Vine borer	India	Palaniswami and Pillai (1982)
	Chrysomelidae	*Crioceris livida* Dalman	Foliage	Nigeria	Asiedu et al. (2001); Echendu and Emehute (1992, 1998)
		Galerucida bicolour Hope	Foliage	India	Kumar (2007)
		Lema lacordairei Baly	Foliage	India	Kumar (2007); Palaniswami and Pillai (1982)
	Dynastidae	*Heteroligus appius (Burmeister)*	Tuber	Jamaica	Ngeve (1999)
		Heteroligus meles (Billberger)	Tuber	Africa, India	Acholo et al. (1997); Asiedu et al. (2001); Umeozor (1998); Ogbomo and Egharevba (2006); Tobih et al. (2007)
	Scarabaeidae	*Heteronychus* spp.	Tuber	Africa	Asiedu et al. (2001); Braimah et al. (2007); Hill (2008)
	Scarabaeidae	*Polyphylla laticollis* Lewis	Foliage	China	Li (1984)
		Prionorcytes caniculus	Root, tuber	Africa	Asiedu et al. (2001); Hill (2008)
		Prionorcytes rufopiceus	Root, tuber	Africa	Braimah et al. (2007); Hill (2008)
		Schizonycha sp.	Root and tuber	Africa	Asiedu et al. (2001); Braimah et al. (2007); Hill (2008)
		Stenocrates cultor Burmeister	Root and tuber	Brazil	Venzon and Pallini Filho (1995)
		Leucopholis coneophora Burmeister	Root and tuber	India	Pillai et al. (1993)
	Scolytidae	*Xyleborus ferrugineus* (Fab.)	Foliage	Nigeria	Williams (1988)
	Curculionidae	*Xystus arnoldi* Kirby	Foliage	Brazil	Ritzinger et al. (2003)
	Unknown	*Papuana* sp.	Tuber	Africa	Risimeri (2001)
Diptera	Cecidomyiidae	*Lasioptera* sp.	Galls on leaves	Nigeria	Emehute (1998)
Hemiptera	Cercopidae	*Ptyleus grossus* Fab.	Xylem sap feeder	Africa	Hill (2008)
	Aphididae	*Aphis craccivora* Koch	Phloem sap feeder & virus vector	Tropics	Nienhaus (1987); Odu et al. (2004); Reckhaus (1979); Thouvenel (1984)
		Aphis gossypii Glover	Phloem sap feeder & virus vector	Tropics	Nienhaus (1987); Odu et al. (2004); Reckhaus (1979); Thouvenel (1984)
	Aphididae	*Rhopasosiphum maidis* (Fitch)	Sap sucker & virus vector	Tropics	Reckhaus (1979); Thouvenel (1984); Nienhaus (1987); Odu et al. (2004)
		Toxoptera citricida (Kirkaldy)	Sap sucker & virus vector	Tropics	Reckhaus (1979); Thouvenel (1984); Nienhaus (1987); Odu et al. (2004)
		Aspidiotus destructor Signoret	Foliage	West Africa, USA	USDA (1978); Braimah et al. (2007)
	Aleyrodidae	*Dialeurodes* sp.	Sap feeder	Cuba	Vazquez et al. (1995)
	Pseudococcidae	*Ferrisia virgata* Cockerell	Foliage	India, Ghana	Nair et al. (1982); Braimah et al. (2007)
	Pseudococcidae	*Planococcus dioscorea* Williams	Foliage, tuber	Papua New Guinea, West Africa	Braimah et al. (2007); Quin (1985); Risimeri (2001); Szent Ivany (1974)
		Planococcus kenyae Le Pelley	Foliage and tuber	East and West Africa	Hill (2008)
	Pseudococcidae	*Planococcus citri* (Risso)	Foliage, virus vector, tuber	Asia, South America, East and West Africa	Acholo et al. (1997); Asiedu et al. (2001); Iheagwam (1986); Iheagwam and Wojtusiak (1989); Morse et al. (2000); Philips et al. (1999)
	Diaspididae	*Quadraspidiotus perniciosus* (Comstock)	Foliage	South East Asia	Hill (2008)
	Coreidae	*Leptoglossus australis* Fab.		Africa, Asia	Hill (2008)

(*continued*)

Table 1. (*Continued*).

Order	Family	Species	Damage	Geographical distribution	References
Hymenoptera	Tenthredinidae	*Ansioarthra coerulea* Cameron	Foliage	India	Shylesha et al. (2006); Rajasekhara Rao et al. (2006); Vasu et al. (2000)
		Senoclidia purpurata (F. Smith)	Foliage	Nigeria, Papua New Guinea	Risimeri (2001); Szent Ivany (1974); Xiao (1993)
Isoptera	Termitidae	*Amitermes* sp.	Dried roots and tuber	Africa	Asiedu et al. (2001); Braimah et al. (2007)
		Ancistrotermes sp.	Dried roots and tuber	Africa	Venzon and Pallini Filho (1995); Ogbedeh et al. (2007)
		Macrotermes spp.	Dried roots and tuber	Africa	Braimah et al. (2007); Ogbedeh et al. (2007); Venzon and Pallini Filho (1995)
		Microtermes spp.	Dried roots and tuber	Africa	Braimah et al. (2007); Ogbedeh et al. (2007)
		Odontotermes escherichi (Holmgren)	Dried roots and tuber	India	Palaniswami and Pillai (1982)
Lepidoptera	Acrolepiidae	*Acrolepiopsis* spp.	Leaf miner	Japan, China	Oikawa et al. (2004); Tanaka et al. (2001); Wakamura et al. (2001); Yasuda (2000)
	Blastobasidae	*Blastobasis* sp.	Foliage	Papua New Guinea	Quin (1985); Risimeri (2001)
	Lymantriidae	*Dasychira mendosa* Hubner	Foliage	India	Palaniswami and Pillai (1982)
	Sphingidae	*Hippotion celerio* L.	Foliage	Papua New Guinea	Risimeri (2001)
	Noctuidae	*Pseudoplusia* sp.	Foliage	Brazil	Ritzinger et al. (2003)
	Hesperiidae	*Tagiades litigiosa* Moschler	Foliage	Papua New Guinea	Risimeri (2001)
		Tagiades nestus (C. Felder)	Foliage	Papua New Guinea	Risimeri (2001)
Thysanoptera	Thripidae	*Thrips crawfordi* Nakahara	Foliage	USA, Canada	Nakahara (1994)

Tagiades nestus (C. Felder) (Lepidoptera: Hesperiidae) and *S. purpurata* (Hymenoptera: Tenthredinidae) (Risimeri 2001). Quin (1985) reported *Blastobasis* sp. as a serious pest of *D. alata*.

Some of the sap-sucking insects of yam also transmit pathogenic virsuses. Aphids and mealybugs transmit Yam Mosaic Virus (YMV) and *Dioscorea alata* bacilliform virus (DaBV). The first virus disease of *D. rotundata*, probably YMV with symptoms ranging from mottling to distortions of various sorts, was observed in Togo (Reckhaus 1979). YMV is transmitted mechanically by the aphids (Hemiptera: Aphididae) *Aphis gossypii* Glover, *A. craccivora* Koch, *Rhopalosiphum maidis* (Fitch) and *Toxoptera citricida* (Kirkaldy) in a non-persistent manner. The virus, which belongs to the Potyvirus group (Reckhaus 1979; Thouvenel 1984; Nienhaus 1987), is the most important virus infecting *Dioscorea* spp. in the tropics (Odu et al. 2004). DaBV from Barbados and West Africa and from other *Dioscorea* spp. from West African, Caribbean, Asian and South American countries is transmitted by the mealybug, *Planococcus citri* Risso (Phillips et al. 1999).

The Greater Yam Beetle *Heteroligus meles* (Billberger) (Coleoptera: Dynastidae), was considered to be the single largest cause of yam tuber rot in Africa (Acholo et al. 1997; Asiedu et al. 2001). Yam setts are attacked by the adults of *H. meles* shortly after planting. *H. meles* also feeds on tubers, making holes of 1–2 cm diameter prior to harvest, resulting in a low market value and a predisposition to fungal and bacterial infections in the field and during storage (Tobih et al. 2007). In Cameroon, the main biotic constraints upon yams are Yam Beetle *H. meles*, tuber rots, as well as the high cost of planting material, and increased labour costs in procuring stakes (Ngeve 1999). *H. appius* (Burmeister) and *Apomecyna dioscoreae* Pierce (Coleoptera: Curculionidae) bore into yam roots and tubers in the field in Jamaica and Cuba (Hill 2008). The larvae of *Leucopholis coneophora* (Coleoptera: Scarabaeidae) attacks root and tubers (Pillai et al. 1993). During severe infestations, the intensity of damage is 10–35 pits per tuber (Kumar 2007). Another four species of scarabaeids, *Prionoryctes caniculus, P. rufopiceus, Schizonycha* sp. and *Heteronychus* spp., also bore into and feed on the tubers during the pre-harvest period (Asiedu et al. 2001; Braimah et al. 2007; Hill 2008).

2.2. *Post-harvest insect pests*

Much of the post-harvest damage to the tubers occurs in storage. A list of insect species that attack yam tubers in storage is given in Table 2. Insect pests can be the cause of serious yield losses in stored roots and tubers of yams. Surveys carried out in 1981, 1983 and 1984 in Côte d'Ivoire showed increasing levels of infestation of stored yams over a period of 4 months of

Table 2. List of insect pests of yam: post harvest/storage.

Order	Family	Species	Geographical distribution	References
Coleoptera	Anobiidae	*Lasioderma serricorne* (Fab.)	Nigeria	Adesuyi (1979); Osuji (1980)
	Anthribidae	*Araecerus fasciculatus* De Geer	Nigeria, India	Adesuyi (1979); Osuji (1980); Iheagwam (1986); Pillai et al. (1993); Iheagwam and Wojtusiak (1989); Lal and Pillai (1997); Pillai and Rajamma (1997); Palaniswami et al. (1979); Emehute and Echendu (1992)
		Araecerus laevigatus (Fab.)	India	Pillai and Rajamma (1997)
	Bostrichidae	*Dinoderus bifoveolatus* Wollatson	Benin	Vernier et al. (2005)
		Dinoderus porcellus Lesne	Nigeria	Adesuyi (1979); Osuji (1980)
		Rhyzopertha dominica (Fab.)	Nigeria	Osuji (1980)
	Bruchidae	*Callosobruchus maculatus* (Fab.)	Nigeria	Adesuyi (1979)
	Cucujidae	*Cryptolestes pusillus* (Schonherr)	Nigeria	Adesuyi (1979)
	Curculionidae	*Palaeopus coslicollis* Marshall	Jamaica	Quarterly Bulletin. (ca. 1920)
		Sitophilus zeamais Motschulsky	Nigeria	Adesuyi (1979); Osuji (1980)
	Dynastidae	*Heteroligus meles* (Billberger)	Africa, India	Acholo et al. (1997); Aighewi et al. (2002); Asiedu et al. (2001); Ogbomo and Egharevba (2006); Morse et al. (2000); Tobih et al. (2007); Umeozor (1998)
	Nitidulidae	*Brachypeplus pilosellus* Murray	Nigeria	Osuji (1980)
		Carpophilus dimidiatus var. *contingens* Walker	Nigeria	Adesuyi (1979); Connell (1975)
		Carpophilus hemipterus (L.)	Nigeria	Osuji (1980)
	Scarabaeidae	*Prionorcytes caniculus*	Africa	Asiedu et al. (2001); Hill (2008); Acholo et al. (1997)
	Tenebrionidae	*Palorus subdepressus* Wollatson	Benin	Vernier et al. (2005)
		Tenebroides mauritanicus (L.)	Nigeria	Osuji (1980)
		Tribolium castaneum (Herbst)	Nigeria	Adesuyi (1979); Iheagwam (1986); Iheagwam and Wojtusiak (1989); Osuji (1980)
		Tribolium confusum Duval	Nigeria	Osuji (1980)
Hemiptera	Diaspididae	*Aspidiella hartii* Cockerell	West Africa, India	Aighewi et al. (2002); Morse et al. (2000)
	Pseudococcidae	*Planococcus citri* (Risso)	Asia, South America, East and West Africa	Asiedu et al. (2001); Iheagwam (1986); Morse et al. (2000); Philips et al. (1999)
Lepidoptera	Pyralidae	*Euzopherodes vapidella* Mann	Nigeria	Ashamo and Odeyemi (2001); Akinneye and Ashamo (2006); Asiedu et al. (2001); Moyal (1988); Sauphanor and Ratnadass (1985)
	Tineidae	*Dasyses incrustata* Meyrick	Nigeria	Iheagwam, (1986)
		Dasyses rugosella Stainton	Nigeria	Ashamo (2005); Ashamo and Odeyemi (2004); Iheagwam and Ezike (1989)
		Decadarchis miniscula (Walsingham)	Nigeria	Echendu and Alozie (1990)
		Opogona sacchari (Bojer)	Barbados	Gibbs (1991)
		Setomorpha rutella Zeller	Nigeria	Iheagwam (1986); Iheagwam and Wojtusiak (1989)

storage, with 63% of stored tubers being infested by moths and weight losses of 25% attributed to the insects (Sauphanor and Ratnadass 1985). A few species of insects described in the previous section are also pests of yam in storage. Feeding damage by *H. meles*, *P. caniculus* and *A. hartii* allows fungal infections to develop in the tubers (Acholo et al. 1997). Yam Weevil *Palaeopus costicollis* Marshall (Coleoptera: Curculionidae) was intercepted in the luggage of a passenger from Jamaica to South Carolina; one yam contained 14 adults, 23 pupae and 12 larvae of this insect (Quarterly Bulletin . . . ca. 1920).

The Yam Beetle *H. meles* and the scale insect *A. hartii* caused considerable damage to seed yams in

Asaba and Lokoja of Nigeria (Aighewi et al. 2002). Between 47 and 90% of farmers in those localities had a combination of pests and rots in their seed yams. Ashamo and Odeyemi (2004), and Iheagwam and Ezike (1989) recorded a Yam Moth, *Dasyses rugosella* Stainton (Lepidoptera: Tineidae), in Nigeria. Moyal (1988) studied the infestation of stored yams by larvae of *Euzopherodes vapidella* Mann in the savannah area for two species of *Dioscorea, D. alata* and *D. cayenensis*. The damage to tubers reached 10% to 50% in some localities after 5 months of storage (Sauphanor and Ratnadass 1985; Moyal 1988). Gibbs (1991) reported that a hieroxestid moth, *Opogona sacchari* (Bojer) (Lepidoptera: Tineidae), damaged tubers cv. White Lisbon (*D. alata*) in storage in Barbados, although cv. Oriental tubers (*D. opposita*) stored in the same building were unaffected. Laboratory choice and no-choice tests showed that adults of *O. sacchari* preferred cv. White Lisbon tubers with dead epidermis to those of either White Lisbon with healthy skin or Oriental tubers (Gibbs 1991). The extent of internal damage by the larvae appeared to influence the degree of tuber sprouting and growth of the shoot from the tuber. The Water Yam, *D. alata*, on sale at Nsukka market, Nigeria, was sampled for moth infestation (unknown species) and damage from December 1985 to July 1986 (Ezike and Iheagwam 1988). The percentage of infested tubers increased continuously from February, reaching a peak of 54% in June. An average of 12.6% of all tubers collected was infested.

Beetles, in order of decreasing importance, that were found attacking dried yams during a survey carried out at depots, markets and storehouses in the Ibadan area of Nigeria were: *Dinoderus porcellus* Lesne (Bostrichidae) (Osuji 1980) followed by *Sitophilus zeamais* Motschulsky (Curculionidae), *Tribolium castaneum* (Herbst) and *T. confusum* Duval (Tenebrionidae), *Brachypeplus pilosellus* Murray (Nitidulidae), *Rhyzopertha dominica* (F.) (Bostrichidae), *Tenebroides mauritanicus* (L.) (Tenebrionidae), *Lasioderma serricorne* (Fab.) (Anobiidae), *Araecerus fasciculatus* (De Geer) (Anthribidae), *Cryptolestes pusillus* (Schonherr) (Cucujidae), *Callosobruchus maculatus* (Fab.) (Bruchidae), *Carpophilus hemipterus* (L.) and *C. dimidiatus* var. *contingens* Walker (Nitidulidae) (Adesuyi 1979; Osuji 1980; Iheagwam 1986; Iheagwam and Wojtusiak 1989).

Dried yams are virtually free of infestation on arrival at the depots but rapidly become heavily infested as they are stored in open packages. The weight loss in 4.5 months was 29.5% in newly dried yams and 39.2% in stock that had already been in store for 6 months (Adesuyi 1979). Under laboratory conditions, *D. porcellus* caused much more damage to yam than the other three most abundant species (Adesuyi 1979). Marketed Yams were uninfested in October–March; infestation first became apparent in April, and reached a peak in August (Adesuyi 1979). Fewer *T. castaneum* adults emerged from yam and cassava flour when compared to the flours of wheat, sorghum and maize (Ajayi and Rahman 2006).

Tubers with cut surfaces are more prone to attack by Lepidoptera than those with unbroken epidermis, possibly because first-instar larvae are better able to penetrate the skin of the former (Iheagwam and Wojtusiak 1989). Signs of infestation are visible externally as holes filled with larval faecal matter held together by silken thread produced by the larvae themselves (Iheagwam 1986; Iheagwam and Wojtusiak 1989). *A. hartii* (Akinlosotu and Kogbe 1988; Pillai and Rajamma 1997; Asiedu et al. 2001)*, H. meles* and *H. appius* (Tobih et al. 2007) continue to be important insect pests of yam tubers in storage because of favourable temperatures and humidity in storage rooms. *H. meles* was reported to be the single largest cause of yam tuber rots (Acholo et al. 1997). Storage facilities with poor ventilation favour heavy infestation by *P. dioscoreae* on newly emerged sprouts (Quin 1985).

Stored yam tubers were found to be infested by *Xyleborus ferrugineus* (Fab.) (Coleoptera: Scolytidae) in Nigeria (Williams 1988). Infestation started in November when the tuber moisture content was about 62%. Eggs were laid on the tuber surface damaged during harvesting and the first-instar larva burrowed inside the yam. Research at the Central Tuber Crops Research Institute (CTCRI), Trivandrum, India, revealed that *A. hartii* and *Araecerus laevigatus* were the key pests of Lesser Yam (*D. esculenta*) in storage (Pillai and Rajamma 1997). In addition to these two insects, Coffee Bean Weevil, *A. fasciculatus*, damages tubers of Greater Yam *D. alata* (Palaniswami et al. 1979; Lal and Pillai 1997; Pillai and Rajamma 1997). In *D. alata*, 16% of the samples and in *D. rotundata* 60% of the samples were infested by *A. fasciculatus* after 2 months of storage. *A. fasciculatus* completes its life-cycle in 30–40 d in *D. alata* and *D. rotundata* (Rajamma et al. 2004). Fewer *T. castaneum* adults emerged from yam and cassava flour compared to the numbers emerging from the flours of wheat, sorghum and maize (Ajayi and Rahman 2006).

3. Management

3.1. Management of pre-harvest insect pests

3.1.1. Host plant preference and/or tuber resistance

Many workers have recorded variation in infestation of tubers of different species of yam, but it is not known what factor is responsible for such a differential attack; differences in the quantities of alkaloids and other secondary plant metabolites have been postulated. In India, between 1979 and 1982, several genotypes of *D. alata*, and *D. esculenta* were found to be susceptible to *A. hartii*; however, *D. bulbifera* and *D. hispida* were free of *A. hartii* (Abraham et al. 1979). The mealybug

Ferrisia virgata was observed only on *D. dumatorum* (Nair et al. 1982). The Central Tuber Crops Research Institute (CTCRI) has released varieties of yam suitable for cultivation by farmers in different parts of India. Five genotypes of *D. alata*, Sree Keerthi, Sree Roopa, Sree Shilpa, Sree Karthika and Orissa Elite are resistant to *A. hartii*. In Nigeria, during 1998 to 1999, 24 *D. rotundata* varieties were evaluated for their resistance against YMV transmitted by several aphids. In a screenhouse evaluation involving mechanical and vector transmission, three varieties remained free from YMV infection, confirming resistance to YMV (Hughes et al. 1998).

Natural seed set is rare in *D. alata* and *D. esculenta*. However, hybrid seeds and sexual progeny were successfully produced through germplasm exploration, judicious selection and timely planting of flowering accessions to achieve flowering synchrony of males and females, and through artificial pollination techniques. Sree Shilpa, the first intervarietal hybrid of *D. alata* was released for cultivation in 1998 in India (CTCRI 1998).

Data obtained on development and longevity of Yam Moth, *D. rugosella*, on different yam species *D. alata, D. rotundata, D. cayenensis* and *D. dumetorum* showed that *D. alata* was the most susceptible of all yam species tested (53.3% adult emergence); the least susceptible was *D. dumetorum* with 20% adult emergence (Ashamo 2005). Ashamo (2005) postulated that tannins, alkaloids and sapogenins, present in high levels in *D. dumetorum*, may have been responsible for the differences in insect attack. Echendu and Alozie (1990) screened tubers of six yam cultivars, which were subjected to natural infestation with *Decadarchis minuscula* (Walsingham) (Lepidoptera: Tineidae) under two storage conditions in Nigeria; all cultivars currently recommended for yield and storage were found to be susceptible. Higher values of crude protein, water and reducing sugars, found in cv. UM 680 compared to other cultivars, indicating that nutritional, as well as physical differences may be responsible for differences in cultivar susceptibility to *D. minuscule* (Echendu and Alozie 1990).

The Yam Beetle, *D. porcellus*, has been reared on four species of yam, namely, *D. alata, D. rotundata, D. dumetorum* and *D. cayenensis*. *D. porcellus* preferred to lay more eggs on *D. dumetorum* and the fewest eggs on *D. alata* in a no-choice test. However, in a choice test, the highest number of eggs was recorded on *D. rotundata* (50) and the lowest (30) on *D. cayenensis* (Adedire and Oni 1998). The low oviposition preference and prolonged developmental period of *D. porcellus* on *D. cayensis* may be due to the presence of some oviposition deterrents and anti-feedant factors in the Yellow Yam. There were significant differences in the frequency with which different varieties of yam were attacked by *H. meles* and subsequently infected with *Fusarium* spp. In an independent survey of farmers' experience of yam rot, varieties that scored well correlated with apparent resistance to the beetle and *Fusarium* spp. (Acholo et al. 1997). Studies on the suitability of yam periderm and cortex to *A. fasciculatus* revealed that infestation was more severe when the cortex was cut open. Protection afforded by the periderm differed significantly within and between the species of *Dioscorea*, and was greater in *D. alata* cv. UM 680 than in two cultivars of *D. rotundata* or *D. alata* (Emehute and Echendu 1992). *D. alata* was the most preferred host for the diaspidid scale insect *A. hartii* when compared to three other species of yams: *D. esculenta, D. rotundata* and *D. dumetorum* (Akinlosotu and Kogbe 1988).

Breeding programmes for pest resistance are constrained because of male and female flower asynchrony as well as shortage of suitable pollinators. Ant pollinators are adversely affected by the various types of saponins present in the leaves (Rahbe et al. 1988). There was a negative correlation between leaf saponin content of the yam species and foraging intensity of the ant, *Acromyrmex octospinosus* (Reich) (Hymenoptera: Formicidae); however, the main yam sapogenin, the steroid diosgenin, had no effect on foraging behaviour (Rahbe et al. 1988). Foragers of the formicid ant, *A. octospinosus* were given a choice between plant discs from two cassava varieties, sweet potato and yam. Yam (*D. cayenensis*) was the least preferred (7%) when compared to sweetpotato (16%), and the most preferred was cassava (42.5%) (Therrien 1988).

3.1.2. *Treatment/dipping of the heads*

Healthy planting material offers protection against insect pests for a certain period. Dipping the yam heads before planting in strong lime-sulphur and water (1:10) is effective for the management of *A. hartii*. Reinfestation, however, may come from crawling larval stages blown by the wind or carried on the feet of birds or larger insects; thus a new yam patch should preferably be to the leeward side of a previously infested one (Ritchie 1918, 1919). Before planting, immersion of yam tubers in a solution containing 1 part of fusel oil in 10 parts of water was found successful in controlling Yam Scale *Targionia hartii* (Wilson 1921). A Kerosene-fusel oil emulsion, unlike other contact insecticides, requires no heat when mixing, and in the West Indies fusel oil is cheap. Yams in Jamaica have been seriously damaged by an unidentified borer in the tubers and heads, particularly of Yellow Yams. Immersing the infested heads in a concentrated solution of Jeyes' Fluid® and lime has proved beneficial.

Careful selection of yam heads at planting time and destruction of infested tubers during storage is a prophylactic against Yam Weevil (*P. costicollis*) infestation. Increase in yield of yam was achieved by dipping the setts in 0.3% solutions of fenitrothion, pirimiphos-methyl or diazinon, the highest yields being achieved with diazinon (Akinlosotu and Kogbe 1988). Aighewi et al. (2002) conducted a survey in 35 villages of Oyo North, Asaba, Lokoja, and Lafia areas of the yam belt of Nigeria, involving 299 farmers. Over 57% of the farmers used seed yams from their farms for propagation. Between 50.0 and 65.0% of farmers in Asaba treated seed yams with purchased chemicals before planting to protect against *H. meles*, while in other locations less than 35% of farmers undertook any form of treatment.

3.1.3. *Organic manures*

Stenocrates cultor Burmeister (Coleoptera: Scarabaeidae) was found on yams cultivated with a high quantity of organic matter in Minas Gerais, Brazil (Venzon and Pallini Filho 1995). A marked reduction in termite (Genera *Microtermes, Ancistrotermes* and *Macrotermes)* (Isoptera:Termitidae) damage on yam was recorded in plots applied with organic manures (municipal waste) but reduced the yields (Ogbedeh et al. 2007).

3.1.4. *Cropping systems*

The influence of different intercrops comprising pigeonpea + yam, pigeonpea + cassava, pigeonpea + cocoyam, pigeonpea + maize, and of a pigeonpea monoculture, on the foliar damage by insect pests was studied at the University of Nigeria, Nsukka during 2002 and 2003 cropping year (Dialoke and Ezueh 2006). Pigeonpea in intercrops involving cassava and maize suffered low foliar damage while intercrops involving yam, cocoyam and pigeonpea monoculture suffered moderate damage (Dialoke and Ezueh 2006), but it is not known which species of insects were involved in that study. In our own studies, in the North Eastern Hill Region (NEHR) India (Rajasekhara Rao et al. 2006), we recorded a low incidence of insect pests of component crops in the mixed/intercropping systems involving sweetpotato, colocasia, yam, ginger, maize and vegetables. However, we did not monitor all of the insect pests in these cropping systems (Rajasekhara Rao 2005; Rajasekhara Rao et al. 2006).

3.1.5. *Pheromones*

A sex pheromone, found to be effective in trapping males of the leaf-mining moth *A. nagaimo*, has been identified (Tanaka et al. 2001; Wakamura et al. 2001). Three electrophysiologically active compounds in the abdominal tips of virgin females of *A. nagaimo* were identified: (Z)-11-hexadecenyl acetate (Z11-16:Ac), (Z)-11-hexadecenal (Z11-16:Ald) and (Z)-11-hexadecen-1-ol (Z11-16:OH) at 1.8, 0.6 and 0.2 ng/female, respectively (Wakamura et al. 2001). The optimum blend for male attraction was determined to be 200–1000 μg/septum of a 50:50:2 blend of Z11-16:Ac, Z11-16:Ald and Z11-16:OH, respectively. More than ten times as many males were captured with this blend than with 2 to 3 d-old virgin females (Tanaka et al. 2001).

3.1.6. *Biological control*

The use of parasitoids and predators in biological programmes has been successful in several crops where these agents attack the pests when they are on the foliage (Pradhan 1991). However, in crops such as *Dioscorea* and other tuber crops, economically important insect pests colonise the crop in the field and emerge during storage; thus, the natural enemies are unable to locate the hosts in storage. Palaniswami and Pillai (1982) recorded *Pseudalsomyia* sp. (Diptera: Tachinidae) parasitizing the grubs of leaf-feeding beetle *Lema* sp. The field level parasitism ranged from 7 to 9% and the parasite pupated along with the host. The adult flies emerged 6–7 d after pupation.

Entomopathogenic nematodes *Steinernema corpocapsae* and *Heterorrhabditis bacteriophora* at a rate of 200 infective juveniles per larva were found to be effective in achieving mortality of larvae of Asian saw fly *A. coerulea* (Shylesha et al. 2006). *S. carpocapsae* caused a mortality level of 92.7% in 48 h, when compared to 98.6% to that of *H. bacteriophora* in 72 h (Shylesha et al. 2006).

3.1.7. *Chemical control*

The most conventional way of controlling insect pests in yam is through the use of pesticides. Insecticides are applied as dusts on the planting material or the soil during the tuber-forming period, or as sprays applied to the growing crop. Dipping setts of *Dioscorea* in 0.3% diazinon solution was effective in controlling *A. hartii* (Akinlosotu and Kogbe 1988). Carbofuran 3G (at 47 kg/ha) applied at the time of planting significantly reduced the amount of damage by *H. meles* and *H. appius* (Umeozor 1998). The effects of wood ash, carbofuran and aldrin dust on the control of Yam Tuber Beetle (*H. meles*) and the performance of *D. rotundata* was studied by Ogbomo and Egharevba (2006). The vines emerged earlier from the insecticide treated-setts than the untreated setts, and the emergence was much higher in carbofuran (25.3%) than wood ash (22.3%) and aldrin dust (20.4%). Ogbomo and Egharevba (2006) hypothesised that *H. meles* have developed resistance to aldrin, as there was no significant difference between damage in the aldrin treated setts and the control. They also recommended use of wood ash instead by resource-poor farmers when carbofuran is unavailable.

3.2. Management of post-harvest insect pests

3.2.1. Temperature and humidity

Storage of yam tubers at low temperatures (but higher than 12°C) significantly retarded the development of yam moths, *E. vapidella* (Ashamo and Odeyemi 2001) and *D. rugosella* (Ashamo and Odeyemi 2004) on *D. alata*. In another study by Nwankiti et al. (1988), *D. rotundata* cv. Abii, Nwopoko and Okwocha and *D. alata* cv. Nvulaogbe tubers stored in covered barns with or without rodent-proofing and were compared with traditional open barn storage. An average temperature of 26.5°C and RH of 78.5% in the covered barns, prevented much moisture loss and helped to maintain sustained food quality. In the traditional open barn, an average temperature of 34°C and RH of 60% reduced food quality which resulted in a weight loss of up to 40% after storage for 6 months, as compared to 10–13% in covered barns.

3.2.2. Storage methods and media

Several local methods of storing tubers are mentioned in the literature but we found no mention of the extent of damage by pest insects in these systems. Different methods of tuber storage in different media were studied at CTCRI, India, over a decade. Lesser Yam, *D. esculenta*, tuber damage due to *A. hartii* and *A. laevigatus* infestation was lowest when these tubers were stored in sand (14.4%) and highest in open conditions i.e. control (50.6%). The percent weight loss of tubers after 3.5 months ranged from 20 to 41% in different media, the lowest being in sand. Storing the tubers in sand resulted in a 92.3% reduction in the incidence of *A. hartii*. *A. hartii* populations were controlled by up to 86.5% in sawdust. Very severe damage by *A. laevigatus* and *A. hartii* was observed in the exposed storage (control) as well as in straw + mud paste storage. In exposed storage (control), *A. hartii* populations increased from 39 (initial) to 159 and beetle population increased from zero to 88 per sample after 3.5 months. Tubers can be stored in sand to achieve effective protection against the insect pests. Storing the tubers in sawdust, paddy husk and wood ash was found to be effective against three insect pests: Coffee Bean Weevil, *A. fasciculatus, A. hartii* and *A. laevigatus*, whereas storing the seed yams in fine sand was found to be best for the control of the aforementioned pests (Pillai and Rajamma 1997).

3.2.3. Biological control

Thaneroclerus buqueti (Lefevre) (Coleoptera: Cleridae) was found preying on the larval stages of genus *Heteroligus, Planococcus* and *Aspidiella*, and an unidentified parasitoid wasp was also observed emerging from yam tubers (Adesuyi 1979). Braconid parasitoids have been recorded on the stored yams in Nigeria (Iheagwam 1986). Palaniswami (1991) reported the emergence of two parasitoids, the aphelinid *Coccobius comperei* and the encyrtid *Adelencyrtus moderatus*, from *A. hartii* on yams in India.

3.2.4. Chemical control

Pests and diseases are favoured by current production and storage practices. Good hygiene, cleaning and disinfestation of the store structure is of paramount importance in insect control including, particularly, the destruction by burning of infested tubers. It may still be necessary to use some form of chemical control, especially if storage is extended over several months. Deltamethrin used as a spray of 2.5 g active ingredient per 100 l of water, has been reported to be effective in controlling moths (Tineidae sp.) on stored yams (*D. alata* and *D. cayenensis*) (Sauphanor and Ratnadass 1985).

The general perception of the occurrence of rots in tubers during storage is that damage inflicted in the field prior to storage is far more important than damage caused during storage. This has led to much research directed at the minimisation of field damage, with relatively little work done on the amelioration of insect damage during storage. Insecticide treatment of yam tubers prior to storage could provide a relatively cheap and effective means of preservation. The study of Morse et al. (2000) examined whether insect damage inflicted on yam, *D. rotundata* (cv. Akpaji and cv. Ekpe) tubers during storage in specialized barns near Idah, Kogi State, Nigeria, is an important factor in the incidence of fungal disease. It was found that treatment of tubers with insecticide dust (pirimiphos-methyl 2%) significantly reduced fungal infections (caused by *Fusarium* spp., *Penicillium* spp., *Aspergillus* spp., *Curvularia* spp., *Epicoccum* spp. and *Helminthosporium* spp.) resulting from insect attack (mainly by *H. meles, P. citri* and *A. hartii* during storage). Acholo et al (1997) reported that Yam Beetle *H. meles* was the largest single cause of *Fusarium* infection.

The processing of yam into dehydrated chips is used extensively in many parts of the world to stabilize the product. However, the chips are often severely attacked by borers, which reduce whole stocks to powder within a few months (Vernier et al. 2005). The level of protection provided by various biological products derived from neem (*Azadirachta indica*) and *Crotalaria caricea* were compared with that of a synthetic pesticide, Sofagrain® (1.5% deltamethrin + 0.5% pirimiphos methyl), a reference chemical for stored products in Benin. Insect damage was assessed over a period of 10 months in a storeroom. After 10 months, Sofagrain® still provided a good level of protection, whereas the untreated control was severely attacked by *L. serricorne, Palorus subdepressus* Wollatson, *T. castaneum, D. porcellus, D. bifoveolatus*, and, *R. dominica*. Among the biological products used, the three neem-based treatments (oil, seed powder and leaf powder) gave the best level of protection, whilst *C. caricea* seeds and periodic turning over of storage bags did little to reduce damage (Vernier et al. 2005). The tineid moth, *O. sacchari*, found damaging *D. alata* cv. White Lisbon tubers in storage in Barbados is controlled either by dipping tubers in an 85% solution of Sevin® (carbaryl) WP at 1 kg/200 l of water, or by covering tubers with lime and/or ash (Gibbs 1991). For the storage of seed materials, a mixture of sand and benzene hexachloride (BHC) dust (100:1) was found to be the best medium for achieving complete control of *A. laevigatus* and *A. hartii*. Treating the tubers with monocrotophos (0.05%) and then storing in sand is also effective (Pillai and Rajamma 1997).

4. Conclusions

Yam production in tropical and sub-tropical countries is constrained by many factors including lack of effective and economical insect pest management strategies in the field as well as in storage. Pest control measures, in general, have to be integrated into an operational module, be it large or small in scale, if they are to be effectively applied. While it is not possible to control every insect pest in field, often good crop husbandry can reduce insect infestation, thus leading to minimal interventions in storage.

Development of plant resistance to biotic and abiotic factors has been a focus of attention. Transfer of complementary traits from one *Dioscorea* sp. to another is in progress at IITA, Nigeria (IITA 2007). Although, yam cultivars with resistance to anthracnose and other viral diseases have been developed (IITA 2007), efforts need to be aimed at identification of insect resistance genes in wild yam species, particularly for *H. meles, P. citri* and *A. hartii* and subsequent transfer to cultivated yam species. Although poor pollination and flowering asynchrony are considered to be constraints in yam breeding for resistance, the world's first hybrid, Sree Shilpa, was successfully developed and released for cultivation in India (CTCRI 1998). The roles of yam lectins (Gaidamashvili et al. 2004) and saponins (Francis et al. 2002), are believed to play an important role in host plant defence against insects (Francis et al. 2002), needs to be studied.

The strategy of crop breeding to select yam varieties suitable for various cropping systems must encompass multidisciplinary systems approach or a sustainable supply chain management. Manipulation of the microclimate in yam crop with suitable inter- or mixed-crops, may increase the numbers of beneficial insects. Tropical tuber crops such as sweetpotato, colocasia and yam are grown with maize, ginger and vegetables by farmers in North Eastern Region of India (Rajasekhara Rao 2005). This promotes not only soil and water conservation but is also aimed at reducing the incidence of insect pests, due to allelopathic effects (Rajasekhara Rao 2005). Identification of a suitable yam-based cropping system that takes into account the resources of farmers, as well as concerns of agroecosystem, is imperative.

Development of yam varieties with the straight-growing tubers in soil is important, so that they can be harvested without any mechanical damage. Harvesting of the tubers is one of the constraints in hard soils and alfisols, wherein the direction of tuber growth in the soil is limited by the hardness of the soil, causing the tuber to grow in different directions; tuber damage by implements is inevitable. Tubers damaged or cut during harvesting time are mostly preferred by Lepidopteran larvae (Iheagwam 1986; Iheagwam and Wojtusiak 1989), thus enhancing the risk of attack by fungal rots (Acholo et al. 1997).

Several species of ladybeetles (Coccinellidae) are used effectively for the suppression of *Planococcus* sps. and *Aspidiella* on other crops (Puttarudriah and Channabasavanna 1953; Chacko et al. 1978; Kontodimas et al. 2004). Inundation or augmentation of coccinellid predators in yam can enhance their biological activity in pure and inter- and or mixed-cropping systems, and could help to control pest populations.

Selection of pest-free planting material is important since scales and mealybugs persist on flower buds and tubers. The treatment of tubers or trenches with safe insecticides may ensure protection from these insects. If the incidence of insect pests during crop growth stage is minimized by various methods of integrated pest management, much of their damage in storage could be avoided.

Sorting of undamaged and disease-free tubers soon after harvest and proper curing, is vital for avoiding the yield losses in storage. Subsistence farmers can opt for storing the tubers in sand, wood husk or sawdust, according to the availability, in covered barn storage. This method is an accepted strategy for farmers (Nwankiti et al. 1988). In India, an evaporative cool chamber (ECC), made of bricks in two layers, with dimensions $4 \times 1.5 \times 1.5$ m size, is widely used by farmers for storage of vegetables, and could be an option for small-scale farmers. ECCs are popularly termed zero-energy cool chambers. The gap between two layers of bricks, approximately 10 cm, is filled with sand and water, to maintain the temperatures at around 22–27°C. Research and application of modified and controlled atmosphere for storage of yam need to be focused. In the case of large scale and commercial storage structures, the tubers can be stored at lower temperatures.

Treatment of tubers with insecticide dust before storage is prophylactic against *A. hartii* and *P. citri* which can be used by resource-poor as well as resource-rich farmers. Storing the tubers along with leaves of neem (*Azadirachta indica*), *Eucalyptus* spp., yam bean

(*Pachyrhizus erosus*), or *Crotolaria* spp. can be tried as a repellent or feeding deterrents to beetles in storage.

Fumigation by methyl bromide offers protection against a wide range of insect pests in storage. Insecticidal atmospheres, especially in combination with other treatments such as heat (Yahia 2006) seems to be very promising and should be further investigated for tropical crops like yam. Irradiation can be a phytosanitory measure in case the tubers are transported across regions. White peach scale, *A. destructor*, is controlled with an irradiation dose of 150 Gy (Follett 2006).

The semiochemicals of many species of pest insects have been identified and can be used against these insects by using traps designed to suit yam bulk storage systems. It is essential to follow at least a few of these methods, if not all, according to economic and social conditions, for managing yam insect pests and to ensure a supply of clean and healthy tubers for planting, storage, consumption and processing.

Acknowledgements

We thank Mr Bram Cornelissen, Plant Research International, Wageningen University & Research, Wageningen, The Netherlands; Dr Keith Tomlins, Natural Resources Institute, University of Greenwich, United Kingdom, for making corrections in the manuscript and for their valuable suggestions.

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