Table 1. Evaluation of some new insecticides on *Helicoverpa armigera* in pigeonpea cv LRG 30 at the Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, India, 1990/91 and 1991/92.

Insecticide	Dose/ concentration (%)	No. of larvae/ 5 plants[1]		Pod borer damage[2] (%)		Grain yield (kg ha^{-1})	
		1990-91	1991-92	1990-91	1991-92	1990-91	1991-92
Ethofenprox	0.1	12.2 (3.6)	2.0 (1.7)	19.8 (28.2)	2.7 (9.5)	580	1180
Carbosulfan	0.1	14.2 (3.9)	1.8 (1.7)	6.1 (14.2)	2.8 (9.5)	620	1000
Quinolphos	0.1	10.3 (3.4)	1.5 (1.6)	13.5 (21.5)	2.7 (9.2)	630	1080
Pyraclofos	0.1	11.0 (3.4)	1.8 (1.7)	13.0 (21.1)	3.0(10.0)	610	1180
Sulprofos	0.1	11.0 (3.4)	1.7 (1.6)	13.0 (21.1)	2.9 (9.8)	640	1160
Flucycloxuron	0.01	11.3 (3.5)	2.2 (1.8)	12.0 (21.2)	2.8 (9.6)	540	1120
Diflubenzuron	0.01	13.0 (3.7)	2.8 (2.0)	7.8 (16.2)	2.8 (9.6)	420	970
Flufenoxuron	0.01	10.8 (3.4)	2.5 (1.8)	22.9 (28.5)	2.5 (9.0)	470	1000
Teflubenzuron	0.01	13.8 (3.9)	2.8 (2.0)	4.4 (12.1)	2.9 (9.8)	440	860
Barcillus thuringiemis	0.1	13.7 (3.8)	3.0 (2.0)	8.2 (16.3)	2.9 (9.8)	490	1040
Methamidophos	0.1	10.3 (3.4)	2.3 (1.8)	16.3 (23.7)	3.1 (10.2)	540	1040
Triazophos	0.1	14.0 (3.9)	2.7 (1.9)	7.6 (15.8)	2.8 (9.5)	510	940
Fenpropathrin	0.06	11.3 (3.5)	2.2 (1.9)	12.0 (20.2)	3.0 (9.9)	470	910
Control	-	17.0 (4.2)	3.2 (2.0)	14.7 (22.5)	2.7 (9.5)	470	910
CD (0.05)		NS	NS	(4.1)	NS	100	NS
CV (%)		(8.8)	(10.0)	(12.2)	(15.5)	11.2	15.2

1. Figures in parentheses are $\sqrt{x+1}$ transformed values.
2. Figures in parentheses are $\sin^{-1}\sqrt{\%}$ values.

be developed to effectively control polyphagous pests such as *H. armigera,*

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Natural Enemies Associated with Arthropod Pests of Pigeonpea in Eastern Africa

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Insect pests are among the major biotic constraints to pigeonpea production in eastern and southern Africa

(Lateef 1991). Results from recent surveys in farmers' fields in four major pigeonpea - producing countries in the region (Kenya, Malawi, Tanzania, and Uganda) showed that insect pest damage on pigeonpea seeds was 25% in Kenya, 15% in Malawi, 14% in Tanzania, and 16% in Uganda (Minja et al. 1996). Important insect pests are pod-boring Lepidoptera *(Helicoverpa armigera* Hubner, *Maruca vitrata* Geyer, and *Etiella zinkenella* Treitschke), pod-sucking bugs (*Clavigralla tomentosicollis* Stai), and pod fly (*Melanagromyza chalcosoma* Spencer). Other pests include flower thrips (*Megalurothrips sjostedti* Trybom), flower [pollen or blister] beetles (*Mylabris* spp. and *Coryna* spp.), aphids *(Aphis craccivora* Koch), termites (*Microtermes* spp.), stem borers (*Sphenoptera* sp. and *Alcidodes* sp.), and red spider mites *(Tetranychus* sp.).

Most of the insect pests reported on pigeonpea also damage other grain legumes in the region (Le Pelley 1959, Materu 1970). Although these pests are common and widespread, little information is available on the natural enemies associated with these pests on pigeonpea in the region. Materu (1970) reported *Hadronotus gridus* Nixon (Hymenoptera: Scelionidae) as an egg parasitoid of *C. tomentosicollis* and possibly C. *horrida* Germ., and *Mormonomyia argentifrons* Walker (Diptera: Tachinidae) as a parasite of *C. horrida* adults in Tanzania. Sithanantham and Reddy (1990) reported *Bracon* sp. near *greeni* (A.K. Walker, IIE) as a parasitoid associated with pigeonpea pod fly *M. chalcosoma* in Kenya, Malawi, and Zambia. The two authors also reported insect-feeding spiders (*Thomisus* and *Xysticus* [Thomisidae], and *Tetragnatha* [Tetragnathidae]) on pigeonpea in Kenya, Malawi, and Zambia. There is a need to establish the status of major arthropod pests and their natural enemies as a first step towards understanding their population dynamics and developing management strategies.

Surveys were conducted in farmers' fields in the major pigeonpea-growing areas in Kenya, Malawi, Tanzania, and Uganda to determine the abundance of common and widespread pests and beneficial species on pigeonpea. Two surveys were carried out in each country during the pigeonpea-growing season in 1995 and 1996.

Table 1. Occurrence of natural enemies associated with major insect pests on pigeonpea in Kenya (1), Malawi (2), Tanzania (3), and Uganda (4).

	Insect pest					
Natural enemy	*Helicoverpa*	*Etiella*	*Clavigralla*	*Melanagromyza*	*Callosobruchus*	*Aphis*
Bracon sp. near *hancocki* Wilkinson, Braconidae [A.K. Walker (HE) det.]	–[1]	1, 2, 3, 4	–	–	–	–
Bracon celer Silvestri, Braconidae	–	–	–	–	–	3,4
Bracon sp. near *celer* Szepligeti, Braconidae [A.K. Walker (HE) det.]	–	–	–	1,2,3,4	–	–
Bracon sp., Braconidae [A.K. Walker (HE) det.]	–	1	–	–	–	–
Campoplex laphygma Wilkar, Ichneumonidae	1	–	–	–	–	–
Cosmoiestes sp., Reduviidae	1	–	1	–	–	–
Dinarmus basalts Rondani, Eulophidae	–	–	–	–	3	–
Euderus sp., Eulophidae [J. LaSalle (IIE) det.]	–	1,2,3,4	–	–	–	–
Linnaemyia spp., Tachinidae	1	–	–	–	–	–
Palexorista sp., Tachinidae	1	–	–	–	–	–

1. Absent

Table 2. General predatory arthropods associated with insect pests on pigeonpea in Kenya (1), Malawi (2), Tanzania (3), and Uganda (4).

Predator	Order	Family	Country
Thornisus sp.	Acarina	Thomisidae	1,2,3,4
Xysticus sp.	Acarina	Thomisidae	1,2,3,4
Tetragnatha sp.	Acarina	Tetragnathidae	1,2,3,4
Adonia variegata Goeze	Coleoptera	Coccinelidae	1,3,4
Callida fuscita Dej	Coleoptera	Carabidae	1
Cheilomenes lunata Fabricius	Coleoptera	Coccinelidae	1,2,3,4
C. posticalis Fairm	Coleoptera	Coccinelidae	1
C. vicina Muls.	Coleoptera	Coccinelidae	1,2,3,4
Exochomus flavipes Thunberg	Coleoptera	Coccinelidae	1,2,3,4
Paederus sabeus Er.	Coleoptera	Staphylinidae	1
Forficula sp.	Dermaptera	Forficulidae	1,2,3,4
Harpactor segmentarius Germar	Hemiptera	Reduviidae	1
H. tibialis Stal	Hemiptera	Reduviidae	1
Anoplolepis custodiers Fred Smith	Hymenoptera	Formicidae	1,3
Camportotus rufoglaucus Emery	Hymenoptera	Formicidae	1,2,3,4
Dorylus sp.	Hymenoptera	Formicidae	1,4
Oecophylla longinoda Latreille	Hymenoptera	Formicidae	1,3,4
Phyllocrania sp.	Dictyoptera	Mantodea	1,2,3,4
Pseudocreobotra sp.	Dictyoptera	Mantodea	1,2,3,4
Eublemma sp.	Lepidoptera	Noctuidae	1,3
Hemerohius sp.	Neuroptera	Hemerobiidae	1,2,3,4

Surveys were timed to coincide with similar pigeonpea growth stages in the four countries. Fields were selected at random. Between 30 to 150 pigeonpea pods were collected from each field. The number of pods sampled from each field depended on farm size, plant population, and fanner cooperation. The pods were examined externally and internally to determine seed damage and to identify arthropods associated with the damage. In the field we recorded insect pests and their natural enemies. Samples of insect pests and emerging natural enemies were collected for further identification. Some pest and natural enemy specimens were sent to the International Institute of Entomology, London, UK, for identification. Observations were also recorded during the research station field trials.

Three major insect pest groups were found to be associated with pigeonpea in Kenya, Malawi, Tanzania, and Uganda. They were: pod-boring Lepidoptera (H. *armigera, M. vitrata* and *E. zinkenella),* pod-sucking bugs (mainly *C. tomentosicollis),* and pod fly (*M. chalcosoma).* The magnitude of damage by each group varied across seasons and locations. Natural enemies included Coleopterans, Hymenopterans, Dipterans, and Hemipterans (Tables 1 and 2). Natural enemies of the insect pests were surveyed more frequently in Kenya than in other countries.

Eggs of *Lampides boeticus* Linnaeus (Lepidoptera: Lycaenidae) were observed on the plants, but the population of larvae was quite low. There is a possibility that the list of natural enemies can be added to with more intensive surveys and laboratory rearing of the insects collected in the field. There is a need to study the biology and behavior of some of the natural enemies to establish their population dynamics. Such studies will generate information on their contribution to natural control and the possibility of conserving and augmenting them for pest management in the region.

Acknowledgment. We thank farmers and national agriculture research and extension personnel in Kenya, Malawi, Tanzania, and Uganda for their assistance. Support to E M Minja by the African Development Bank (AfDB) is gratefully acknowledged.

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Solarization to Protect Pigeonpea Seeds from Bruchid Damage during Storage

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Bruchids [*Callosobruchus* spp.) are important storage pests of grain legumes, known to cause substantial economic losses (Ramzan et al. 1989; Srivastava and Pant 1989). This is one of the reasons farmers are often reluctant to grow legumes. Their produce has to be sold and cleared immediately after the harvest even though the market price may not be very remunerative at that time. Sometimes, even storing seeds for sowing becomes difficult, and farmers are forced to buy seed from other sources. In many developing countries of the semi-arid tropics (SAT), the seed industry is not well developed and the availability of quality seed is a major limitation. As farmers are not able to store their seed under pest-free conditions, these are often damaged by insects, particularly bruchids. Seeds damaged by bruchids do not germinate well and thus affect plant stand and consequently yield. This is especially so when the time between harvest and the next sowing is very long, as is the case with several short-season legumes. For example, the interval between harvest and sowing of the next season's crop of extra-short-duration pigeonpea [*Cajanus cajan* (L.) Millsp.] can be 6-9 months as compared to merely 2 months for long-duration pigeonpea cultivars. Thus, a cost-effective technique needs to be developed to protect seeds from postharvest bruchid damage.

Farmers currently use several chemical and nonchemical methods to protect seeds from bruchid attack. Chemical methods such as fumigation or admixture of insecticides such as malathion, though effective, are hazardous and environmentally unsafe. On the other hand, nonchemical methods do not provide foolproof protection either. Sun-drying in an open yard is a common practice employed by SAT farmers. This process in its current form depends upon a variety of environmental factors such as the prevailing temperature, humidity, and cleanliness of the drying area. The process could be enhanced with a little improvization. As in the case of soil solarization (Chauhan et al. 1988), the effectiveness of the sun's rays in disinfecting seeds may be enhanced substantially if seeds were kept in small polythene bags instead of being spread in the open. This study examined the level of accumulation of temperature in polythene bags and its effect on bruchid survival and infestation in the pigeonpea seed contained in them.

Eight polythene bags of 21 x 28 cm size and 100 mm thickness were each filled with 1 kg seed of a medium-duration pigeonpea variety, ICPL 87119. Twelve adult bruchids (*Callosobruchus maculatus* F) in pairs (male and female) were introduced in each bag and the bags were then sealed using adhesive tape. Four of the sealed bags with seeds and insects were exposed to the sun for a week (maximum outside air temperature 42°C) and the same number was kept in the laboratory at 30-35°C in June 1998. The rise in temperature inside the bag was measured using a mercury thermometer inserted into it. The edges at the contact point between thermometers and bags were also sealed with adhesive tapes so that hot air inside the bag did not escape. Germination was tested in the laboratory at 25°C in three replications in petridishes lined with filter paper, holding 10 mL of distilled water. Ten seeds were placed in each petridish and germination was recorded after 3-4 days.

The temperature in the bags exposed to sunlight began to rise with time of the day until evening (Fig. 1). The maximum recorded temperature was about 65°C. This rise in temperature is comparable to the rise noted in surface layers of soils covered by transparent polythene (Chauhan et al. 1988). Unlike soil, where temperature declines in deeper layers due to close packing of soil particles preventing free air flow, there is considerable space between seeds due to their larger size and often irregular shape. This permits quick and uniform distribution