Biology of the African Sweetpotato Weevil Species *Cylas Puncticollis* (Boheman) and *C. Brunneus* (Fabricius) (Coleoptera: Apionidae)

N. E. J. Smit and A. Van Huis

International Potato Centre (CIP), Uganda Office, P. O. Box 7878, Kampala, Uganda; Department of Entomology, Wageningen Agricultural University, P. O. Box 8031, 6700 EH Waginingen, The Netherlands.

Abstract

The bilogy of two African sweetpotato weevils species, *Cylas punticollis* and *C. brunneus* (Fabricius) (Coleoptera: Apionidae),was studied in laboratory experiments carried out at 27± 1 ° C, 45± 5% RH, and a 12 h photophase. *Cylas puncticollis* females lived longer than *C. bruneus* (141 ± 10 and 92±12 days respectively), develop faster (egg to adult 20-28 days, and 32-41 days respectively) and a lower oviposition rate (1.10±0.04 and 1.53 ±0.06 eggs per female per day respectively). The total egg production per female (average 101), sex ratio (1:1) and proportion of eggs surviving to adulthood (average 89%) were similar for both species. The intrinsic rate of increase was higher for *C. puncticollis* (0.553 per 10-day period compared to 0.521 for *C. brunneus*). Under field conditions for sweet potato weevils, like dry spells which expose tubers for egg laying. *Cylas puncticollis* will benefit from its longer longevity during less favourable conditions, as females can survive extended periods when no oviposition sites are available and then resume egg laying when conditions improve.

Key words: Sweetpotato weevil, *Cylas puncticollis, Cylas brunneus, Ipomea batatas*, biology, Kenya.

Introduction

Sweetpotato (*Ipomea batatas* (L) Lam.) is one of the world's most widely grown crops. Farmers in more than 100 countries in tropical, sub-tropical and warm temperate areas rely on its ability to produce good yields on marginal lands with little investment (Horton *et al.*, 1989). In East Africa, sweetpotato is an important subsistence food crop, used as a staple, and as a famine reserve food supply (Scott and Ewell, 1992).

Sweetpotato weevils of the genus *Cylas* are considered to be the most destructive pests of sweetpotato in the world (Chalfant *et al.*, 1990; Jansson and Raman, 1991). Even small populations reduce quality of the roots (Proshold,1993). In response to weevil feeding, the crop produces bitter-tasting and toxic sesquiterpences which render storage roots unfit for human consumption (Akazawa *et al.*, 1960). In Uganda crop losses up to 73% have been reported (Smit, 1997).

All known or suspected pest species of the genus *Cylas* occur in Africa and /or Madagascar, *Cylas puncticollis* (boheman) and *C. brunneus* (Fabricius) being the major ones (Wolfe, 1991). Only *C. fomicarius* (Fabricius) is found circumglobally outside Africa (Wolfe, 1991; CAB International, 1993). All current data indicate that the sweetpotato originated in or near northwestern South America (Austin,1988). *Cylas punticollis* and *C. brunneus* could not have evolved with the sweetpotato as Europeans brought the crop to the African continent. Therefore, the weevils must have originally been associated with other convolvulaceius host plants (Austin *et al.*, 1991). Despite significant attempts to find *C. formicarius* in continental Africa, only two localities have been identified: Msabaha, Kenya and the Natal province, South Africa (Wolfe, 1991; Parker *et al.*, 1992). Numerous recent publications report the ocurrence of *C. formicarius* in East Africa (Gowdey, 1912; Le Pelley, 1959; Ingram, 1967; Mwanga and Wanyera, 1988; Autriqu and Perraeux, 19989; Lenne, 1991; CAB International, 1993). In most cases, however, these reports are based on misidentifications of bicolored specimens of *C. brunneus*.

The International Institute for Tropical Agriculture (IITA) (1997) concentrated research on *C. puncticollis* because this was a more serious pest than *C. brunneus* on their research station in Ibadan, Nigeria. During a survey in South Nyanza, Kenya's principal sweetpotato-growing region, both African weevil species appeared to be of similar importance (Magenya and Smit, 1991). Species composition in Central Uganda could be determined as infested sweetpotato roots were collected during 2 years at a research station. Although the proportions of *C. brunneus* and *C. puncticollis* emerging from incubated roots varied over the different harvest periods, the species were in general equally important (Smit, 1997). Therefore, both species need research attention in the development of an IPM strategy.

Virtually all information on the biology of *Cylas* weevils relates to *C. formicarius* (Mullen, 1981; Jansson and Hunsberger, 1991; and the references in Sutherland, 1986 and Chalfant *et al.*, 1990). There are no published studies on the biology of *C. brunneus*. Eulitz (1974), Nwana (1979), IITA (1982), Anota and Odebiyi (1984), Daiber (1994; referring to data of Eulitz (1974) and Sathula *et al.* (1997) reported on aspects of the biology of *C. punticollis*. Basic biological information is essential for developing control strategies for insect pests. Therefore, the present study concentrated on the comparison of growth rates of *C. puncticollis* and *C. brunneus* populations by measuring the fecundity, longevity, development time, sex ratio and survival rate.

Materials and Methods

Four laboratory experiments were conducted between January 1991 and December 1992. Sweetpotato storage roots, infested with *C. puncticollis* and or *C. bruneus*, were harvested from farmers' fields around the ICIPE Mbita Point Filed Station, Mbita, South Nyanza, Kenya. Emerged adults, separated by species, were cultured on '*Kalamb Nyerere*' roots in a controlled-environment chamber set at 27.0± 1.0 ° C, 45± 5% RH, and a 12 h photophase. These conditions are comparable to the average ambient conditions at Mbita.

Age-specific fecundity and longevity

Fifteen newly enclosed (up to 24-h old) adult male and female pair of each species reared from incubated pupae were placed

in a square Petri dish (9.0 cm, 1.5 cm high). One fresh, healthy, Sweetpotato (variety *Kalamb Nyerere*) root piece (±3 by 2 cm) was placed in each Petri dish with the periderm facing upwards. Freshly excised root pieces were provided daily. Used root parts were removed and examined under a stereomicroscope. The periderm and cut surface were carefully peeled back with a razor blade in order to account the numbers of eggs laid per female. Female mortality was recorded daily. Dead males were replaced if they died before their mate and laid her first egg. Two out of the 15 test-females for each species showed signs of having obtained injuries during handling and produced an exceptionally low number of eggs; these data were not included. The experiment was terminated when all females had died.

Developmental Period

Individual fresh, healthy, sweetpotato roots (variety *Kalamb Nyerere*) were exposed to 100 2- to 3-week-old adult weevils of either species for 24 h. After exposure, the roots were incubated. Eggs were examined daily for hatching by carefully peeling back the periderm of two to four roots with a razor blade. After egg hatch was complete, roots were dissected every 2 to 3 days and the numbers of larvae, pupae and adults counted. When only adults were found dissection stopped. This destructive method had to be used because sweetpotato weevils, when developing in infested roots, cannot be observed without disturbing them; the procedure was similar to the one used by Mullen (1981) for *C. formicarius*.

Sex ratio

Twenty sweetpotato roots larger than 300 g were exposed to >500 adults of either *C. brunneus* or *C. puncticollis* taken from the laboratory culture at random. After two days the adults were removed. The roots were labelled with the date of first exposure, and incubated until most individuals were in the pupal stage (see previous experiment). After dissecting the roots, all pupae were collected in a square Petri dish (9.0 cm by 1.5 cm high) and counted. The pupae were incubated and checked daily for emergence of males and females.

Survival (proportion of egges surviving to adulthood)

Six or eight individual fresh, healthy, medium-sized sweetpotato roots (variety *Kalamb Nyerere*) were exposed to 50 pairs of 2-to-3 week-old males and females of either one of the species for 24 h. Immediately after exposure , half the number of roots were dissected by carefully peeling back the periderm with a razor blade and counting the number of eggs. This destructive methods had to be used, as it was not possible to count eggs accurately based on observed oviposition sites. The remaining roots were incubated in individual containers for 26 days for *C. puncticollis* and 37 days for *C. brunneus*. Adults in the containers were counted and roots were dissected to count the remaining number of adults. The total number of adults retrieved after incubation was related to the number of eggs found directly after exposure in roots infested on the same day. The test was repeated three times for each species.

Calculation of the rate of increase

The first modification of the Leslie-Birch method, as described by Howe (1953) was used to calculate the intrinsic rate of increase (r_m) in this study. This method is suitable for insect species with a long oviposition cycle. The unit period used for the calculation was 10 days. The parameters in the calculation are: the number of female eggs, the proportion of eggs surviving to adulthood, the developmental time and the oviposition time.

Results

Longevity

The percentage of adult female beetles that survived decrease linearly with time (Fig. 1), but females of *C. puncticollis* lived significantly longer (48 days) than those of *C. brunneus* (**Table 1**).

Fig. 1. Longevity of *C. puncticollis* and *C. brunneus* females on "Kalamb Nyerere" sweetpotato root pieces at 27° C (n=13)

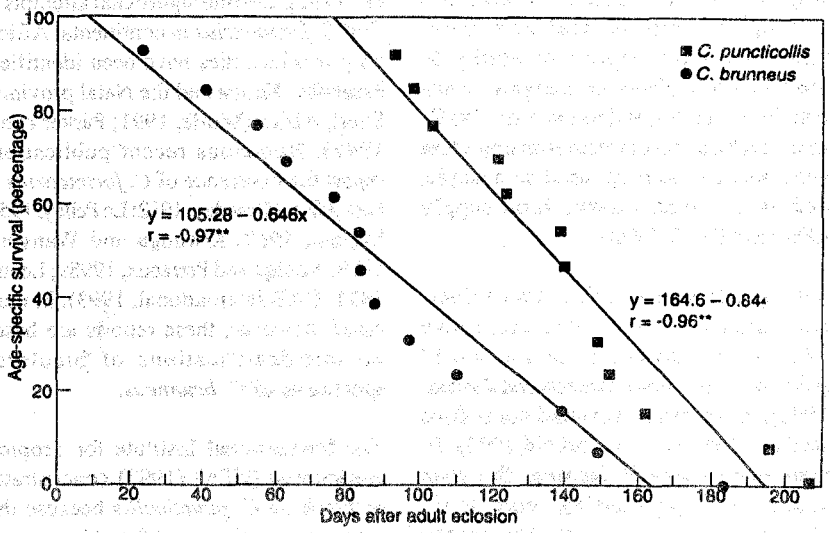


Table 1. Mean duration (in days) of the longevity, and the pre-oviposition and post-oviposition periods (±SEM) for 13 *C. Puncticollis* and 13 *C. Brunneus* females on sweetpotato storage root pieces (variety *Kalamb Nyerere*') at 27° C.

Cylas spp.	Longevity	Pre-oviposition	Oviposition	Post-oviposition
puncticollis	140a±10 (93-207)	13.9a± (0.6 (9-16)	110a±10 (67-171)	15.8a±3.6 (0-37)
brunneus	92b ±12(23-183)	11.4b ±0.6(8-15)	74b ±12 (14-171)	7.0a ±2.4 (0-23)

Means within a column followed by different letters are significantly different by t-test ($p \leq 0.001$ for longevity, $p \leq 0.05$ for the other parameters). Ranges in parenthesis.

Table 2. Mean total and daily (between 15 and 84 days) number of eggs per female (±SEM), survival (proportion of eggs surviving to adulthood) and sex ratio for *C. Puncticollis* and *C. Brunneus* on sweetpotato variety '*Kalamb Nyerere*' at 27° C.

Cylas spp.	Number of eggs per female	Number of eggs per female per day	Survival (% eggs)	Sex ratio (% females)
puncticollis	103a±16 (44-230)	1.10 b ± 0.04	91 a ± 4	49.7a
brunneus	100a±18 (7-177)	1.53 a ± 0.06	87 a ± 3	51.5a

Means within a column followed by different letters are significantly different by *t*-test $p \leq 0.05$ for the other parameters). Ranges in parenthesis

Fecundity

For both speicies maximum oviposition occurred between day 15 and 85 after adult eclosion (**Fig. 2**). After 85 days more than 60% of the *C. brunneus* famales had died (**Fig. 1**) and those that survived continued to oviposit only at a very low rate. All *C. puncticollis* females were still alive on day 85, but from that day onwards the numebr of eggs produced per female per day dropped sharply and remained very low. The pre-oviposition and oviposition period of *C. puncticollis* was significantly longer (2.5 and 36 days respectively) than that of *C. brunneus* (**Table 1**). The total egg production was similar for both species, i.e. about 100 (**Table 2**). *Cylas brunneus* females laid their eggs just beneath the periderm of the root surface, while *C. puncticollis* females laid them slightly deeper. Very few eggs were laid on the cut surfaces of sweetpotato roots.

Developmental preiod

Eggs, larvae and pupae of *C. puncticollis* developed faster than those of *C. brunneus* (**Fig. 3**). The first adult weevils of *C. puncticollis* and *C. brunneus* emerged from the infested roots 24 and 34 days respectively after exposure of the roots to oviposition. Adult eclosion usually occurred 1 to 4 days before emergence from the root and was dependent on the proximity of the pupal chamber to the surface.

Sex ratio

For *C. puncticollis* 5501 pupae enclosed from 20 roots and for *C. brunneus* this figure was 3792. In both cases the sex ration did not depart significantly from 1:1 (Table 2).

Survival

Egg and larval mortality was low, 9% for *C. puncticollis* and 13% for *C. brunneus*, the difference not being significant (Table 2).

Intrinsic rate of increase

The intrinsic rate of increase of *C. puncticollis* was 140 days, similar to the value reported by Sathula *et al.*, 1997), while Anota and Odebiyi (1984) and Eulitz (1974) found considerable shorter female longevities (Table 3). However, the experimental conditions used in the last two references were probably less appropriate for famale survival. *Cylas brunneus* females lived 48 days shorter than those of *C. puncticollis* (Table 3). This longevity does not differ much with the average longevity of *C. formicarius* as reported by Mullen (1981) and Jansson and Hunsberger (1991), i.e. 79 and 76 days respectively.

Fig. 2. Daily oviposition by *C. puncticollis* and *C. brunneus* females on "Kalamb Nyerere" sweetpotato root pieces at 27° C (n=13)

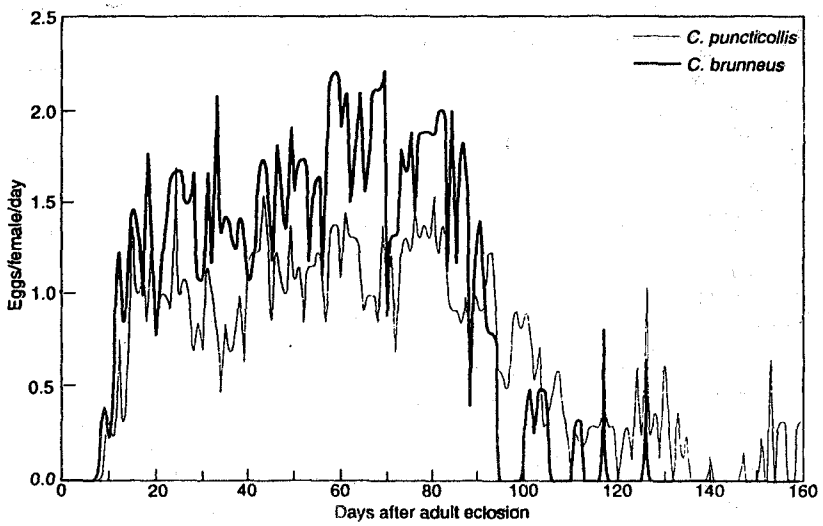
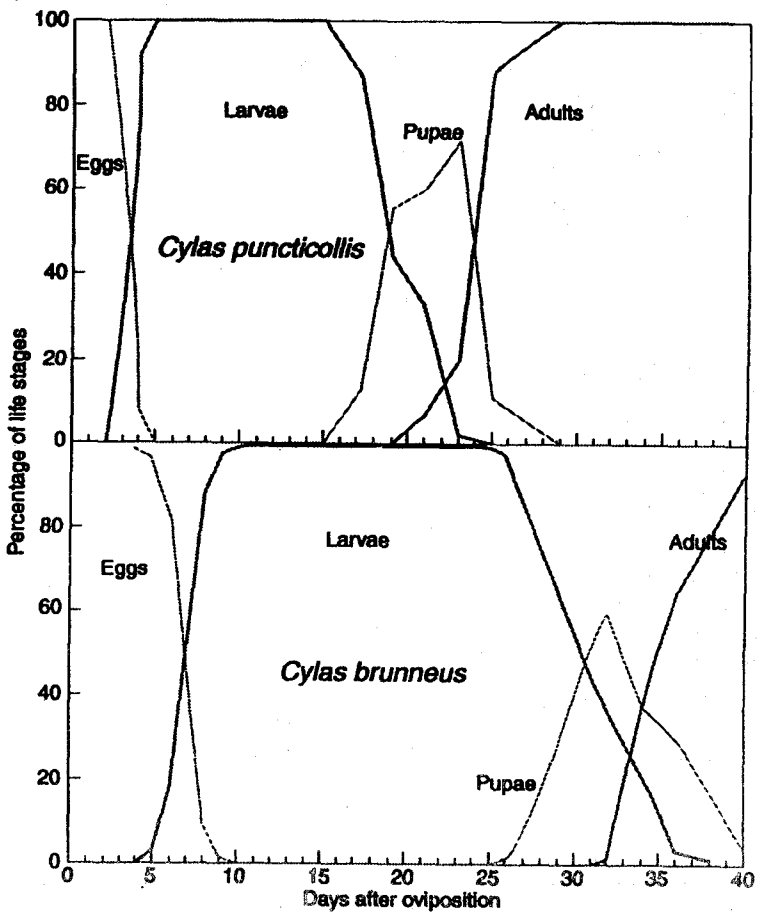


Fig. 3. Development of *C. puncticollis* and *C. brunneus* in sweetpotato (var. "Kalamb Nyerere") roots at 27° C



Fecundity

The fecundity of *C. puncticollis* in this study was 3 times lower as that measured by Anota and Odebiyi (1984) but similar to those reported by Eulitz (1974) and Sathula *et al.* (1997) (Table 3). The experimental conditions under which Anota and Odebiyi (1984) conducted their experiments were probably more stressful for the females which may have induced oviposition. The actual fecundity they found may have been even higher because they used the average number

Table 3. Longevity, fecundity, developmental period (egg to adult) and intrinsic rate of increase[1] of three Cylas spp., from different studies[2]

	female longevity	Average number eggs per female	Developments period	Intrinsic rate of increase
C. brunneus				
This study	92	100	32-41	0.521
C. puncticollis				
This Study	140	103	20-28	0.553
Eulitz (1974)	72	117	16-23	0.69
Nwana (1979)	-	-	22-32	-
Anota and Odebiyi (1984)	81	308	19-25	1.05
Sathula *et al.* (1997)	143	115	-	-
C. formicarius				
Mullen (1981)	79	88	25-31	0.82
Jansson &Hunsberger (1991)	76	122	-	

[1]In 10-day periods according to the first modification of the Leslie-Birch method (Howe, 1953).

[2]Experimental conditions:	Site	Temp (° C)	%RH	Photophase	Variety
This Study	Laboratory	27±1	45±5	12	Kalamb Nyerere
Eulitz (1974)	Laboratory	27	65	12	Mafuta
Nwana (1979)	Laboratory	22-31	63-94	?	?
Mullen (1981)	Laboratory	27±2	60±5	12	jewel
Anota & Odebiyi (1984)	Laboratory	25-30	70	12	TIB4
Jansson & Hunsberger (1991)	Laboratory	27±3	60	12	Picadito
Sathula *et al.* (1997)	Screenhouse	8 - 35	?	?	SPNO (vines)

of viable offspring per female (ovisposition x survivoship to adulthood). Our fecundity data for *C. puncticollis* and *C. brunneus* females are similar to those reported for *C. formicarius* (Table 3).

Pre-oviposition period

The previous oviposition period for *C. puncticollis* in this study was 13.9 days, 10.1 days more than that found by Anota and Odebiyi (1984) and 6 days more than that reported by Eulitz (1974) (Table 1). Anota and Odebiyi (1984) did not describe how they obtained the virgin females; if adult age was taken as the period after leaving the root, the actual age post-emergence was greater than that reported. This is because adults may remain an average of 6 days within the root before they eat their way out (Eulitz, 1974). Recently emerged adult weevils often 'hide' in exit tunnels, as they appear to be attracted to dark places. Therefore, the above differences in pre-oviposition period may be an artefact.

Developmental period

The developmental period (egg to adult) for *C. puncticollis* in this study (20-28 days) is similar to that founded by Anota and Odebiyi (1984) (Tabe 3), while Eulitz (1974) found a 4-5 days shorter and Nwana (1979) an 2-4 days longer developmental period (Table 3). Nwana (1979) dissected the insects daily from root pieces, a disturbance which may have slowed down their development. The developmental period of *C. brunneus* is 12 to 13 days longer and that of *C. formicarius* 3 to 5 days longer (as reported by Mullen, 1981) than that of *C. puncticollis*.

Sex ratio

The sex ratio of both *C. brunneus* and *C. puncticollis* in our study was 1:1. The same values were found for *C. puncticollis* (Anota and Odebiyi, 1984; Eulitz, 1974) and *C. formicarius* (Mullen, 1981).

Survival

Only 10% of the eggs did not develop into adults. No information could be found in the literature on the proportion of eggs surviving to adulthood. Anota and Odebiyi (1984) included the proportion in their fecundity figures, as they counted emerged adults.

Intrinsic rate of increase (r_m)

The r_m value of *C. puncticollis* was higher than that of *C. brunneus*. The two species did not differ in sex ratio, Survivorship to adulthood and the total egg production per female. However, *C. brunneus* had a longer development duration and a shorter oviposition period than *C. puncticollis* and because the r_m was lower for *C. brunneus* than that of *C. puncticollis*, the longer developmental duration proved to be most important. The data for *C. puncticollis* provided by Eulitz (1974) and Anota and Odebiyi (1984) are sufficient to estimate a r_m value, although the daily oviposition pattern had to be estimated from their graphs, and female survivorship from the average longevity and its range. The r_m values calculated this way, are higher than one obtained in this study (Table 3). Anota and Odebiyi (1984) reported a higher oviposition a much higher total fecundity, while Eulitz (1974) reported a higher oviposition rate during the first weeks after sexual maturity than recorded in this study. The difference in r_m values between the *C. puncticollis* data documented in this study and the results of Eulitz (1974) and Anota and Odebiyi (1984) are due to differences in experimental conditions such as the method of confinement of couples, fitness of weevil culture, sweetpotato cultivar, etc. The data provided by Mullen (1981) and Jansson and Hunsberger (1991) allows the calculation of the r_m values to *C. formicarius* at 27° C (Table 3). These r_m values are higher than those obtained for *C. brunneus* and *C. puncticollis* in this study. The reason for this is a higher oviposition rate during the first three weeks after female sexual maturity. It might be worthwhile to study whether the differences in r_m values ot the 3 *Cylas* species are caused by the experimental conditions.

Based on the r_m values, the population of *C. puncticollis* would within one year be 672 times larger than that of *C. brunneus*. However, population increase is not dependent solely on the r_m value, especially as conditions in the field do not remain identical over a long period. For example,the higher oviposition rate of *C. brunneus* would favour this species during short periods of favourable conditions like dry spells which expose tubers for egg laying. However, *C. puncticollis* is favoured when oviposition sites are not available over long periods, because the females live longer and are able to lay eggs again once oviposition sites become available. The fluctuating ratio between the two species, as observed over one growing season in sweetpotato crops (Smit, 1997), proves that other factors besides the r_m value are important for population increase.

Acknowledgements

The authors would like to thank the Director General and staff of the International Centre of Insect Physiology and Ecology (ICIPE) for providing laboratoryy facilities at the Mbita Point Field Station, South Nyanza, Kenya and their support during the research. Luke Matengo and Justus Ochwedo are

thanked for their dedicated conribution in data collection. Dr. Bruce L. Parker, CIP consultant, is acknowledged for his support during the first phase of the study. We are grateful to CIP collegues and Prof. Joop van Lenteren for reviewing the paper. Ineke Kok is thanked for communication support.

References

Akazawa T., Uritani I, and Kubota H. (1960) Isolation of ipomoeamarone and two coumarin derivatives from sweet potato roots injured by the weevil, Cylas formicarius elegantulus. Arch. Biochem. Biophys. 88. 150-156.

Anota T. and Odebiyi J. a. (1984) The biology of the sweet potato weevil, *Cylas puncticollis* boheman (Cleoptera: Apinidae) in south-western Nigeria. Nigerian J. Ent. 5, 10-19.

Austin D. D. (1988) The taxonomy, evolution and genetic diversity of sweet potatoes and related wild species, pp. 27-60. In Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources. International Potato Centre (CIP), Lima, Peru.

Austin D. F., Jansson R. K and Wolfe G. W. (1991) Concolvulaceae and Cylas: A propose hypothesis on the origins of this plant/insect relationship. Trop. Agric. (Trinidad) 68, 161-170.

Autrique A. and Perreaux D. (1989) Maladies et Ravageurs des Cultures de la Region des Grand Lacs d' Afrique Centrale. 232 pp. Administration Générale de la Coop'eration au Developpement. Brussels, Belgium.

CAB Iinternational (1993) Distribution Maps of Pests. Series A. Map No. 278. Cylas formicarius (Fabricius). Map No. 279. *Cylas puncticollis* (Bohoman). Map No. 537. *Cylas brunneus* (Fabricius). CAB International, UK.

Chalfant R. B., Jansson R. K., Seal D. R. and Schalk J. M. (1990) Ecology and Management of sweetpotato insects. Annu. Rev Entmol. 35, 157-180.

Daiber K. C. (1994) Injurious Insects, spider mites and nematodes on sweet potatoes in southern Africa. J. Plants Dis. Prot. 101. 550-557.

Eulitz E. G. (1974) Die biologie van die patakalander. 82 pp. MSc Thesis, University of Pretoria, Pretoria, South Africa.

Gowdey C.C. (1912) An Account of Insects Injurious to Economic Products and Their Control. Department of Agriculture, Uganda Protectorate, Entebe, 32 pp.

Horton D., Prain G. and Gregory P. (1989) High-level investment returns for global sweetpotato research and development. CIP Circular 17, 1-11.

Howe R. W. (1953) The rapid determination of the intrinsic rate of increase of an insect population. Ann. Appl. Biol. 40. 134-151.

IITA (1977) Research Highlights 1976. 157 pp. International Institute of Tropical Agriculture, Ibadan, Nigeria.

IITA (1982) IITA Annual Report 1981. 178 pp. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Ingram W. R. (1967) Chemical control of sweetpotato weevil in Uganda. East Afr. Agric. Forest. J., 163-165.

Jansson R. K. and Hunsberger A. G. B. (1991) diel and ontogenetic patterns of oviposition in the sweetpotato weevil (Coleoptera: Curculionidae). Environ. Entomol. 20, 545-550.

Jansson R. K. and Raman K. V. (1991) Sweetpotato pest management: a global overview, pp. 1-12. In sweet Potato Pest Management. A Global Perspective (Edited by R.K. Jansson and K.V. Raman). Westview Press, Boulder, Colorado.

Lenné J. M. (1991) Diseases and Pests of Sweet Potato. Bull No. 46. 116 pp. Natural Resources Institute, Overseas Development administration, London, UK.

Le Pelley R.H. (1959) Agricultural Insects of East Africa. 307 pp. East African High Commission, Nairobi, Kenya.

Magenya O. and Smit N.E.J.M. (1991) Preliminary note on sweetpotato pests and local control practices in South Western Kenya, pp. 130-138. In the role of Root Crops in Regional Food Security and Sustainable Agriculture (Edited by M.N. Alvarez and R. Asiedu).

Proceedings of the Fourth Eastern and Southern Africa Regional Workshop on Root and Tuber Crops, Mansa, Zambia, 29 Oct.-2 Nov. 1990. IITA, Ibadan, Nigeria.

Mullen M.A. (1981) Sweetpotatoweevil, cylas formicarius elagantulus (Summers). Development, fecundity and longevity. Ann. Entomol. Soc. Am. 74, 478-481.

Mwanga R.O.M. and Wanyera N.W. (1988) Sweetpotato growing and research in Uganda, pp. 187-198. In Improvement of Sweetpotato (Ipomoea batatas) in East Africa. Report of the workshop on sweetpotato improvement in Africa, Nairobi, Kenya. International Potato Centre, Lima, Peru.

Nwana I.E. (1979) The biology of Cylas puncicollis Boheman (Coleoptera: Apionidae) on Ipomoea batatas (Leinneaus) Lamarck. Nigerian J. Ent. 3, 185-190.

Parker B.L., Wolfe G.W. and Abubaker A. (1992) Occurrence of Cylas formicarius (F.) (Col., Apionidae) in Central and Sourthern Africa. J. Appl. Ent. 114, 400-402.

Proshold F.I. (1983) Mating activity and management of Cylas formicarius elegantus (Coleoptera: Curculionidae) on sweetpotato. Proc. Amer. Soc. Hortic. Sci. Trop. Sect. 27(B), 81-92.

Sathula R.A., Logan J.M., Munthali D.C. and Nyirenda G.K.C. (1997) Adult longevity, fecundity and oviposition characteristics of *Cylas puncticollis* Boheman on sweetpotatoes. Afr. Crop Sci. J. 5,39-45.

Scott G.J. and Ewell P.T. (1992) Sweetpotato in African food systems, pp. 91-104. In Product Development for Root and Tuber Crops. Vol. III – Africa. Proceedings of the Workshop on Processing, Marketing and Utilization of Root and Tuber Crops in Africa, October 26-November 2, 1991, Ibadan, Nigeria. (Edited by G. Scott, P.I. Frguson and J.E. Herrera). CIP. Lima, Peru.

Smit N.E.J.M. (1997) The effect of the indigenous cultural practices of in-ground storage and piecemeal harvesting of sweetpotato on yield and quality loss caused by sweetpotato weevil in Uganda. Agric. Ecosyst. Environ. 64,191-200.

Sutherland J.A.(1986) A review of the biology and control of the sweetpotato weevil Cylas formicarius (Fab.). Trop. Pest Mnage. 32, 304-315.

Wolfe G.W. (1991) The origin and dispersal of the pest species of Cylas with a Key to the pest species groups of the world, pp. 13-44. In Sweetpotato Pesrt Management. A Global Perspective. (Edited by R.K. Jansson and K.V. Raman). Westview Press, Boulder, Colorado, USA.