Biology of Tortoise Beetle (*Coleoptera: Chrysomelidae*) on Sweet Potato

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Abstract

The biology three tortoise beetle of *Aspidomorpha confinis* klug,1835, *Aspidomorpha equatoriensis* Borowiec, 1986 and *Conchyloctenia punctata* Fabricius,1787 which commonly feed on sweet potato in Wolaita, southern Ethiopia was studied under laboratory condition. Adults and larvae were reared separately on fresh sweet potato leaves in plastic containers (28cm x 20cm x 8 cm) under ambient condition (21-28°C). Females *A. confinis, A. equatoriensis* and *C. punctata* had 16.8±0.6, 22.8±0.7and 20.1±1.0 days pre-oviposition, 44.6±3.2, 28.3±1.8 and 32.3±2.0 days oviposition, and 15.7±1.9, 17.8±1.9 and10.7±1.4 days post oviposition periods, respectively. *A. equatoriensis* lived longer with the longest oviposition period than others. *C. punctata* and *A. equatoriensis* lay their eggs in golden brown ootheca having 10-40 and 3-35 distinct oothecal membranes, respectively. The ootheca of *A. confinis* is a simple translucent creamy parchment, enclosing a single ovum. A female of *A. equatoriensis* laid a total of 615 eggs, *C. punctata* 327 and *A. confinis* 157. The average numbers of eggs per female per day were 14.4 ±0.9, 16.2±0.3 and 40.6±0.6 for *A. confinis, A. equatoriensis* and *C. punctata*, respectively. The incubation period of eggs was 10.3±0.1, 9.4±0.1 and 11.2±0.4 days in *A. equatoriensis, C. punctata and A. confinis* beetles, respectively. Larval period lasts 18.4±0.2, 18.4±0.2 and18.8±0.6 days for, *A. equatoriensis, C. punctata*, and *A. confinis*, respectively .Early instars of *A. equatoriensis* and *C. punctata* are gregarious whereas *A. confinis* were solitary. Pupation was completed in 6.2±0.1, 6.5±0.3 and 8.8±0.2 days for *A. equatoriensis, C. punctata* and *A. confinis*, respectively. All the three species suffered the highest mortality during the first larval instars period. Net reproductive rates (R_o) of 44, 22 and 18 were recorded for *A. equatoriensis, C. punctata and A. confinis*, respectively. *A. equatoriensis, C. punctata* and *A. confinis* had total generation period of 50.7, 57.6 and 58.7 days, respectively, showing that they can complete 6 to 7 generations per annum.

Introduction

In Ethiopia sweet potato is produced mainly for human consumption. Southern Ethiopia is the main sweet potato growing region of the country where about 3% of the total crop area is annually allotted for sweet potato and more than 16% of the total volume of production of the country comes from this region (CSA 2002). Since sweet potato is mostly produced in low input agricultural system, losses due to insects may often reach 60–100% (Chalafant *et al.* 1990; Sorensen 2009). Several species of tortoise and leaf beetles (Chrysomelidae), the sweet potato hornworm (*Herse convolvuli*) and the sweet potato butterfly (*Acraea acerata*) are defoliators of sweet potato (Hill, 1983; Smit *et al.*1997). Defoliators of sweet potato have previously been considered as pests of minor importance (Azerefgne, 1999). However, the sweet potato tortoise beetles have been economically important pest in parts of Africa (Hill 1983; Smit *et al.*1997).

Over twelve species of insects have been recorded on sweet potato in Ethiopia. The most important among these are: the sweet potato leaf miner (*Bedellia somnulentella)*, sweet potato weevil (*Cylas spp.*), sweet potato tortoise beetles *(Aspidomorpha* spp.), and sweet potato butterfly (*Acraea acerata)* (Adhanom *et al.*, 1985). So far nine species of tortoise beetles have been recorded on sweet potato in Ethiopia. These are: *Aspidomorpha apicalis* (Klug), *Aspidomorpha areata* Klug, *Aspidomorpha areata var nigripennis*, *Aspidomorpha cincta* Fabricius, *Aspidomorpha quadrimaculata* (Oliver), *Aspidomorpha tecta* (Beheman), conchylo tortoise beetles; (*Conchyloctenia hybrida* (Beheman), *Conchyloctenia illota* (Beheman), and *Conchyloctenia punctata* (Ferdu *et al.*2009).
According to Ferdu *et al.(*2009) the importance of this beetle was minor , however during the survey period(2008) of this study it was a big problem even for Msc students who work their research on sweet potato under filed conditions and they sprayed more than two times. This is may be due to the sporadic nature of the insect. Adults are metallic and very colorful, ranging from gold to green to yellow (Ghidiu, 2006). Both larvae and adults of tortoise beetles are leaf eaters.

Tortoise beetles cause serious damage sporadically (Ghidiu, 2006). Newly set plants are most susceptible, and can be severely damaged or killed by feeding of this pest (Shepard *et al* .1999; Ghidiu 2006; Bwana 2008). However, life history studies have not been conducted on any of the Ethiopian cassidinae species and little is known about their importance. Thus the study was conducted to understand the biology of three common species of tortoise beetles, *Aspidomorpha confins*, *Aspidomorpha equatoriensis*, and *Conchyloctenia punctata* which commonly feed on sweet potato in southern Ethiopia. There is no related work on the biology of the these species in other countries. The absence of this information may be due to lack of biological study about the species.

Material and Methods

Biology of *A. equatoriensis, A. confinis* and *C. punctata* was studied at Crop Protection Laboratory of Hawassa University, Ethiopia in 2008-2009. The adults and larvae of the three tortoise beetles were separately collected from sweet potato fields in Wolaita, southern Ethiopia where sweet potato is intensively cultivated in January 2008. Samples of adult tortoise beetles were preserved in 70% ethanol and sent to Zological Institute, University of Wroclaw in Poland for identification. The Remaining adults and larva collection were reared separately in plastic containers (measured 28 x 20 x 8 cm^3) under ambient condition (temperature range 21-28°C). Complete randomized design was used for the experiment with three replication .The insects were fed on fresh leaves of sweet potato and checked daily for oviposition. Larvae of the three species were fed separately on leaves of sweet potato until they complete their life cycle.

Eggs laid on a particular day on leaves of sweet potato were kept separately in Petri-dishes (Ø9 cm) and the number of days needed for hatching was recorded. The development of the larvae was checked daily for molting to identify the number of instars and stadium by observing the insect every day. Duration of pupae was determined by monitoring daily emergence of adults. And the pupation took place in petri –dishes. The adult beetles of the three species which emerged on the same date were put together to get mating couple for subsequent studies. The beetles were frequently checked within a day to note the start of mating. The numbers of adult males and females were recorded separately for the tree species to determine the sex ratio. The sexes were identified while they mate, males of the tree species are relatively smaller in size which was clearly visible. Males of *C. punctata* have 15-17 and females 19-23 small black spots. The number of insects which survived at each stage was recorded for each cohort and the survivorship of each species was determined. The number of cohort used for each species and different parameters was different as indicated in the result part in the table for each parameter.

Paired Couple of the newly emerged adults were placed in Petri dishes (9mmØ) with fresh leaves of *sweet* potato and data were collected on mating, pre-oviposition, oviposition, post-oviposition, longevity and fecundity. Egg masses were collected and counted daily from each pair and kept for hatching. The adults were kept and offered leaves of sweet potato until they die. The number of larvae hatched from each egg batch was recorded and percent hatchability was determined (larvae/ootheca). When hatching ceased, all ootheca were dissected under a microscope to determine the total; number of eggs per ootheca, and the number of fertile and unfertile eggs, respectively. Eggs with larval head capsules were classified as fertile (Jimenez –Perez *et al.*2004).

For each of the three species their fecundity (the total number of eggs laid per adult female), the mean number of eggs per female per days, fertility (the proportion of fertile eggs), and longevity (duration from emergence to death) were determined. The mean longevity of males and females was calculated, assuming that an individual died the day before it was found dead in the Petri dish (Devis and Van Lenteren, 2002). The net reproductive rate (*Ro*, mean number of female offspring/female) $\sum lxmx$ were computed for the three beetles following the method used by Birch (1948).

Result and Discussion

Description of the life stages

Adult

Adults of *A. equatoriensis* have flattened, oval, and convex shaped bodies. They are gold or bronze in color. *C. punctata* adult are brown and larger in size than the other two species investigated. The elytra contain black spots on the transparent extension of the elytra and 19-24 small black spots for the female and 15-19 for the male. The adults of *A. confinis* are green and the smallest of the three. Female body size tends to be larger than male in all the three species (Figure1).

Figure1.Adults of *A. equatoriensis* (top left), *C. punctata* (below) and *A. confines* (top right)

The elytra ground color of the three species changed remarkably with age. Though the changes were gradual, three color phases in *A. confinis* and *C. punctata* beetles and four in *A. equatoriensis* were recognized (Table 1). In the three species the last color phase coincides with sexual maturity. Knowledge on the color change can provide a rough measure for determining the age of adult in the field and can be used to take management actions before the beetles start mating and ovipositbecause mating was took place at the last color phase. A. *confinis* females started mating 12.8±1.3 (N=44) days, *A. equatoriensis* 10.5±0.5 (N=72) aand 15.1±0.3(N=132) days for *C. punctata* after emergence. Females of *A. equatoriensis, C. punctata* and *A. confinis* first laid eggs at 4.5±4.7 (N=72), 8.5±0.5 (N=132) and 7.2±0.6 (N=44) days after mating. Males and females of the three species repeatedly mate and spend long hours in copula.

Table 1. Change in ground color of elytra in *A. equatoriensis, C. punctata* and *A. confinis*

Species	Age (days after emergence)	Phase	Color
A. equatoriensis	0-2	I	White
	2-6	II	yellow-brown
	6-11	III	Dark brown
	11and above	IV	Golden (bronze)
C. punctata	1-2	I	White
	2-5	II	Light yellow
	5and above	III	Brown
A. confinis	0-2	I	White
	2-6	II	Light green
	6 and above	III	Green

The sex ratio (female to male) for *A. equatoriensis*, *C. punctata* and *A. confinis* were 1:1.5(N=61), 1:1.4(N=101) and 1:1.7(N=66), respectively.

The three species differed in their mean longevity. The highest and significantly (P<0.0001, LSD) different female longevity were recorded for *A. equatoriensis* 75.6±2.7 followed by *C. punctata* 69.2±2.4 and *A. confinis* 63.1±2.0 days. Significant (P < 0.0001) differences were also observed in longevity of the three male Tortoise beetles. *A. equatoriensis* beetle had the highest male longevity 71.5±3.3days followed by *C. punctata* 62.1±2.5 and *A. confinis* 50.8±2.3 (Table 2). Nakamura *et al.* (1989) also reported 63.8-88.4 days and 83.3-87.9 days of mean longevity for male and female *Aspidomorpha miliaris* and *Aspidomorpha sanctaecrucis*, respectively. The three beetles differed significantly (p<0.05) in the total number of days in ovipositional period (Table 3) *A. equatoriensis* had the longest oviposition period than *A. confinis* and *C. punctata*. The incubation periods of eggs were 10.3±0.1, 9.4±0.1 and 11.2±0.4 days for *A. equatoriensis*, *C. punctata and A. confinis* eggs, respectively and significantly different (p<0.05) (Table 2). Incubation periods of cassidinae eggs had been shown to vary from species to species. For example *Aspidomorpha maculatissima* eggs hatched within 6-10 days (Hawkeswood, 1982), *Chrysomela scripta* 4-5 days (Neel *et al.* 1972) and *Melasoma populi* in about a week (Kadu *et al.*1980).

Table 2. Mean ±SE of the duration (days) of life stages and longevity of the three species under laboratory conditions at Hawassa University, 2008.

Name of Species	Stage and periods									
	Adult longevity		Pre-ovipostion	ovipostion	Post-ovipostion	Incubation period	Larval period	Pupal period	Developmental period	Total Generation
	Male	Female								
A.equatoriensis	71.5±3.3 **(N=68)**	75.6±2.7 **(N=68)**	16.8±0.6 **(N=132)**	44.6±3.2 **(N=69)**	15.7±1.9 **(N=132)**	10.3±0.1 **(N=207)**	18.4±0.2 **(N=246)**	6.2±0.1 **(N=27)**	33.9±0.2 **(N=225)**	50.7
C. punctata	62.1±2.5 **(N=61)**	69.2±2.4 **(N=61)**	22.8±0.7 **(N=72)**	28.3±1.8 **(N=60)**	17.8±1.9 **(N=72)**	9.4±0.1 **(N=246)**	18.4±0.2 **(N=209)**	6.5±0.3 **(N=194)**	34.8±0.3 **(N=201)**	57.6
A. confinis	50.8±2.3 **(N=54)**	63.1±2.0 **(N=54)**	20.1±1.0 **(N=44)**	32.3±2.0 **(N=52)**	10.7±1.4 **(N=44)**	11.2±0.4 **N=129)**	18.8±0.6 **(N=135)**	8.8±0.2 **(N=126)**	38.6±0.7 **(N=128)**	58.7

± = standard error of the mean

Table 3. Mean± of the duration (days) of life stages and longevity of the three species under laboratory condition at Hawassa University, 2008.

Name of specie	Stages and								
	Adult longevity		Pre ovipostion	ovipostion	Post ovipostion	ation	Larvae period	Pupae period	Total developmental period
	Male	Female							
A.equatoriensis	71.5±3.3a	75.6±2.7a	16.8 ±0.6a	44.6±3.2a	15.7±1.9a	10.3±0.1a	18.4±0.2a	6.2±0.1a	33.9±0.2a
C. punctata	62.1±2.5b	69.2±2.4b	22.8±0.7b	28.3±1.8ab	17.8±1.9b	9.4±0.1b	18.4±0.2a	6.5±0.3ab	34.8±0.3ab
A. confinis	50.8±2.3c	63.1±2.0bc	20.1±1.0c	32.3±2.0c	10.7±1.4bc	11.2±0.4c	18.8±0.6a	8.8±0.2c	38.6±0.7c

* Means within column followed by the same letter are not significantly different at P = 0.005 (LSD)

Egg

C. punctata and *A. equatoriensis* laid their eggs enclosed in a translucent golden brown ootheca (Figure 2) .There were 10-40 and 3-35 distinct ootheca membranes in *C. punctata* and *A. equatoriensis*, respectively. Each ootheca membrane contains four eggs in *C. punctata* and three in *A. equatoriensis*. The total number of oothecae laid by *A. equatoriensis* ranged 10-130 per female while 1-24 by *C. punctata*. Females of *C. punctata* produced ootheca per day while it was 1.4 for *A. equatoriensis*. *A. confinis*, however, laid single eggs in an ootheca covered with translucent creamy parchment-like membrane.

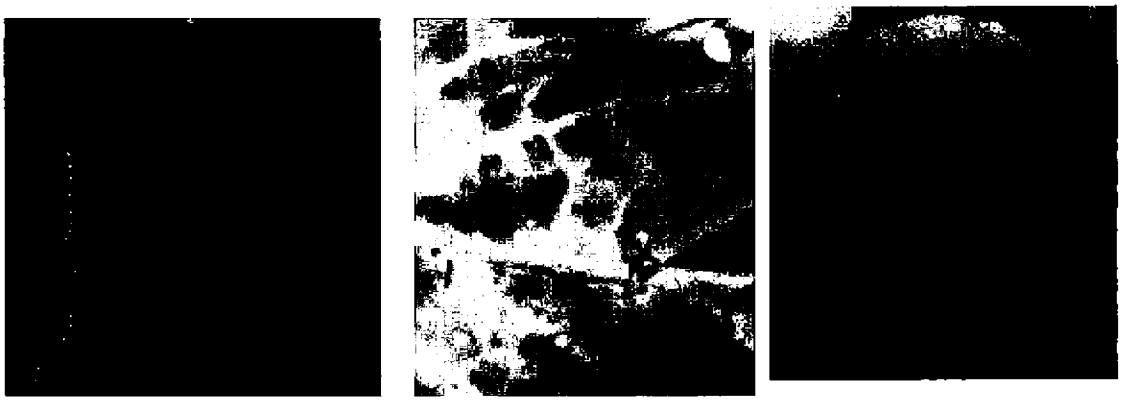

Figure 2. Ootheca of *C. punctata* (left), egg of ootheca of *A. equatoriensis*(middle) and egg of *A.confinis* (right)

Larvae

C. punctata larvae are light brown with black spines. A. *equatoriensis* larvae are flat, light green and possesses lateral fleshy spine. The larva of *A. confinis* are green, flattened, with branched lateral fleshy green spines per segment (Figure3). All the three species undergo 5 larval instars (Figure 4) that was determined by inspection of molting. Larvae of *A. equatoriensis* and *C. punctata* are gregarious at earlier instars. *A. confinis* larvae are strictly solitary. *Aspidimorpha areata* which lays single eggs in an ottheca is similar to *A. confinis* that is also solitary during their larval periods (Heron, 2007). The earlier larval instars (1^{st} to 3^{rd}), feed by scraping the surface of the leaf, whereas older instars (4^{th} to 5^{th}) consume the entire leaf, and create irregular holes between the leaf veins excluding the midribs. The holes formed by the larvae and adults are similar.

Larval periods were similar of the three species. The larval periods were within the range reported by Sanders et. *al.* (2003) for the cassidinae beetles of *Metriona bicolor* that lasted 17–23 and 17-26 days of *Cassida circumdata* (Vasquez and Sajise, 2002).

Figure 3. Larvae of *C. punctata* (left) *A. equatoriensis* (middle) *A. confinis* (right)

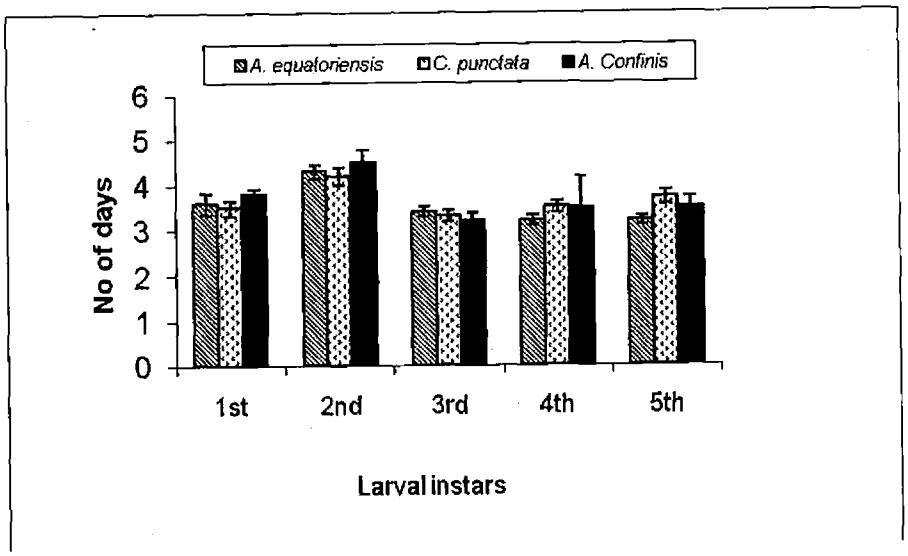

Figure 4. Duration of differnt larval instars of the three species tortoise beetle reared on sweet potato.

Pupae

Pupa of *C. punctata* is yellow with darker shade along the body marginWhile that of Puape of *A. equatoriensis* are light green. As it was the case with larvae, the pupae of *A. equatoriensis* and *C. punctata* bear spines and cast exuviae of larva remain attached to the pupa. Pupa of *A. confinis* is green, oval and flattened (Figure 5).

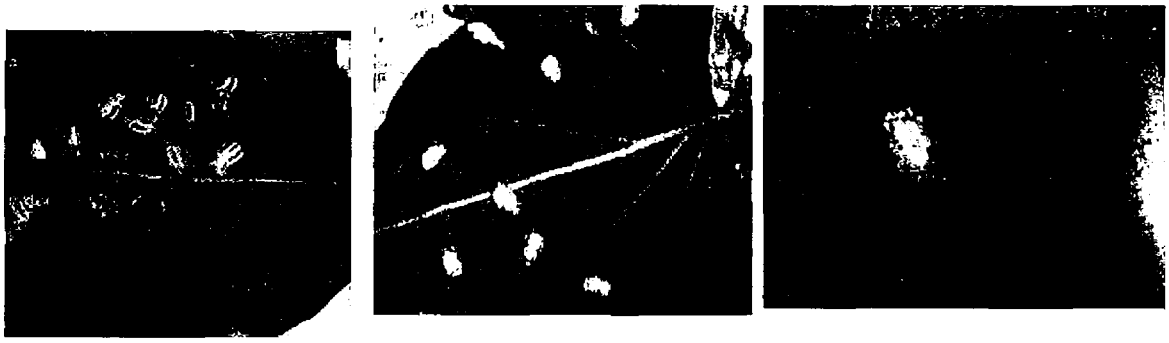

Figure 5.Pupal stage of *C. punctata* (left), *A. equatoriensis* (middle) and *A. confinis* (right)

Pupal period lasted 6.2±0.1, 6.5±0.3 and 8.8±0.2 days for *A. equatoriensis*, *C. punctata* and *A. confinis*, respectively. The pupation periods are within the range reported for other cassidinae. Golden tortoise beetle, *Charidotella bicolor* completes pupation between 7-15 days (Ghidiu, 2006) *circumdata* and *miliaris* 4-8 and 7 days, respectively (Vasquez and Sajise, 2002).

The total life cycle (egg to adult) lasted 33.9±0.2, 34.8±0.3 and 38.6±0.7 days for *A. equatoriensis*, *C. punctata* and *A. confinis*, respectively, which were comparable to other cassidinae. *Charidotella* (=*Metriona*) *bicolor* required about 40 days to develop from egg to adult (Capinera, 2007) and *Aspidimorpha areata* 37–42 days (Heron 2007). Total generation times (egg to egg) were about 51 for *A. equatoriensis*, 58 for *C. punctata* and 59 days for *A. confinis* which suggested that the three beetles can complete about 6 generations per annum if food and other environmental conditions are not limiting.

Survivorship

The three cassidinae beetles differed in their survival rate in which and *A. confinis* had the highest (30%) (Figure 6). *C. punctata* and *A. equatoriensis* had almost similar survival. For all the three species the highest mortality was recorded during the first larval instars period. The survivorship follow type III curve characterized by high infant/juvenile mortality (Begon *et al.*1990). This survivorship curve shows at what age death rates are high and low.

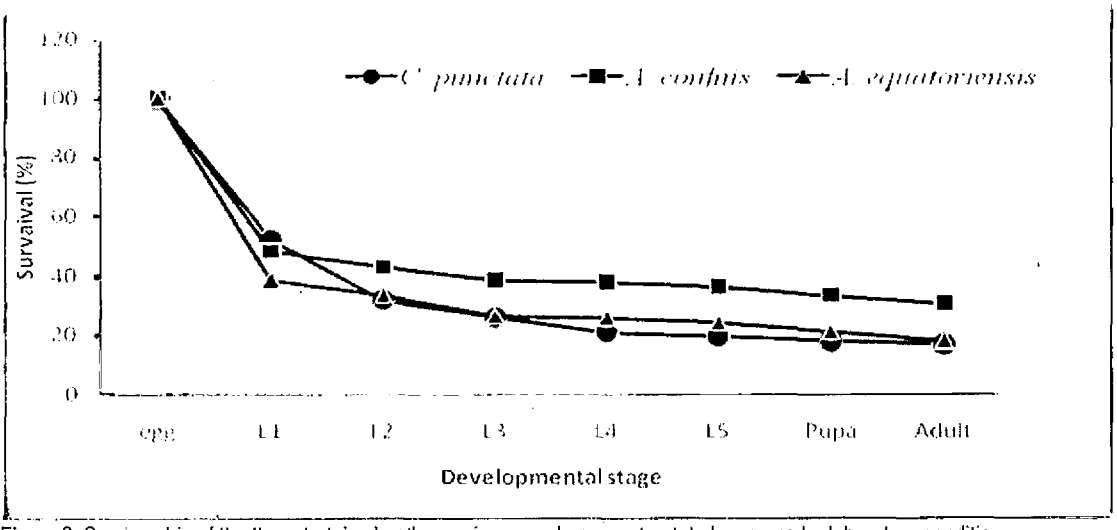

Figure 6. Survivorship of the three tortoise beetle species reared on sweet potato leaves under laboratory conditions.

Population attributes

The gross fecundity (total number of eggs laid per female) differed considerably ($p<0.0001$) among the three tortoise beetles species (Table 4). A female of *A. equatoriensis* laid a total of 615.5±48.6, *C. punctata* 327.1±24.7 and *A. confinis* 157.1 ± 13.6 eggs. The average numbers of eggs per female per day were 14.4 ±0.9, 16.2±0.3 and 40.6±0.6 for *A. confinis*, *A. equatoriensis* and *C. punctata*, respectively (Table 4). The study showed that fecundity is negatively correlated with longevity in *A. equatoriensis* ($r= -0.5$, $P<0.0001$) and *A. confinis* ($r= -0.7$, $P<0.0001$).

Table 4. Reproductive potential of the three tortoise beetles reared on sweet potato leaves under laboratory conditions.

Attributes	*A. equatoriensis*	*C. punctata*	*A. confinis*
Total number of oothecae per female	53.2±4.2 **(N=56)**	8.0±0.60 **(N=55)**	157.1±13.6 **(N=61)**
No of oothecae per day	1.4 ±0.03 **(N=81)**	1.0±0.0 **(N=55)**	
No. of eggs /ootheca	11.5±0.2 **(N=1824)**	40.6±0.6 **(N=895)**	
Total no. of eggs /female	615.5± 48.6 **(N=56)**	327.1±24.7 **(N=55)**	157.1±13.6 **(N=61)**
No. of egg /female/day	16.2±0.3 **(N=56)**	40.6±0.6 **(N=55)**	14.4 ±0.9 **(N= 61)**

Eggs of *C. punctata* had the highest hatchability (51.9%) followed by *A. confinis* (48%) and *A. equatoriensis* (38.3%). Dissection of all the ootheca masses revealed that *A. equatoriensis* and *C. punctata* had some fertile eggs in the ootheeae that failed to hatch. As a result, the fertility of *A. equatoriensis* (52.9±0.7%) was slightly higher than the hatchability while the increase was very high for *C. punctata* (81.8±0.9%). Fertility and hatchability did not differ in case of *A. confinis*.

The beetles had high net reproductive rate (Ro) of 44, 22 and18 for *A. equatoriensis*, *C. punctata and A. confinis*, respectively. The capacity of multiple generation per annum coupled with the high biotic potentials indicate that the three species could build population densities of damaging levels with a couple of generations in absence of limiting factors like natural enemies, food and weather.

Acknowledgment

The authors are grateful for their proficient guidance, Development Innovation Fund (DIF), Hawassa University for their financial support. Dr. Lech Borowiec and Jolanta Swietojanska of University of Wroclaw in Poland are acknowledged for identifying the beetles at the species level.

References

Adhanom Negasi, Tsedeke Abate and Emana Getu.1985. Research on insect pest pf root and tuber crops in Ethiopia. Pp427-431. Tsdecke Abate (ed).A review of crop protection research in Ethiopia. Proceeding of the first Ethioipan crop protection symposium. 4-7 February, 1985. Addis Ababa, Ethiopia.

Begon MJ, Harper L and Townsend RC.1990. Ecology: individuals, populations and communities (2nd ed.) .Blackwell Scientific Publications. 945 pp.

Birch LC. 1948. The intrinsic rate of natural increase of an insect population. *Journal of Animal Ecology 17:* 15-26.

Bwana E. 2008. Controlling Tortoise Beetles in Sweet potatoes. CTA, Article : 5583

Capinera JL.2007. Golden Tortoise Beetle, *Charidotella (Metriona) bicolor* (Fabricius) (Insecta: Coleoptera: Chrysomelidae). Sweet Potato Pest Insects. Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Florida.

Central Statistical Authority (CSA). 2002. Ethiopian Agricultural Sample Enumeration. 2001/2002 (1994 E.C). Report on the preliminary result of area, production and yield of temporary crop (Meher season, private peasant holdings). Volume I, part II. Addis Ababa, Ethiopia.

Chalafant RB, Jansson RK, Seal DR and Schalk JM.1990. Ecology and management of sweet potato insects. *Annual Review of Entomology* 35:157-180.

Devis MJ and Van Lenteren JC. 2002. Longevity, fecundity, oviposition frequency and intrinsic rate of increase of the greenhouse whitefly, *Trialeurodes vaporariorum* on greenhouse tomato in Colombia. *Bulletin of Insectology* 55 (1-2): 3-8

Ferdu Azerefegne, Bayeh Mulatu, Emana Getu, Temesgen Addis, Eyob Tadesse, Messele Gemu and Brook Wubshet. 2009. Review of entomological research on root and tuber crops in Ethiopia. Abraham Tadesse (ed). In: Increasing crop production through improved plant protection. PPSE and EIAR, Addis Ababa, Ethiopia. 2: 21-24.

Ferdu Azerefegne.1999. Biology and economic importance of the sweet potato Butterfly in Ethiopia. PhD thesis. Swedish University of Agricultural Sciences. Uppsala, Sweden.

Ghidiu GM. 2006. Tortoise Beetles. Fact sheet. Insect Pests of the Home Garden Series. The State University of New Jersey. New Jersey.

Hawkeswood TJ. 1982. Notes on the life history of *Aspidomorpha maculatissima* Boheman (Coleoptera: Cassidinae at Townsville, North Queensland. *Victoria Naturalist*.99: 92-101

Heron HD.2007. The life history of *Aspidimorpha areata (Klug, 1835)' (Coleoptera: Chrysomelidae: Cassidinae). African Entomology* 15(1):75-87.

Hill D. 1983. Agricultural insect pests of the tropics and their control, second edition. Cambridge University Press, Cambridge. 45pp.

Jimenez-Perez A, Wang Q and Markwick N. 2004. Intrinsic rate of increase in *'Cnephasia' jactatana* Walker (Lepidoptera: Tortricidae), a pest of kiwifruit. *New Zealand Entomologist* 27: 109-112.

Kadu IK, Ali HA and Hamadi MK.1980. General entomology. Book House for Publishing and Printing, Iraq. In Arabic. 395pp.

Nakamura K, Abbas I and Hasyim A.1989. Survivorship and fertility schedules of two Sumatran tortoise beetles, *Aspidomorpha miliaris* and *A. sanctaecrucis* (Coleoptra; Chrysomelidae) under laboratory condition. *Researches on Population Ecology* 31: 25–34.

Neel WW, Morris RC and Head RB.1972. Biology and natural control of the cotton wood leaf beetle *Chrysomela scripta* Fab. (Coleoptera: Chrysomelidae). Mississippi, USA. *Review of Applied Entomology*. 66: 282

Sanders HM and Eubanks M D. 2003. Comparative water relations of adult and juvenile tortoise beetles: differences among sympatric species. *Comparative Biochemistry* and *Physiology*, Part A, 135: 625-634.

Sheppard BM ,Carner GR, Barrion AT, Ooi PA and van den Berg H.1999. Insects and their Natural Enemies Associated with vegetables and Soybean in Southeast Asia. Orangeburg, SC: Quality Printing Company. 108 pp.

Smit NF, Lugojja and Ogenga-Latigoo MW. 1997. The sweet potato butterfly (*Acraea acerata Hew.)* Nymphalidae. *A review. International Journal of Pest Management* 43: 275 -278.

Sorensen KA. 2009. Sweet potato Insects: Identification, Biology and Management. Springer Netherlands. Netherlands. pp 161-188.

Vasquez EA and Sajise CE. 2002. Biology of Tortoiseshell beetle, *Aspidomorpha miliaris* (F.) Chrysomelidae. PRIS and PRCRTC, Visayas State College of Agriculture, Baybay, Leyte, Philippines. 66 pp.