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Biology of the Enset Root Mealybug *Cataenococcus ensete* and its Geographical Distribution in Southern Ethiopia

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ABSTRACT

Objective: The aim of this study was to study the biology of the Ensete root mealybug *Cataenococcus ensete* in southern Ethiopia.

Methodology and Results: During 2004-2005, the biology of *C. ensete* was studied in the laboratory of the Southern Agricultural Research Institute, Awassa, Ethiopia. The distribution and importance of the insect was also investigated in 25 districts of southern Ethiopia from where a total of 163 sites were visited from July to December 2004. The females are viviparous and produce 253±17.4 nymphs/female. The average duration of the first, second and third-instar nymphs was 16.2±0.47, 18.15±0.69 and 19.75±0.47 days, respectively. The average life span of the adult female is 49.95±0.47 days. The body length and width of the adult female mealybugs ranged from 2.9 - 4 mm and 2.5 - 3.5 mm, respectively when measured with wax covering. Adult female mealybugs could not survive more than three weeks in the soil in the absence of plant materials. Although *C. ensete* was observed between 1,054 and 2,977 masl its infestation was severe only between 1,400 to 2,200 masl. The highest infestation (53.6%) was recorded between 1,600-1,800 masl. Although mealybugs were recorded in several districts, the level of infestation was high only in Amaro, Gedeo, Sidama and Bench in which 100, 66.7, 61.5 and 57.1%, respectively of the surveyed farms were infested. The survey revealed that more than 30% of the total surveyed farms were infested. The highest mean number of mealybugs (81mealybugs/plant) was recorded in Gedeo zone and the lowest (3.3 mealybugs/plant) in Yem district. Knowledge about the biology and distribution of this species has paramount importance in devising proper management strategies.

Conclusion and application of findings: The current study revealed that the enset root mealybug is a serious pest that is causing heavy damage to enset. Hence there is a dire need for strengthening extension programs in order to educate people on the level of distribution and severity of the pest. Techniques for the production of clean planting materials in nurseries and a regulation of the distribution and exchange of planting materials should be devised.

Key words*:* enset, infestation, instar, survival

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INTRODUCTION

In Ethiopia enset is a multi-purpose crop utilized for food, animal feed, fiber construction materials and medicines by more than 15 million people in the highlands of southern Ethiopia. However, the sustainability of enset agriculture is threatened by a number of biotic and abiotic factors. In a recent study, 82.2% of farmers were of the opinion that enset production is decreasing due to various diseases, insect pests, vertebrate pests, drought, declining soil fertility and an increasing human population (Addis, 2005; Addis *et al*., 2006). Bacterial wilt and enset root mealybug are the most important constraints.

In the afro-tropical region, several mealybug species including *Dysmicoccus brevipes* (Cockerell), *Dysmicoccus grassii* (Leonardi), *Ferrisia virgata* (Cockerell), *Paracoccus burnerae* (Brain), *Paraputo anomalus* (Newstead), *Planococcus citri* (Risso), *Planococcus musae* (Matile-Ferrero and Williams), *Planococcus ficus* (Signoret), *Cataenococcus ensete* (Williams and Matile-Ferrero) and *Cataenococcus ferris* (Williams and Matile-Ferrero) have been reported on the Musaceae family, comprising the genus *Musa* and *Ensete*. The last three species were reported from Ethiopia and *P. burnerae* from Kenya infesting *Ensete* spp. (Williams & Matile-Ferrero, 1999).

Cataenococcus ensete is a major pest of enset in southern Ethiopia, having been first reported at Wonago (Tsedeke, 1988). Although the insect has been present in Gedeo, Sidama, Gurage, Kembata Tembaro, Hadyia, Keffa and Bench zones and Amaro and Yem districts for long, it has become a serious threat to enset production only in recent years (Addis, 2005). The Enset root mealybug is known by different local names in different areas; '*Tsete'* in Gedeo, '*Chea'*, '*Churcha'* and '*Hufaro'*, in Sidama, '*Buno'*, '*Osk'*, '*Oote'* and '*Dachu'* in Bench language. The insect attacks enset of all age groups, but it is more serious on 2 to 4 years old enset plants (Anonymous, 2000).

In view of the existing knowledge gap on its distribution, biology and economic importance, it is imperative that investigations be carried out on *C. ensete* to generate information that would assist to design appropriate management methods. The objectives of this study were therefore (i) to study the biology of *Cataenococcus ensete* and (ii) to determine the distribution of the insect in the main enset growing areas of southern Ethiopia.

MATERIALS AND METHODS

Identification of mealybugs: Enset root mealybugs were collected from Wonago located at 38° 12'E, 6° 12'N, 1,763 masl in southern Ethiopia. The different stages were grouped based on their body size. Each group was kept in 70% ethanol in 1.8ml size vials and sent to the International Institute of Tropical Agriculture (IITA), Biological Control Center for Africa/Biodiversity Center in the Republic of Benin where they were identified.

Biology of Enset Root Mealybug

Study site: The biology of the enset root mealybug was studied at the Awassa Agricultural Research Center, Entomology laboratory, located at 38° 31'E; 07° 04'N and 275 km from Addis Ababa, at 1,700 masl. The studies were conducted at room temperature of approximately 25.3±0.2°C and relative humidity of 59.7±1.9 %.

Rearing mealybugs: Different plants and their parts were evaluated for suitability as substrate to rear enset root mealybugs. Pumpkin (whole and slice), enset (root and slices of corm) and potato tubers were tested as rearing substrates. Two of each of enset roots (about 5 cm long), pumpkin (whole and slices) and potato tubers were placed in Petri dishes and two first-instar mealybugs were introduced onto each substrate in the Petri dish. Mealybugs such as *Planococcus citri* (Risso) which is a vector of banana streak virus have been reared successfully on pumpkins in Uganda (Williams Tinzaara, personal communication). Potato sprout have been used widely in different parts of the world as a rearing substrate for various mealybug species including the enset root mealybugs in Petri dishes (Blumberg & Swirskii, 1997), the citrus mealybug, the oleander mealybug, the obscure mealybug and others (Wakgari & Giliomee, 2004; 2005).

Whole pumpkin, pots and dishes were initially washed in 5% sodium hypochlorite (Chlorox) to remove fungi and inhibit their further growth. The substrates were then washed with soap and rinsed with tap water to remove the sodium hypochlorite. The suitability of the different substrates for rearing mealybugs was conducted by introducing 30 first-instar nymphs on each substrate (Enset roots, Enset corm, whole pumpkin, slices of pumpkin and potato tubers). The mealybugs were kept in boxes covered with black muslin cloth. Pumpkin slices, enset corms and roots were changed every three days and the insects were transferred to new substrates.

Survival of mealybugs: Survival of enset root mealybugs in the soil in the absence of any plant material (food) was also tested in the laboratory. Instars and adult female mealybugs were kept in Petri dishes containing moist and sterilized soil (Nitosols). A drop of water was added at two day intervals to make the soil soft and mortality data was taken daily.

Biology: The biology of enset root mealybug was studied by infesting 20 pumpkins each with 20 first-instar nymphs. The growth pattern and other biological attributes of each individual were recorded daily until the insect died. On death of an insect, similar-aged mealybug was introduced from the stock culture. The mealybugs introduced on to the pumpkins were maintained in boxes covered with black muslin cloth. The number of nymphs produced per adult female (i.e. fecundity), the number of instars, and the period taken to complete each stage, growth and survival were recorded. The new recruits were removed everyday to avoid repeated counting. Based on the information obtained from this study, the duration for one generation and the number of generation per annum was calculated.

The body size and moulting time was used to distinguish among the different instars as indicated by Ghose (1971); Cadee & Van Alphen (1997) and Gullan (2000), among others. The body size of each instar was measured dorso-medially by taking the longest length of the insect from the head to the tip of the abdomen. The body length and width of thirty individual mealybugs for each developmental stage (first-instar nymph, second-instar nymph, third-instar nymph and adult female) was measured to determine the body size. The body size of unborn first instars was also measured by dissecting ovipositing females and sampling 50 bright to yellow orange crawlers.

Distribution of mealybugs

Survey sites: The main enset producing areas and the agro-ecological map of enset distribution (MoA, 1982) was used to select the survey sites. Sidama, Gedeo, Wolyita, Gurage, Siltie, Bench, Maji, Kembata Tembaro, Gamo Goffa, Keffa, Sheka, Hadyia, West Showa, Jimma zones and Amaro and Yem Districts of southern Ethiopia were included. A structured random sampling procedure was adopted. Based on the area coverage of each zone, more than 25 districts were selected and from each district three peasant associations (PAs) and in each PA two farms were selected randomly with some bias to road accessibility. In addition, enset nursery sites and maintenance fields of the Bureau of Agriculture and the Southern Ethiopia Agricultural Research Institute (SARI) were also surveyed.

Farm observations: Farmers were interviewed regarding: (1) age of the plant sampled, (2) time of sucker production, (3) time of transplanting, (4) frequency of transplanting, (5) sources of suckers, (6) local name of enset root mealybug, (7) management of enset root mealybug, (9) enset production status, (10) name of enset clones present in the farm and the two most dominant clones, and (11) cropping system and pattern.

Based on the information obtained from farmers, the two most dominant enset clones from each farm were selected for root and corm damage assessment. Two to four years old enset plants were selected and from each clone three plants, i.e. a total of 978 plants were dug out and assessed for presence or absence of mealybugs and where present the numbers of mealybugs were counted in infested plants. The level of mealybug infestation at each farm was recorded on a 0 to 4 scale as described by Ngeve (2003), where 0 = free from mealybugs; 1 = 1- 25% of sampled plants infested; 2 = 26- 50% of sampled plants infested; 3 = 51- 75% of sampled plants infested; and 4 = > 75% of sampled plants infested.

Data Analyses: The distribution of mealybugs and the intensity of infestation were analyzed using SPSS for windows version 11.0. Percent weighted average infestation (WAI) for each area was calculated by using the formula;

$$\text{WAI (\%)} = \frac{\sum_{i=0}^{4} fixi}{(MIS(4))x(TNF)} x100$$

Where; f_i = number of farms attributing a given score, x_i = Infestation classes of the location (from 0 = none of sampled plants infested to 4 = more than 75% of the sampled plants infested), MIS = Maximum Infestation Scale, and TNF = Total Number of Farms.

RESULTS AND DISCUSSION

The identity of enset root mealybug, previously known as *Paraputo* sp., was confirmed as *C. ensete* in accordance with Williams & Matile-Ferrero (1999). The root mealybugs collected from a related plant species (*Heliconia* sp.) were, however, identified as *Trochiscococcus speciosus* (De Lotto) (Homoptera: Pseudococcidae) (De Lotto, 1961).

Although enset root mealybug was first reported in Ethiopia in 1988 (Tsedeke, 1988), much has not been known about its biology. Enset root mealybug has an elongate, oval body covered with a thin layer of wax on the dorsal and lateral sides that gives the insect the appearance of a cottony, spine-like projection. These waxes are not part of the insect's body but they are incorporated into the new wax secretions at each successive moulting.

The enset root mealybug has different development stages: (1) bright-orange to yellow-orange colored "crawlers" or rapidly moving first-instar, (2) second- and third-instars that begin to develop distinct lateral and posterior cerarii, increase in body size, and start to produce large amounts of honeydew and (3) the pre-ovipositing adult female. Males are unknown for *C. ensete* and none were observed during this study too.

The first- and second-instars were relatively easy to differentiate, because the moults or exuvae were clearly observed. Also, a difference in the number of cerarii and body size was observed distinctly. However, the duration taken by the third-instar to complete its development to the pre-ovipositing adult female was difficult to determine because no clear moulting was observed. Thus the duration of the third-instar was estimated from the time when individual second-instars entered the third-instar to the time when the bright orange to yellow-orange "crawlers" were seen inside the body or 'egg-sac' of the ovipositing female. The total duration of the insects' life is over a 100 days (Table 1).

The average duration of the first-, second- and third-instar was 16.2±0.5, 18.2±0.7 and 19.8±0.4 days, respectively. The average development period of the mealybug from the first-instar to the adult female was 54.1±1.0 days and the life span of the adult female was 50.0±0.5 days (Table 1). Thus the estimated generation time of the enset root mealybug is 94 -113 days. Enset is a perennial crop and can support development of the mealybug throughout the year. Based on the data obtained from this study, enset root mealybug can have up to three generations per year.

Adult females showed a pronounced crosswise segmentations running down their body. They are viviparous and each female mealybug produced 156 to 383 nymphs in its lifetime. Each female gave birth to an average of six nymphs per day. The crawlers usually remained beneath their mother's body or 'egg sac' for about four days. After emerging the crawlers wondered around until they found suitable feeding and settlement sites.

The body size of the different nymphal stages when measured with the thin wax coverings ranged from 0.5 to 2.7 mm in length and 0.3 to 1.9 mm in width (Table 2). The nymphs are similar in body shape to the adult mealybugs but smaller in body size. The body size of adult mealybugs ranged from 2.9 to 4.0 mm in length and 2.5 to 3.5 mm in width (Table 2). This concurs with the findings of Williams & Matile-Ferrero (1999) who indicated that the body size of adult female enset root mealybugs ranged from 2.80 to 4.00 mm in length and 2.85 to 3.70 mm in width.

Table 1: Average duration of different stages of *Cataenococcus ensete* (N = number of insects tested).

Stage	N	Duration (days)	Range (days)
First-instar	20	16.2 ± 0.5	13 - 19
Second-instar	20	18.2 ± 0.7	13 - 25
Third-instar	20	19.8 ± 0.4	16 - 23
Adult female	20	50.0 ± 0.5	46 - 53
Total duration	20	103.9 ± 1.1	94 - 113

N = number of insects tested; values are mean +SE.

Table 2: Mean body length and width of the different stages of *Cataenococcus ensete.*

Stage	N	Length (mm)	Range (mm)	Width (mm)	Range (mm)
First-instar	30	0.79 ± 0.04	0.5 - 1.2	0.41 ± 0.09	0.3 - 0.6
Second-instar	30	1.71 ± 0.03	1.5 - 1.9	1.28 ± 0.15	1.1 - 1.4
Third-instar	30	2.46 ± 0.03	2.2 - 2.7	1.64 ± 0.15	1.5 - 1.9
Adult female	30	3.31 ± 0.07	2.9 - 4.0	2.95 ± 0.27	2.5 - 3.5

N = number of insects measured; Values are mean+SE

The enset root mealybugs encountered in the field during this study were larger in body size than those reared in the laboratory. This was found to be the case contrary to the expectation that laboratory conditions are more conducive for growth compared to natural field situations. However, the favorability of their natural niches in terms of availability and suitability of requisites for growth might have been best acquired by the insects under natural filed conditions since the substrates on which they were reared during this study in the laboratory was not particularly the most preferred. Cox (1987) mentioned that individual adult female mealybugs of different species vary in body size according to the environmental conditions under which they developed, and all undergo enlargement after they reach maturity.

The adult enset root mealybug has short, well-developed legs and a pair of eight-segmented antennae, each about 450 to 550 µm long (Williams & Matile-Ferrero, 1999). In specimens collected from Awassa, the number of conical setae in each anal lobe cerarii varied from 2 to 8. This number varied from 5 to 7 in some specimens collected at Wonago. Williams & Matile-Ferrero (1999) have reported that such cerarii in *C. ensete* ranged from 15-29.

The first-instar nymph of *C. ensete* was found most susceptible to starvation whereas the adults were better in tolerating starvation. However, all stages succumbed to death within three weeks when exposed to continuous starvation (Fig. 1). The survival of the mealybug was also tested on different plants and plant parts in the laboratory. The insect survived well when reared on whole pumpkin compared to sliced pumpkin (Fig. 2). This could be due the fact that sliced pumpkins had lost moisture so quick that the mealybugs were not able to acquire the sap or nutrients needed for survival and growth. Moreover, sliced pumpkins were attacked by profuse growth of sooty molds that have hampered the survival of the insect. On intact pumpkin, nymphs survived well and progressed from one stage to the next; however, with enset corm and roots all nymphs died within eight to ten days, respectively due to the need for frequent replacement of the substrates (Fig. 2).

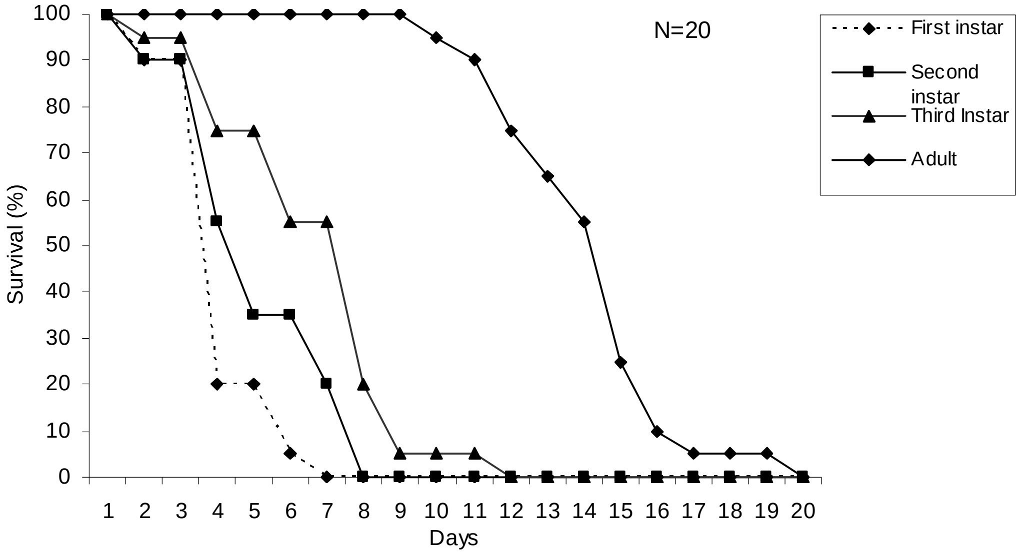

Figure 1: Effect of food deprivation on survival of the different stages of *Cataenococcus ensete* in the soil (N = number of mealybugs evaluated).

Cataenococcus ensete was observed in Gedeo, Sidama, Bench, Hadyia, Gurage, Kembata Tembaro, Keffa zones and Yem and Amaro districts. However, surveyed enset farms in Wolyita, Silte, Maji, Gamo Goffa, Sheka, West Showa, and Jimma were free from enset root mealybugs.

Out of the 163 farms surveyed, more than 30% were infested by the mealybug. According to Addis *et al.* (2006) most of the enset farmers (78.6%) produce their own suckers for planting. However, some farmers (20.2%) purchase suckers from local suppliers because they believe that those suckers raised on their own farms were not performing as well. The remaining 1.2% got suckers freely from government nursery sites. In areas where there was frequent exchange of planting materials among farmers like in Amaro, Gedeo, Sidama and Bench, there was high level of infestation by *C. ensete* (100.0, 66.7, 61.5 and 57.1%, respectively) (Table 3). However, in Hadyia, Gurage, Kembata Tembaro, Keffa and Yem where there was limited exchange of planting materials, the infestation was relatively low (16.7, 8.3, 25.0, 28.6 and 16.7% respectively) (Table 3). This showed that the exchange of planting materials was one of the principal ways by which the infestations of mealybugs were spreading in the absence of proper local quarantine services.

Although *C. ensete* was observed between 1,054 and 2,977 masl, its infestation was severe only between 1,400 to 2,200 masl. The highest infestation (53.6%) was recorded between 1,600-1,800 masl (Fig. 3) and the lowest above 2,200 masl and below 1,400 masl. This is probably due to the low and high soil temperature, respectively that might not be suitable to the insect and also due to soil moisture level and other edaphic factors that change with elevation.

The highest density of *C. ensete* was recorded in Gedeo zone (82.2 mealybugs/plant), which was significantly higher ($P < 0.05$) than the other zones (Table 3), while the lowest was recorded at Yem (3.3/plant). The highest Weighted Average Infestation (WAI) was recorded in both Gedeo zone and Amaro district (58.33) (Table 3). The observations showed that mealybug damage was severe at Gedeo, Sidama, Amaro and Bench where farmers usually exercise mixed cropping system. Although pest density is usually higher in mono-cropping system compared to mixed-cropping system (niche suitability theory), the reasons for observing more pest load in mixed-cropping system could be factors other than niche suitability such as climatic and edaphic factors, cultural practices used in the different zones and some ecological differences, and the sources of planting materials used. Moreover, in Gedeo, Sidama and Amaro areas weeding and cultivation of enset fields was found to be poor.

Table 3: Population density of *Cataenococcus ensete* in different areas of southern Ethiopia.

Area	Number of farms visited	Severity scale					Proportion % sites with enset root mealybugs	Weighted Average Infestation (WAI [%])	Mean number of adult mealybugs/plant
		0	1	2	3	4			
Gedeo	21	7	1	1	2	10	66.7	58.33	81.2
Sidama	26	10	0	5	9	2	61.5	43.27	65.2
Amaro	6	0	2	0	4	0	100	58.33	49.7
Hadyia	12	10	0	2	0	0	9.3	8.33	33.5
Bench	7	3	4	0	0	0	57.1	14.28	31.5
Keffa	7	5	0	2	0	0	29.6	14.28	29.0
Gurage	12	11	1	0	0	0	9.3	2.08	19
Kembata Tembaro	12	9	3	0	0	0	25	6.25	14.7
Yem	6	5	1	0	0	0	17.7	4.17	3.3

The severity of *C. ensete* was higher in areas having Nitosols according to the USDA report (Ethiopian Mapping Authority, 1988). Therefore, the effect of chemical and physical characteristics of the soil on the population density of the pest merits further investigations. The observations made during this study and the information obtained from farmers showed that damage by the mealybug was severe during the dry season. This could probably be due to the fact that more energy is invested on conservation of moisture by the plant for vital physiological activities rather than spending energy on tolerating or evading pest attack. Brandt *et al.* (1997) also indicated that damage by *C. ensete* was more severe during the dry season. In addition, Ngeve (2003) mentioned that the impact of cassava root mealybugs, *Stictococcus vayssierei* Richard, was higher in the dry season. Farmers practice repeated plowing and farm sanitation as means of curbing the population of *C. ensete* since such practices expose the insects to direct sunlight and other adverse conditions. This was also observed by Tadesse *et al* (2003).

C. ensete was found exclusively on the roots and corm of enset plant. Plants damaged by *C. ensete* showed retarded growth, lack of vigor and subsequent death especially when there is moisture stress. It was also observed that infested plants have lower number of roots as compared to healthy ones. In addition, enset plants were easily uprooted when they were infested by *C. ensete*. However, early infestation by *C. ensete* can be easily overlooked. Visible effects of root mealybugs on their host plant is not easy to observe on the above ground part of the plant until the insects make extensive damages (Hara *et al.,* 2001). Thus it is usually too late to remedy the situation by the time the damage symptoms are noticed on plants.

All nymphal stages of *C. ensete* were mobile and the first-instar by far the most motile, whilst adult mealybugs were slow moving and do so only when disturbed. It was observed that some of the enset nurseries found in southern Ethiopia (Yirgachefe and Wonago districts) were highly infested by mealybugs. It has been reported that some development organizations have been procuring suckers from these nursery sites and maintenance fields in order to distribute them to different areas of the country where farmers are trying to adopt enset production. Thus, the use of infested suckers from such centers has facilitated the distribution and spread of the insect to new areas.

Farmers produced suckers from corms that are already infested and/or in areas where there is mealybug infestation. Moreover, farmers sell some of the suckers they produced on their farms without any quarantine services thus enhancing the spread of the mealybug to new areas. Mealybugs also spread by farm implements and soil movement during cultivation and repeated transplanting operations conducted at different times. During transplanting, farmers pull out all transplants including infested ones. It appears that there is little or no advisory services provided by the extension agents to mitigate the distribution of the mealybugs.

Some ants were observed during this study tending the mealybugs. These ants were involved not only in protection of the mealybugs but in their transportation as well. Malsch *et al.* (2001), for instance, mentioned that when the mealybugs are disturbed at the time of cultivation, weeding, transplanting and harvesting, their attendant ants carry them to new plants or root parts. Moreover, ants help the mealybugs to find new niches (hidden places in the roots and corm), which are very difficult to reach even with insecticides.

In conclusion, the current study revealed that enset root mealybug is a serious pest that is causing heavy damage to enset. Hence there is a dire need for strengthening extension programs in order to educate people on the level of distribution and severity of the pest. Techniques of production of clean planting materials in nurseries and regulation of the distribution and exchange of planting materials should be devised. Emphasis should also be given to affordable management techniques like cultural methods and the use of indigenous plant materials with pesticidal activities or botanicals. The association between ants and the mealybug needs to be investigated. Furthermore, natural enemies (predators, parasitoids, microbial agents, etc) that might be associated with enset root mealybug need to be identified and their potential as biological control agent investigated.

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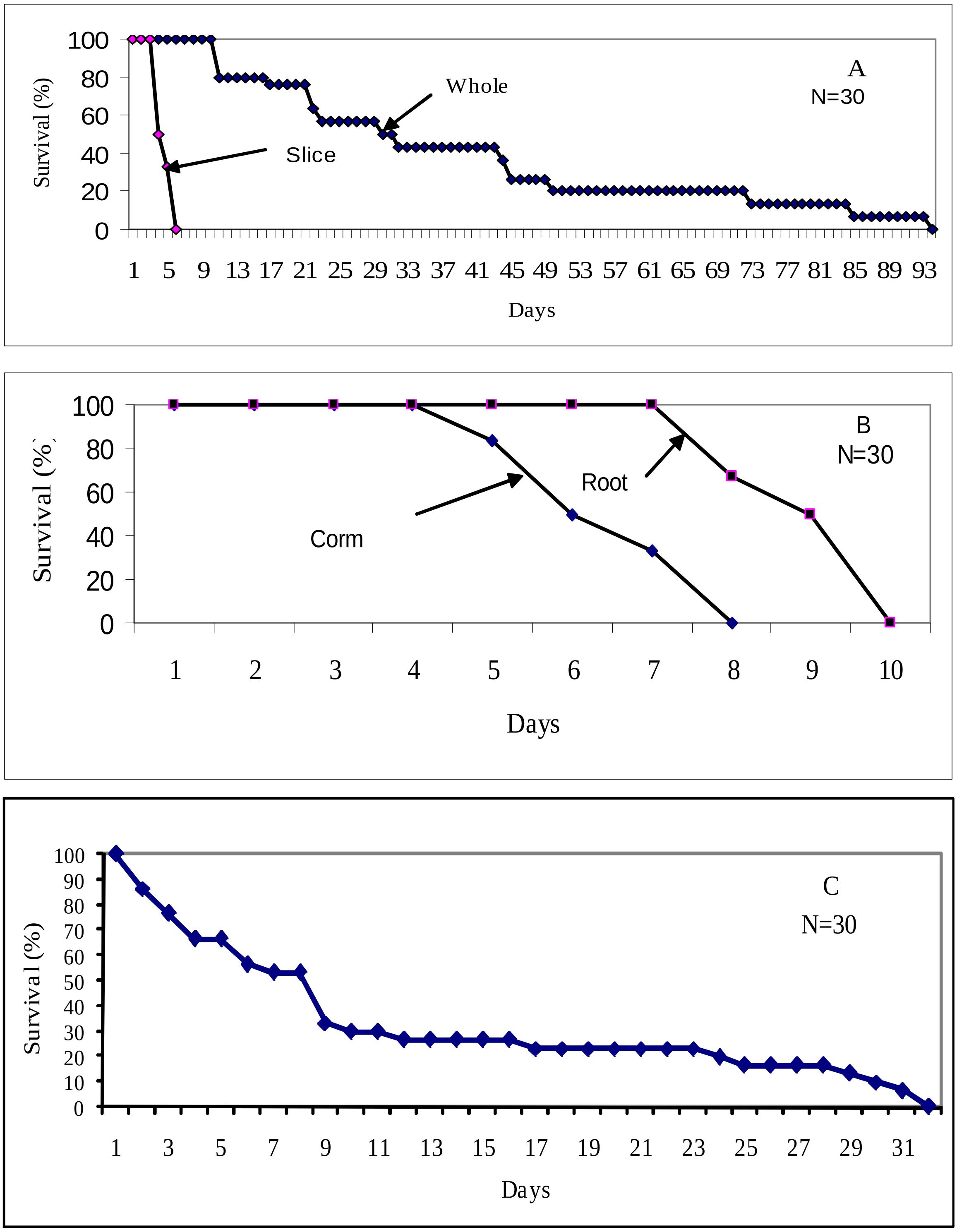

Figure 2: Survival of *Cataenococcus ensete* nymphs reared on A) whole and slices of pumpkin, B) corms and roots of enset and C) potato tubers. N= number of mealybugs tested.

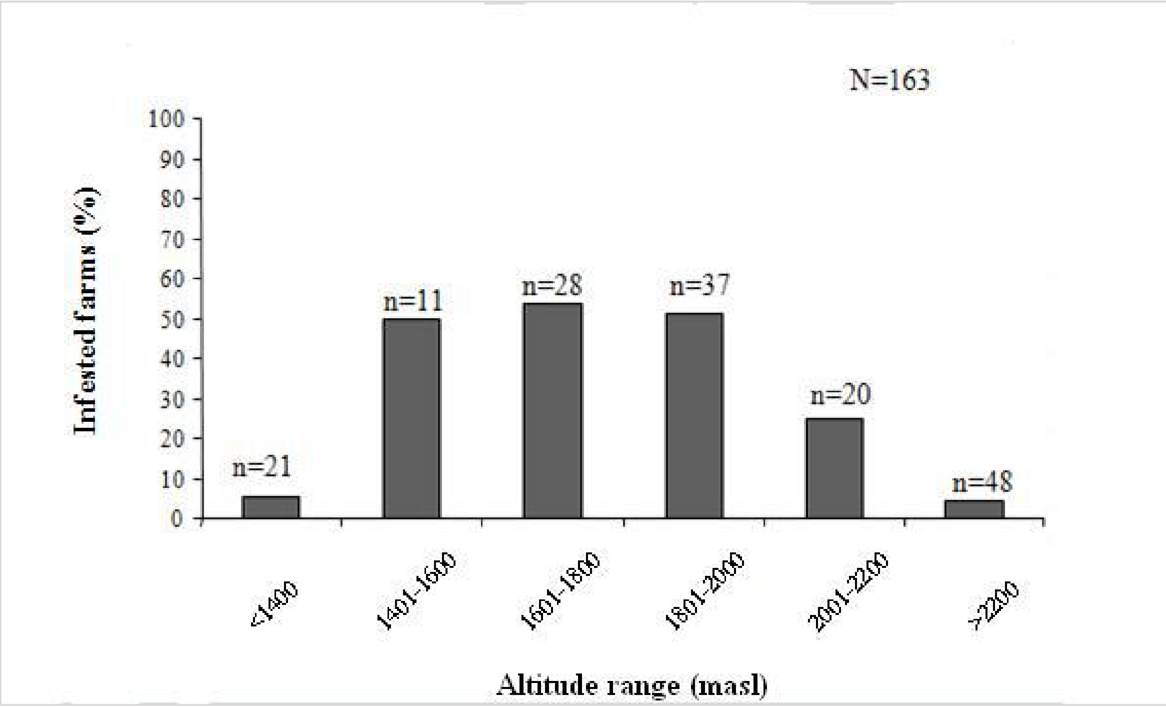

Figure 3: Incidence of *Cataenococcus ensete* at different altitude ranges (N = number of farms surveyed; n = the number of farms surveyed in each altitude range).

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