Arthropods, 2021, 10(1): 18-33

Article

Seasonal variation and biology of *Delena cancerides* Walckenaer (Araneae: Sparassidae) in a banana agroecosystem

Akamu Jude Ewunkem[1], **Nelson Neba Ntonifor**[2], **Christophe Parr Mbua**[3]
[1]Department of Nanoscience, University of North Carolina at Greensboro, USA; Department of Biology, North Carolina Agricultural and Technical State University, Greensboro, USA
[2]Department of Agronomy and Applied Molecular Sciences, University of Buea, Buea, Cameroon
[3]GlaxoSmithKline Biologicals SA (Vaccines)/Tech Mahindra Limited Belgian Branch Office, Waterloose Steenweg, Brussels, Belgium
Email: judeakamu@gmail.com, ajewunke@uncg.edu, aewunkem@ncat.edu

Received 18 December2020; *Accepted 22 January 2021*; *Published 1 March 2021*

Abstract

Bananas are the fourth-ranked agricultural crop in monetary value. Cameroon is one of the world top producers of bananas. Huntsman spiders are often seen in commercial banana agroecosystems in Cameroon and bananas destined for export causing fear among handlers and customers. High population density of *Delena cancerides* are ubiquitous in commercial banana agroecosysyems in Cameroon. However, no information has been made available regarding the biology and ecology of *D. cancerides* in banana agroecosystem. In this study we accessed habitat distribution during the rainy and dry seasons and biology of *D. cancerides*. *Delena cancerides* were commonly found under barks of pseudeostems, spaces between leaf petioles and sometimes on foliage. The population of *D. cancerides* significantly increased during the dry season and declined during the rainy season. A significantly (t=5.4, df=46, *P*<0.05) higher number of *D. cancerides* was seen on preflowering pseudostems (ca 61.4%) than pseudostems with bunches (ca 37.9%). The population of *D. cancerides* was significantly (t=6.5, df=22, *P*<0.05) greater in the morning (ca 58.9%) than in the afternoon (ca 41.1%). After mating, the female produced an egg sac 21± 0.6mm in which she laid 70.8 ± 0.8 eggs and stood guard over it without eating. At ca 29±0.6d after oviposition, the eggs hatched into 60.3 ± 1.4 spiderlings. Females required a significantly (t=0.7, df=18, *P*>0.05) longer time to develop (339.4±49.0d) compared to the males. These findings may help facilitate the accumulation of data about *D. cancerides* and its role in shaping invertebrate communities in a banana agroecosystem.

Keywords *Delena cancerides*; banana; population; spiderlings; agroecosystem.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

The consumption of fruits promotes general good health by lowering the risk of various diseases (Bowen-Forbes et al., 2010; Amira et al., 2012; Giampeiri et al. 2012; Nile and Park, 2014). Banana is one of the most popular fruits in the world; more than 100 billion bananas are consumed around the world every year (Padam et al., 2014; Coltro and Karaski, 2019). Banana fruits are notably enriched with phytonutrients, minerals carbohydrates, and proteins (Lim et al., 2007, Davey et al., 2007).

Bananas are widely produced in tropical and subtropical countries (where average temperature is about 80° F (27° C).) where they serve as abundant natural resources (Li et al., 2010; Aziz et al., 2011; Sango et al., 2018). Banana cultivation is an important aspect of agricultural development in Cameroon (Njabe, 2002; Awang, 2016). Cameroon is one of the top banana exporters in Africa. Production, however, has plummeted due to the current anglophone crisis (Brice, 2017). Cameroon exported about 113,600 tons of banana in June 2018 compared to 140,930 tons during the same period a year earlier (Brice, 2018). One of the commercial banana plantations is in Tiko. Tiko produces over 1500 tons of bananas annually for export and therefore it is a foreign exchange earner (Njabe, 2002).

Banana production is associated with diseases and pests. Economically important diseases associated with banana include, yellow Sigatoka (*Pseudocercospora musicola*, Leach), black Sigatoka (*Pseudocercospora fijiensis*, Morelet), Fusarium wilt races 1, 2 and 4 (*Fusarium oxysporum*, cubense), root-not nematodes (*Meloidogyne* spp.)(Luquini et al., 2019). Insect pests known to attack banana include, banana weevil, *Cosmopolites sordidus* Germar (Coleoptera, Curculionidae); sugarcane Weevil, *Metamasius hemipterus sericeus* (Coleoptera: Curculionidae); the banana pseudostem weevil, *Odoiporous longicollis* (Olivier) (Coleoptera: Curculionidae); banana scab moth, *Nacoleia octasema* (Meyrick) (Lepidoptera: Pyralidae), the banana skipper, *Erionota thrax* (Linnaeus) (Lepidoptera: Hesperiidae), the banana thrips *Chaetanaphothrips orchidii* (Moulton), The banana aphid, *Pentalonia nigronervosa* Coquerel, (Hemiptera: Aphididae) (Tinzaara and Gold, 2008; Abagale et al., 2019). Spiders and their eggs are often seen in banana flowers, on psuedostems and in bunches of bananas.

Spiders are generalist predators that function as biological control agents within banana agroecosystems (Schmitz, 2008; Ntonifor et al., 2012; Cotes et al., 2018). Species of spider in the family Sparassidae are frequently, seen in banana farms (Ewunkem et al., 2016). Members of Sparassidae are usually seen in bananas and transported from the farms in Africa and South America into Europe and North America (Vetter et al., 2014*). Heteropoda venatoria* is the commonest species of spider in the family Sparassidae seen hiding in banana bunches shipped from less developed world to the New world (Prajapati et al., 2018). These species of spiders are known to terrified customer and handlers in supermarkets. High population density of huntsman spider, *Heteropoda venatoria* has been reported most commercial banana agroecosystems in Cameroon and its biology and field ecology have been extensively studied (Ross et al., 1982; Ewunkem et al., 2016). A female *H. venatoria* lays about 245 eggs in a cocoon which she carries for about 30 days without feeding (Ewunkem et al., 2016). After 32 days of incubation the eggs hatch into spiderlings. After about 391 and 304 days the spiderlings develop to adult male and female spiders respectively (Ewunkem et al., 2016). Adults and juvenile *H. venatoria* inhibit soil litre mulches, loose leaf sheaths of pseudostems and stumps, leaf petioles and banana bunches (Ntonifor et al., 2012; Ewunkem et al., 2016). Other species of Sparassidae seen in banana agroecosystem include the banded huntsman spiders and the flat huntsman spiders (Ewunkem et al., 2020).

Delena cancerides Walckenaer 1837 (Sparassidae), also known as the flat huntsman spider, is a large, brown huntsman spider native to Australia (Rowell and Avilés, 1995). Members of *D. cancerides* are found under loose barks due to their highly flatten body which distinguishes it from other sparassids (Rowell and Avilés, 1995). *Delena cancerides* have evolved social behaviour in the absence of webs, and very aggressive and cannibalistic toward members from other colonies (Auletta and Rayor, 2011). Colonies of *D. cancerides* may consist of more than 300 individuals living in proximity under bark of dead Acacia, Acacia, Callitris and Casuarina species. *D cancerides* are known to feed communally (Rowell and Avilés, 1995). In contrast to other web-based social spiders, *D. cancerides* are considered as central place 5 foragers, because the leave their retreat at nigh return at night (Yip, 2012).

Commercial agroecosystems have received several complaints from international markets relating to the infestation of their bananas by huntsman spiders (Edward, 2009; Ntonifor et al., 2012; Vetter et al., 2014). However, there have been no report of *D. cancerides* in packaged bananas from Cameroon. Considering the disturbingly high population of *D. cancerides* in one of the commercial banana plantations in Tiko, Cameroon there is a possibility of these spiders being transported to foreign markets. It is, therefore, important to generate basic biological and ecological information on *D. cancerides* as a prelude to designing appropriate spider population control strategies.

2 Materials and Methods

2.1 Study sites

The study was conducted in Tiko and Buea for field and laboratory studies respectively. Tiko is a city found in South-West Province, Cameroon. Tiko is located 4.08 latitude and 9.36 longitude. Tiko is situated at elevation 33 meters above sea level. The average temperature in Tiko is 80.6°F (26.7°C) and, about 2975 mm of precipitation falls annually. Bueais 15.8 km (9.8 mile) (Fig. 1) from Tiko. Buea is situated at the foothill of Mount Cameroon at an elevation of 520 m above sea level. Buea has an average temperature of 67.8°F (21.1°C) and an annual rainfall of 2625mm.The latitude and longitude of Buea are 4.16, and 9.24 respectively.

Fig. 1 Geographical location of field and laboratory studies (http://distance.1km.net/cm/buea/).

2.2 Sampling site

The field study site is one of the commercial banana farms in Tiko. The farm covers a total of 245.3 hectares and about 429,200 banana plants. The bananas are planted by selecting small pieces of rhizomes and planting in shallow holes of about 2 meters apart in a prepared farm. The bananas are planted by selecting small pieces of rhizomes and planting in shallow holes of about 2.0 apart in a prepared farm. Herbicides and other farm practices are applied as necessary. At about 8 - 9 months the plants bear fruits, which are then covered with Dursban impregnated polyethylene bags to protect them from bruises, insects, and birds as well as to maintain optimum temperatures in creating a suitable microclimate.

2.3 Sampling program and techniques

The farm was visited twice weekly in the morning (08:30 hrs) and afternoon (14:30 hrs) to establish any variation in number of spiders with the time of sampling. Sampling was done both during dry season months (November - March) and rainy season months (April - October) to study any seasonal variations in the populations of the various target organisms. The sampling units consisted of 100 pseudostems farm and a 2.0 m circumference around each sampled pseudostem. Twenty-five plants of each of the target growth stages were around the edges or periphery of the farm and twenty-five around the middle. Each pseudostem was stratified into 3 sections based on heights from the ground:

- Section a = ≤ 1 m from the base of the plant
- Section b = ≥ 1.5 m from section 1
- Section c = from upper limit of section 2 to the leaves.

Through direct or *in situ* counts, the number of *Delena cancerides*, different insect species, lizards, geckoes, frogs and toads on each pseudostem and anywhere within the 2.0 m circumference were recorded on data forms. Sampling started from the peripheral pseudostems and progressed systematically one after another towards pseudostems in the middle of the farm.

2.4 Laboratory rearing of *Delena cancerides*

Adults *Delena cancerides* were hand-captured from their hide outs during every farm visit. Samples were collected as quickly as possible to prevent any escape. Captured spiders were put in nylon mesh bags (10 cm wide and 25 cm high) provided with a 30.0 cm string to tie the opening or in plastic specimen cups measuring 7.2 cm deep 6 cm wide around the brim. Each cup was covered with a lid that had several tiny holes on it to aerate the containers. The mesh bags and plastic specimen cups were carefully held and returned to the laboratory. In the laboratory the spiders were transported to each mesh cage (31 cm x 31 cm x 36 cm). Each spider was confined to a specimen cup. The spiders were kept at mean ambient temperatures of 20 ± 3°C and relative humidity of 70 ± 10%. The spiders were fed *ad libitum* with *Musca domestica*, (Insecta: Diptera: Muscidae), and supplemented at time with other insects such as feral moths, crickets, roaches and grasshoppers whenever available. The insects were attracted as described by Ewunkem et al. (2016).

2.5 Incubation period and developmental durations

Ten cocoons constructed by *Delena cancerides* were cut using a razor blade from their oviposition sites on banana pseudostems in the field. Each collected cocoon was put in a specimen cup described above and kept at ambient laboratory conditions. Observation was made daily for hatching. Ten other cocoons were torn open with aid of forceps and the eggs therein counted. Females that had just constructed cocoons and laid eggs therein were confined each in a rearing cage and observed daily until when spiderlings emerged from the cocoon to determine the incubation period. The time interval between ovipisition and the emergence of spiderlings was taken as the incubation period. A total of 10 *D. cancerides* were observed.

After emergence the spiderlings were counted. Thereafter, each individual neonate was weighed (± 0.0001 g) using a Mettler® balance and then held lightly between finger and thumb and transferred into a specimen cup to study the developmental durations. Each neonate was fed *ad libitum* with *Musca domestica*, (Insecta: Diptera: Muscidae). Each neonate was fed *ad libitum* with 6 smaller houseflies (*Musca domestica*) per day till when they grew bigger (5-6 months later) when their food was changed to 8 bigger houseflies per spiderlings per day. The developmental duration after each molt was recorded and the length of the various body parts measured. The specimen cups were cleaned immediately after the spiders had fed, to shun ants which fed on the insect left over. The experiment was replicated 15 times.

2.6 Courtship, mating and oviposition

To study courtship, mating and oviposition, a mature male and female *Delena cancerides* were captured as described above and introduced in the rearing cage. We examined spiders daily for egg sac production and hatching. The total of 10 males and 10 females were used for this experiment. Some of these spiders were reared to adulthood in the laboratory.

2.7 Study of the regeneration of lost limb

All spiderlings that lost any limb during moulting were observed critically after each subsequent moult. A total of four *Delena cancerides* were used. Similarly, one limb of each from 5 adult spiders was purposely amputated by holding the limb and gently pulling it away. Thereafter, the right hind leg of each spider was grasped by forceps and released a in rearing cage, fed and observed daily for the next three months.

2.8 Determination of sexual dimorphism

To measure the length of the various body parts of the spiders, 20 adults (10 of each sex) of and *D. cancerides* were hand captured and killed in killing jars. The length of each body part of each male and female was carefully measured with a meter ruler graduated in millimetres.

2.9 Data analysis

Data on vertical distribution, effect of crop phenology, seasonal changes in field distribution, effect of time of sampling, total developmental periods of male and female were analyzed for significance with *t*-test ($P<0.05$) using GraphPad Prism Version 8.

3 Results

3.1 Seasonal Occurrence of *Delena cancerides* in various habitats

The overall abundance of *Delena cancerides* and the periods of significant outbreaks differ considerably from season to season on banana pseudostems. During the raining season *D. cancerides* remained at low abundance for the season (i.e. from June to October). In contrast the population levels of *D cancerides* increased in abundance during the dry season (i.e. from December to April) (Fig. 2).There was a trend towards higher insect fauna during summer, and low insect fauna abundance during the rainy season (data not shown).

3.2 Vertical distribution of *Delena cancerides*

Delena cancerides exhibited a unique orientation in a wide variety of microhabitats. *D. cancerides* were seen in a face-down orientation in fleshy deep groove in the banana leaf petioles and under loose barks on the pseudostem. The stratification of *D. cancerides* significantly changes dramatically during the season. During the raining season (between May and September), *D. cancerides* were significantly (F=24.35, df=35, $P<0.05$) more abundant at ≥ 1.5 m (stratum “B”) (56.83%) than stratum A(35.25%) and stratum C (7.75%) (Fig. 3). The percent abundance of *D. cancerides* was significantly (F=18.22, df=35, $P<0.05$) greater (57.83%) at ≤ 1m (Stratum A) from the base of the pseudostem during the dry season (October to April) than strata A(31.91%) and C (10.25%)(Fig. 2). Very few *D. cancerides* were seen at stratum C during the raining (7.75%) and dry season (10.25%) (Fig. 3). The difference, however, was not significant (t=0.54, df=22, $P>0.05$) (Fig. 3). Several groups of insects were found in the loose barks of the banana pseudostems. Prominent amongst these were aphids, ants, mealy bugs and roaches (data not shown).

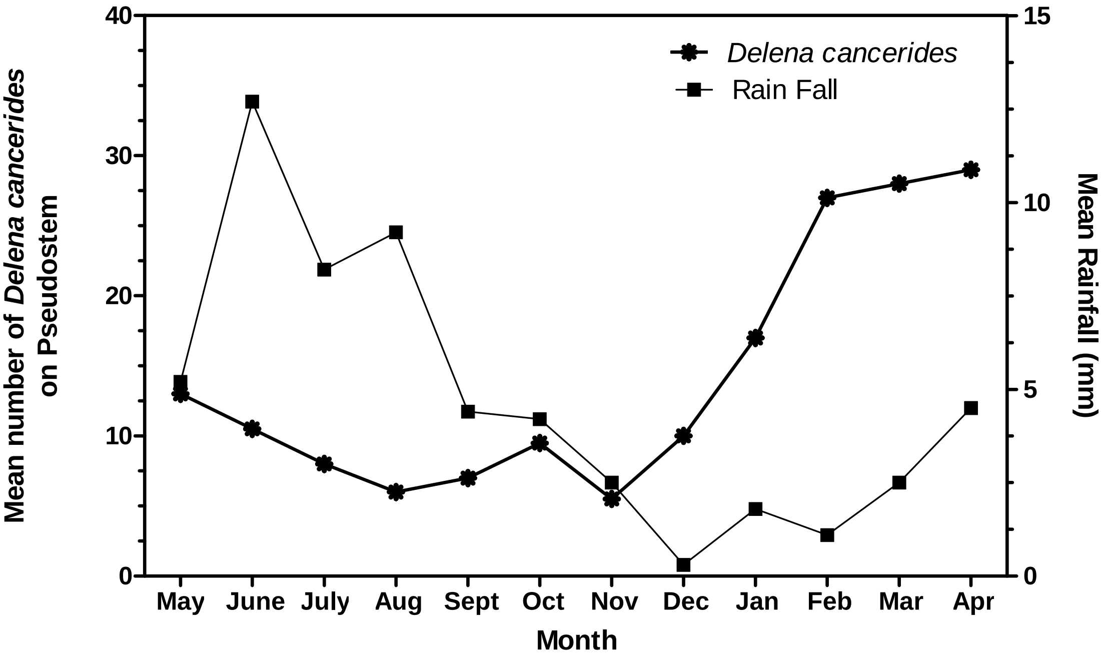

Fig. 2 Seasonal variation in mean number of *Delena cancerides* in Tiko, Cameroon.

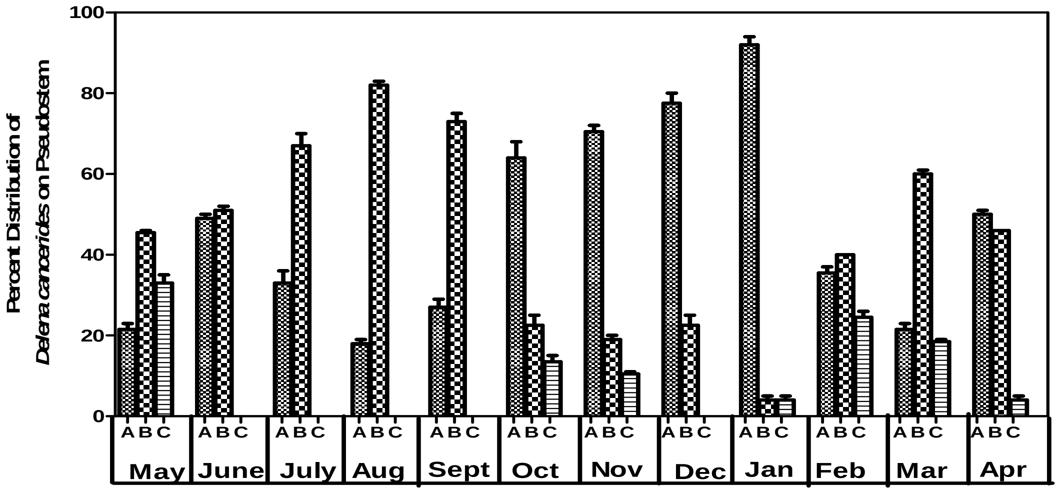

Fig. 3 Seasonal changes in the vertical distribution of *Delena cancerides* density (mean ± SE) on banana pseudostems in Tiko, Cameroon. Each pseudostem was stratified into 3 sections based on heights from the ground: A= ≤ 1 m from the base of the plant; B= ≥ 1.5 m from A; C= from upper limit of C to the leaves.

3.3 Effect of crop phenology on seasonal variation of *Delena cancerides*

The relative abundance of *D. cancerides* varied with crop phenology (Fig. 4). In general, a significantly (t=5.4, df=46, $P<0.05$) higher population density of *D. cancerides* was seen on preflowering pseudostems (61.4%) than pseudostems with bunches (37.9%) (Fig. 4). Also, seasonal variation of *D. cancerides* was clearly different between preflowering and bunched stages (Crop phenology). During the rainy season a significantly (t=2.8, df=22, *P*<0.05) higher density of *D. cancerides* was seen on pseudostems of preflowering stages (61.75%) than bunched stages of banana plants (37.33%) (Fig. 4). The exact same variation was observed during the dry season (October - April) where a significantly, (t=11.55, df=22, *P*<0.05) higher density of *D. cancerides* was seen on pseudostems of preflowering stages (63.3%) than bunched stages (38.41%) of banana plants (Fig. 4).

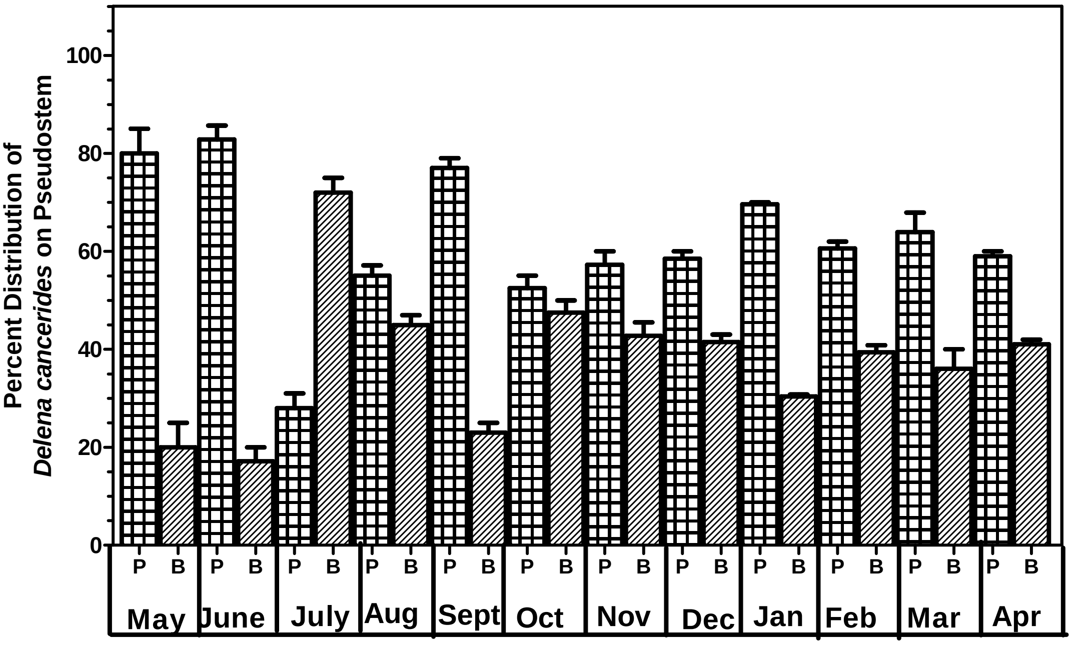

Fig. 4 Seasonal variation of *Delena cancerides* on 100 banana pseudostems with crop phenology. P=Preflowering stage; B=bunched stage.

3.4 Seasonal changes in field distribution of *Delena cancerides*

In general, there was no significant (t=0.1, df=46, *P*>0.05) difference in the population density of *D. cancerides* with different locations in the banana agroecosystem (Fig. 5). However, the difference in abundance greatly varied with seasons. During the rainy season the percent abundance of *D. cancerides* was significantly (t=8.2, df=22, *P*<0.05) greater on pseudostems away from the periphery (middle) (78.6%) than those at the periphery (19.1%) (Fig. 5). In contrast, during the dry season, the percent abundance of *D. cancerides* was significantly greater away from the periphery (56.8%) than those on pseudostems closer to the periphery (43.1%) (Fig. 5).

3.5 Effect of time of the day on seasonal variation of *Delena cancerides*

Time of day affected number of *D. cancerides* on the number of pseudostems. The sample percent distribution showed that the abundance of *D. cancerides* was significantly (t=4.33, df=46, *P*<0.05) higher in the morning (55.7%) than afternoon (44.3%) (Fig. 6). We found a unique variation in *Delena cancerides* between sampling times during the dry season (November-April). Significantly (t=6.5, df=22, *P<0.05*) her population density of *D. cancerides* was seen on pseudostems in the morning (58.9%) than in the afternoon (41.1%)(Fig. 6) However, there was no strong effect (t=1.17, df=22, *P*>0.05) of the time of day (Morning 52.6%; Afternoon 47.3%) on seasonal abundance of *D. cancerides* on pseudostems during the raining season (May -September) (Fig. 6).

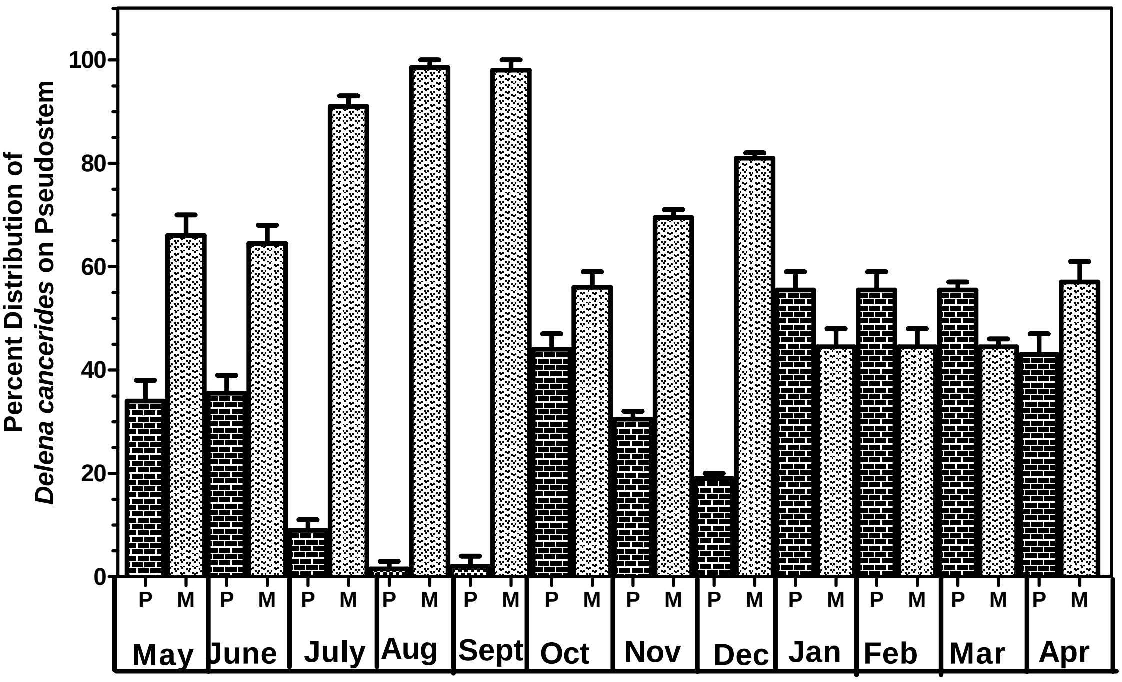

Fig. 5 Distribution of *Delena cancerides* with respect to different areas of the farm. P=Periphery; M=middle.

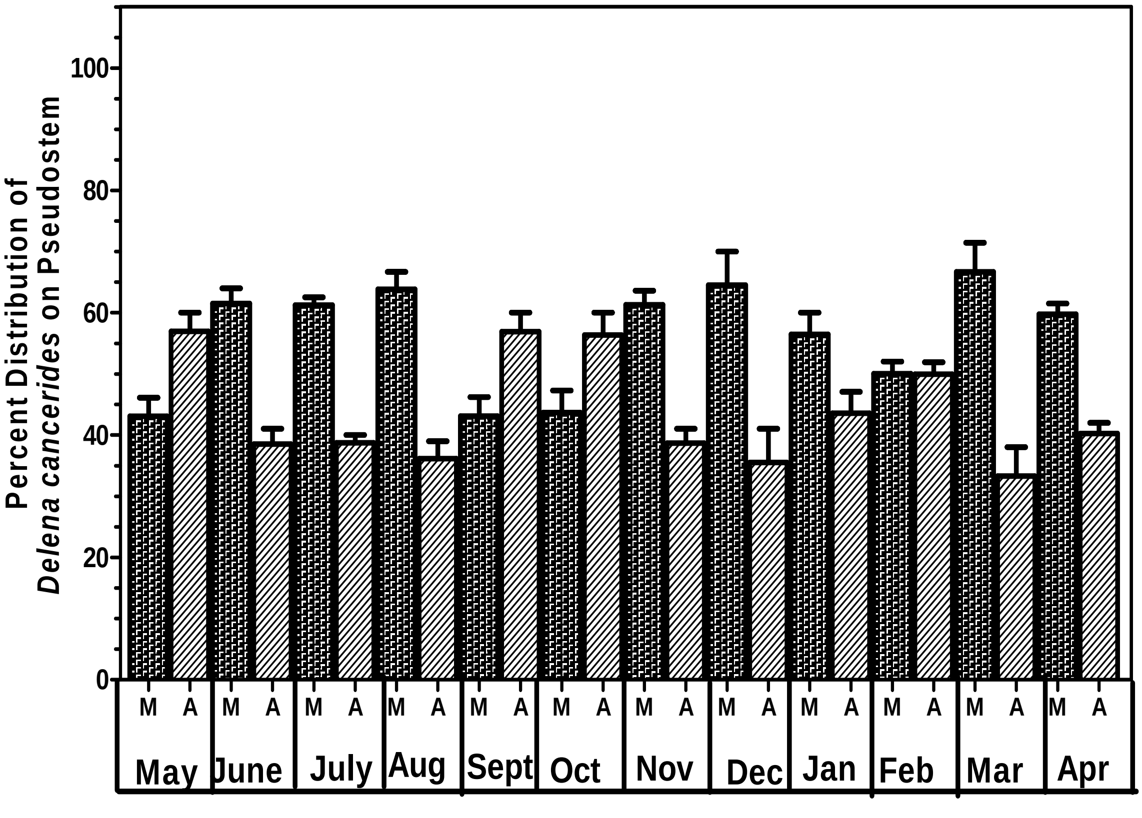

Fig. 6 Seasonal variation in the number of *Delena cancerides* with time of day. M=Morning; A=Afternoon.

3.6 Ovipositionand incubations

Throughout the study period, mating, constructions of egg sacs and oviposition behaviour were not observed. During our laboratory study we were able to determine changes associated with egg sacs over time, incubation period, number of eggs, number of hatchlings, developmental duration, sexual dimorphism and autotomy. After mating, the female produced a flat, oval egg sac of white papery silk on the wall of the specimen cup or rearing cage. The female sat on her cocoon incubating it without feeding and movement was limited. The whitish cocoon gradually turned brown in 8 days. On several occasions two females alternately incubated a cocoon. In the field two or more females were seen guarding a single egg sac. All the females constructed their egg sacs always at night. A total of 10 cocoons (21± 0.6 mm) (Table 1) were observed. The spiders could produce more than one cocoon after mating once. The time interval between the constructions of successive cocoons was between 30-36 days. Most of the spiders constructed 4 cocoons per year. The side of the cocoon attached to the specimen cup was very transparent and weobserved the development of the eggs. After 18 days following the construction of the cocoon, the eggs develop into grey spiderlings. At ca 29 days after oviposition, the eggs hatched into spiderlings. A cocoon contains an average of 60 eggs (Table 1). The whitish cocoon gradually turned brown in 8 days.

Table 1 Mean diameter (mm ± SE) of cocoons, number of eggs and emerged spiderlings per cocoon and egg incubation period of *Delena cancerides*.

Variable	Number of cocoons (n=10)	Number of eggs (n=10)	Incubation period in days (n=10)	Number of spiderlings (n=10)
Mean	21± 0.6	70.8 ± 0.8	29±0.6	60.3 ± 1.4
Range	19-22	66-81	28-31	15-70

n = number of masses studied.

3.7 Developmental duration of various instars

At ca 29 days after oviposition, the eggs hatched into spidelings (60.3 ± 1.4). The spiderlings remained in the cocoon until the first moult. After 2 days the spiderlings left the cocoon and dispersed via ballooning outside through a tiny hole visible around the centre of the cocoon. The female still guarded an empty cocoon for about 5 days. The spiderlings stay did not return into the cocoon through the tiny hole instead they produced silk strands on which they suspend.

The total of 15 spiderlings were studied. On average a spideling moulted once every month. Moulting was at night and lasted for ca 26 minutes. In preparation for ecdysis or moulting, the spiderling became less active for ca 3 days, and gradually turned dark. Thereafter the spiderling stretched its legs and began to moult. Ecdysis lasts for about 20 minutes. After 10 days the spiderling regained its strength and started feeding. Generally, the body length increased with each moult (data not shown). Spiders were also able to regenerate lost appendages (autotomy) after moulting. The regenerated limb slowly became same as the others.

Table 2 Mean incubation (days ± SE) and developmental duration (days ± SE) of various instars of *Delena cancerides*.

Developmental duration (days ± SE) of various instars of flat huntsman		
Incubation period 29±0.6(28-0.6)		
Instars	Male n = 1	Female n = 14
L_1	30	50 ± 0.4 (21 – 104)
L_2	37	26.8 ± 0.6 (22 – 33.1)
L_3	21	27.2 ± 0.6 (22– 38)
L_4	26	28.2 ± 1.2 (13 – 41)
L_5	27	31.5 ± 0.6 (29-34)
L_6	40	28.9 ± 0.8 (20-36)
L_7	36	27.9 ± 1.0 (15 – 26)
L_8	-	30.9 ± 1.0 (17 – 32)
L_9	-	20.8 ± 0.7 (11 – 29)
L_{10}	-	29.6 ± 1.1 (22 – 49)
Total	218.6	339.4 ± 49.0

Values in parentheses represent ranges.

Table 3 Mean length (mm ± SE) of various body parts of adult males and female of *Delena cancerides*.

	Mean length (mm ± SE) of various body parts	
Body Part	Female, n=10	Male,n=10
Pedipalps	4.1 ± 0.08a (4.0 – 4.1)	4.0 ± 0.08a (4.0 – 4.1)
1st Walking leg	20.3 ± 0.08a (19.0 – 21.2)	25.0 ± 0.05b (24.0 -27.0)
2nd Walking leg	22.0 ± 0.53a (21.0 – 23.1)	25.4 ± 0.1b (25.0 – 25.9)
3rd Walking leg	20 ± 0.08a (19.0 – 21.0)	23.1 ± 0.1a (22.0 – 25.4)
4th Walking leg	21 ± 0.24a (20.0 – 22.0)	24.2 ± 0.08b (24.0 – 24.9)
Cephalothorax	5.3 ± 0.08a (4.0 – 6.0)	4.1 ± 0.24b (4.0 – 4.1)
Abdomen	4.3 ± 0.08a (4.0 – 4.6)	3.1 ± 0.1a (3.0 – 3.2)

Means followed by the same letter in the row are not significantly different (P>0.05, t – test).
Values in parentheses represent ranges.

The spiderlings of both sexes after the initial moults resemble each other, but after the final moult the differences in sexes was apparent. Out of the 15 spidelings that were studied one turned out to be male while the rest were females (Table 2). The male spider was more brightly coloured than the female counterpart. Most of the legs (1st pair of legs: t=11.37, df=18, P<0.05; 2nd pair of legs: t=7.709, df=18 ,P<0.05; 3rd pair of legs: t=7.582; df=18, P<0.05; 4th pair of legs: t=6.297, df=18, P<0.05) of the male were significantly longer than the female's (Table 3) ,however, the female had a significantly larger (t=7.031, df=18; P<0.05) cephalothorax (Table 3). The male's pedipalps were greatly enlarged. The male and female moulted 7 and 10 times respectively (Table 2). The total developmental period was 339.4±49.0 days for females was significantly longer (t=0.7, df=18, P>0.05) than the 218.6 days for the male (Table 2).

4 Discussion

Considering the disturbingly high population of *Delena cancerides* on banana plants in Tiko, Cameroon, it was of paramount importance to provide uniquely some useful ecological and biological data as a prelude to designing appropriate spider population control strategies, which may also serve as a biological control agent. *D. cancerides* were often seen face-down in dark secluded places like fleshy deep groove in the banana leaf petioles and under loose barks of pseudostems. The flat body of *D. cancerides* allow them to occupy very spaces. Face-down orientation is an inherit advantage for speed and hunting (Pulchra, 1992; Maciejewski, 2010). Maciejewski (2010) suggested that spiders travel faster down than up. In these habitats the *D.cancerides* matched the colour and pattern of the background, an effective camouflage which protect them from predators and help them unnoticed by prey. Camouflage is also a strategy that helps organisms to survive and reproduce (Bradbury and Wilson, 2019). The spiders were usually seen in colonies sometimes feeding on a prey or guiding an egg sac. Studies have shown that *Delena cancerides* are generally in physical contact with one another (Rowell and Avilés, 1995) and prey sharing benefits spiders that live in groups. Prey sharing gives spiders the opportunities to search for food to avoid starvation. *D. cancerides* are social spiders that live in colonies; however, they are highly aggressive toward members of foreign colonies (Beavis et al., 2007).

Adults *D. cancerides* were seen behind loose psuedostem barks at stratum A i.e. 1m from the base during the dry season. This stratum was an ideal environment due to the presence of insect fauna. However, the population of *D. cancerides* reduced at stratum A during the rainy season. During the raining season water from the leaf blades compels the spiders to migrate upward for shelter (Ewunkem et al., 2016). In contrast during dry spells, most spiders migrate from the petioles and bunches to the pseudostems to forage for insects.

The different phases of banana phenology are related to changes in the population dynamics of *D. cancerides*. Regardless of the season, a high population of *D. cancerides* was recorded on preflowering psuedostems than bunched pseudostems. The presence and development of bunches are known to attract a wide variety of insects which may serve as food for huntsman spiders (Yu et al., 2018; Ewunkem et al., 2016). The spaces between the bunches also known to provide suitable habitat for huntsman spiders due to their flattened bodies adopted for living in narrow spaces (Ewunkem et al., 2016).

The field distribution of *D. cancerides* was dependent on the season and the presence or absence of farm refuge. During the rainy season, the population density of *D. cancerides* generally was significantly higher around the middle of the farms than those close to the edges. Further from the edge heaps of decay, palm trunks are found which attract insects which enjoyed the banquet of moist, rotting decay farm wastes. Spiders are known to thrive anywhere they can find food (Brian and Brenda, 1996). In contrast, there was a decline in the population of *D. cancerides* in this location due to crop or field sanitation that was strongly implanted. Crop sanitation is known to lower or eradicate insect pests hence curbing the population of natural enemies such as spiders (Masanza et al., 2005).

Time of sampling had a significant bearing on the population dynamics of *D. cancerides.* During both the rainy and dry seasons, the population density of *D. cancerides* on pseudostems was typically higher in the morning than the afternoon suggesting that these spiders migrated to the pseudostems in the morning in search for prey, possibly to minimize the risks of being eaten by predators such as lizards and geckoes. Lizards and geckoes were more abundant during the afternoon periods since terrestrial reptiles seek out sources of heat to raise their body temperature (Wessells and Hopson, 1998). In contrast, in the morning these denizens withdrawn to their hideouts.

In this study we did not observe courtship, mating, and oviposition. observation of other species indicates that during courtship a male deliberately produces a vibrating sound and a hissing sound and gently mounts the female (Ewunkem et al., 2016). Mating lasts for about 3 hours, and after 10-15 days following mating the female produces an egg sac. In our laboratory study a female *D. cancerides* produced a flat, oval egg sac of white papery on silk on the wall of the rearing cage in which she laid an average of 60 eggs. Other species are known to carry their eggs sac under their bodies while moving about without eating until the spiderlings emerge (Ross et al., 1982; Ewunkem et al., 2016). A cluster of multiple females were seen under a given pseudostem bark guarding their egg sacs. Sometimes two or more females were seen guarding a single egg sac. Cluster of multiple females on a given psuedostem is an attribute of sociality in spider (Yip and Rayor, 2011).

The time and labour involved in egg sac production and oviposition justifies female *D. cancerides* constructed her egg sac at night. This strategy is likely used to avoid predation. The female provided additional protection against opportunistic predators by guarding her egg sac (Austin, 1985). The dull brown coloured egg sac often further camouflaged with pseudostems to help prevent eggs being eaten or parasitized since Spiders and their eggs are usually preyed by predators such as insects, reptiles, and birds (Foelix, 1996; Rayor, 1996). The egg sac also works as a physical barrier against the hatch external environment (Villanueva-Bonilla et al., 2016).

Female *D. cancerides* produced multiple egg sacs after mating as seen in female *H. venatoria* (Ross et al., 1982; Ewunkem et al., 2016).Females arachnids are known to store sperm to fertilize eggs in several egg sacs each month for about two years after mating (Andrade and Banta, 2002). However, the fertility of the egg sac tends to decrease over time due to a reduction in sperm availability (Andrade and Banta, 2002).

Following incubation, the spiderlings resided within the egg sac until the first moult. This agrees with Hickman (1998) who stated that spiders usually remained in the cocoon for a few weeks and moult once before leaving it. The spiderlings may stay in the cocoon for a few days to avoid desiccation, thermal stress, predator, and prey attack (Norgaard, 1956; Schaefer, 1976; Hieber, 1985; Christenson and Wenzl, 1980; Hieber and Uetz, 1990). The juvenile emerged from the egg sac and moulted once every month until they reached sexual maturity. Moulting in *D cancerides* was a period of extreme change. About 3-4 days prior to moulting, *D. cancerides* became darkened, weakened and feeding ceased as seen in other species of spiders (Vetter and Rust, 2010; Ewunkem et al., 2016). Spiders usually darken a few days before moulting due to the formation of new setae under the old cuticle (Foelix, 1996).

Moulting of *D. cancerides* typically occurred at night to avoid being preyed upon by predators since moulting is generally the most vulnerable situations spiders experience. After moulting *D. cancerides* appeared weak for 3-5 days and still unable to eat suggesting that moulting consumes a considerable amount of energy (Vetterand Rust, 2010). The new exoskeleton is appeared very delicate in this stage, making the spider particularly vulnerable to attack suggesting why moulting occurs at night. The spider resumed feeding resumes until some degree of exoskeletal hardening occurs. Spiders generally darken a few days before moulting due to the formation of new setae under the old cuticle (Foelix, 1996). As adult male and female subsequently moulted 7 and 10 times respectively. Their sexes, however, are conspicuously distinct after the penultimate moult.

As *D. cancerides* matured they become sexually dimorphic. Our laboratory studies demonstrated that females required a longer time to develop when compared to the males. Studies have shown that females required longer time to develop because they need a substantial of reserves to support its large body size, egg formation and other physiological processes (Ewunkem et al., 2016). Males in general become sexually mature before the females as seen in many arthropods, a phenomenon known as protandry (Fagerström and Wiklund, 1982; Gunnarson and Johnson, 1990). Early male maturation increases reproductive success because it facilitates access to a virgin female (Morbey et al., 2012; Morbey, 2013).

One of the amazing things associated with the moulting process is the ability to autotomize (self-amputate) appendages. *Delena cancerides* undergoing ecdysis regenerated appendages (automize) which were lost. The new appendage appeared smaller and gradually got bigger and useable as the original. The ability to regenerate lost appendages occurs in vertebrates, crustaceans, echinoderms and arachnids (Ruth and Roth, 1984; Arnold, 1984; Juanes and Smith, 1995; Uetz et al., 1996; Ramsay et al., 2001). Regeneration of lost appendages is of paramount importance to spiders because they use their appendages for location, prey capture, communication (Wrinn and Uetz, 2007). Autotomy, therefore, enable spiders and other arthropods to avoid been kill (Formanowicz, 1990; Klawinski and Formanowitz, 1994). Autotomy, however, has some costs associated with it which include, the inability to compete, speed reduction, decrease foraging ability and reduce mating ability (Ramsay et al., 2001; Taylor and Jackson, 2003; Apontes and Brown, 2005; Taylor et al., 2006).

5 Conclusion

In a banana agroecosystem *Delena cancerides* are found in colonies under loose barks and spaces between petioles and foliage. The relative abundance of *D. cancerides* is significantly greater during the dry season than rainy season. The female *D. cancerides* produces an egg sac and in which she lays eggs. After several days of incubation, the eggs hatched into spiderlings and females require longer time to develop.

References

Abagale SA, Woodcock CM, Chamberlain K, Osafo-Acquaah, S, van Emden H, Birkett MA, Braimah H. 2019. Attractiveness of host banana leaf materials to the banana weevil, *Cosmopolites sordidus* in Ghana for development of field management strategies. Pest Management Science, 75(2): 549-555

Arnold EN. 1984. Evolutionary aspects of tail shedding in lizards and their relatives. Journal of Natural History, 18(1): 127-169

Amira EA, Behija SE, Beligh ML. Lamia LI, Manel H, Mohamed M, Lotfi A. 2012. Effects of the ripening stage on phenolic profile, phytochemical composition and antioxidant activity of date palm fruit. Journal of Agricultural and Food Chemistry, 60(44): 10896-10902

Andrade MC, Banta EM. 2002. Value of male remating and functional sterility in redback spiders. Animal Behaviour, 63(5): 857-870

Apontes P, Brown CA. 2005. Between-sex variation in running speed and a potential cost of leg autotomy in the wolf spider *Pirata sedentarius*. The American Midland Naturalist, 154(1): 115-126

Auletta A, Rayor LS. 2011. Preferential prey sharing among kin not found in the social huntsman spider, *Delena cancerides* (Araneae: Sparassidae). The Journal of Arachnology, 39(2): 258-263

Austin AD. 1985. The function of spider egg sacs in relation to parasitoids and predators, with special reference to the Australian fauna. Journal of Natural History, 19(2): 359-376

Awang OK. 2016. Sustainability Issues in the Cameroon Banana Supply Chain. Sustainability Issues in the

Cameroon Banana Supply Chain (January 18, 2016).

Aziz NAA, Ho LH, Azahari B, Bhat R, Cheng LH, Ibrahim MNM. 2011. Chemical and functional properties of the native banana (*Musaacuminata balbisiana* Colla cv. Awak) pseudo-stem and pseudo-stem tender core flours. Food Chemistry, 128(3): 748-753

Beavis AS, Rowell DM, Evans T. 2007. Cannibalism and kin recognition in *Delena cancerides* (Araneae: Sparassidae), a social huntsman spider. Journal of Zoology, 271(2): 233-237

Bradbury L, Wilson R. 2019. Cultivating curiosity about creatures. Science and Children, 56(8): 54-62

Bowen-Forbes CS, Zhang Y, Nair MG. 2010. Anthocyanin content, antioxidant, anti-inflammatory and anticancer properties of blackberry and raspberry fruits. Journal of Food Composition and Analysis, 23(6): 554-560

Brice R. 2017. Banana exports plummeted more than 20,600 tons due to bad weather conditions https://www.businessincameroon.com/agro-industry/1112-7621-cameroon-at-october-2017-banana-exports-plummeted-more-than-20-600-tons-due-to-bad-weather-conditions

Brice R. 2018. Cameroon’s banana exports dropped by 27,000 tons during S1, 2018 (Assobacam).https://www.businessincameroon.com/agribusiness/2407-8225-cameroon-s-banana-exports-dropped-by-27-000-tons-during-s1-2018-assobacam.

Coltro L, Karaski TU. 2019. Environmental indicators of banana production in Brazil: Cavendish and Prata varieties. Journal of Cleaner Production, 207: 363-378

Cotes B, González M, Benítez E, De Mas E, Clemente-Orta G, et al. 2018. Spider communities and biological control in native habitats surrounding greenhouses. Insects, 9(1): 33

Christenson TE, Wenzl PA. 1980. Egg-laying of the golden silk spider, *Nephila clavipes* L. (Araneae, Araneidae): functional analysis of the egg sac. Animal Behaviour, 28(4): 1110-1118

Davey MW, Stals E, Ngoh-Newilah G, Tomekpe K, Lusty C, Markham R, Keulemans J. 2007. Sampling strategies and variability in fruit pulp micronutrient contents of West and Central African bananas and plantains (Musa species). Journal of Agricultural and Food Chemistry, 55(7): 2633-2644

Ewunkem AJ, Mbua CP, Ntonifor NN. 2020. Microhabitat preference and biology of *Holconia insignis* (Thorell, 1870)(Araneae: Sparassidae) in banana plantation agroecosystem. Arthropods, 9(4): 155-163

Ewunkem JA, Ntonifor NN, Parr MC. 2016. bioecology of *Heteropoda venatoria* (Linnaeus)(Araneae: Sparassidae) and its implications in a tropical banana agroecosystem. Journal of Global Agriculture and Ecology, 5(3): 164-175

Fagerström T, Wiklund C. 1982. Why do males emerge before females? Protandry as a mating strategy in male and female butterflies. Oecologia, 52(2): 164-166

Formanowixz Jr DR. 1990. The antipredator efficacy of spider leg autotomy. Animal Behaviour, 40(2): 400-401

Foelix RF. 1996. Biology of Spiders: Oxford University Press, New York, USA

Giampieri F, Tulipani S, Alvarez-Suarez JM, Quiles JL, Mezzetti B, Battino M. 2012. The strawberry: composition, nutritional quality, and impact on human health. Nutrition, 28(1): 9-19

Gunnarsson B, Johnsson J. 1990. Protandry and moulting to maturity in the spider *Pityohyphantes phrygianus*. Oikos, 205-212

Hieber CS. 1985. The “insulation” layer in the cocoons of *Argiope aurantia* (Araneae: Araneidae). Journal of Thermal Biology, 10(3): 171-175

Hieber CS, Uetz GW. 1990. Colony size and parasitoid load in two species of colonial Metepeira spiders from Mexico (Araneae: Araneidae). Oecologia, 82(2): 145-150

Juanes F, Smith LD. 1995. The ecological consequences of limb damage and loss in decapod crustaceans: a review and prospectus. Journal of Experimental Marine Biology and Ecology, 193(1-2): 197-223

Klawinski PD, Formanowicz Jr DR. 1994. Ontogenetic change in survival value of leg autotomy in a wolf spider, *Gladicosa pulchra* (Keyserling) (Araneae: Lycosidae), during scorpion attacks. Canadian Journal of Zoology, 72(12): 2133-2135

Li K, Fu S, Zhan H, ZhanY, Lucia L. 2010. Analysis of the chemical composition and morphological structure of banana pseudo-stem. BioResources, 5(2): 576-585

Lim YY, Lim TT, Tee JJ. 2007. Antioxidant properties of several tropical fruits: A comparative study. Food Chemistry, 103(3): 1003-1008

Luquini L, Barbosa D, Haddad FC, Ferreira F, Amorim EP. 2019. Nematode survey and biochemical characterization of *Meloidogyne* spp. in a main banana production area in Brazil. Crop Protection, 117: 94-99

Masanza M, Gold CS, Van Huis A, Ragama PE, Okech SHO. 2005. Effect of crop sanitation on banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) populations and crop damage in farmers' fields in Uganda. Crop Protection, 24(3): 275-283

Maciejewski W. 2010. An analysis of the orientation of an orb-web spider. Journal of Theoretical Biology, 265(4): 604-608

Morbey YE. 2013. Protandry, sexual size dimorphism, and adaptive growth. Journal of Theoretical Biology, 339: 93-99

Morbey YE, Coppack T, Pulido F. 2012. Adaptive hypotheses for protandry in arrival to breeding areas: a review of models and empirical tests. Journal of Ornithology, 153(1): 207-215

Nile SH, Park SW. 2014. Edible berries: Bioactive components and their effect on human health. Nutrition, 30(2): 134-144

Nørgaard E. 1956. Environment and behaviour of *Theridion saxatile*. Oikos, 7(2): 159-192

Prajapati JN, Patel SR, Surani GG, Radadia P. 2018. Agrobiont spiders (Araneae) from five ecosystems of Navsari Agricultural University, Navsari, Gujarat, India. IJCS, 6(3): 2547-2550

Pulchra G. 1992. Life cycle and habitat preferenc e of the facultatively arboreal wolf spider, *Gladicosa pulchra* (Araneae, Lycosidae). The Journal of Arachnology, 20: 157-164

Ramsay K, Kaiser M, Richardson C. 2001. Invest in arms: behavioural and energetic implications of multiple autotomy in starfish (*Asterias rubens*). Behavioral Ecology and Sociobiology, 50(4): 360-365

Ross J, Richman DB, Mansour F, Trambarulo A, Whitcom WH. 1982. The life cycle of *Heteropoda venatoria* (Linnaeus)(Araneae: Heteropodidae). Psyche: A Journal of Entomology, 89(3-4): 297-305

Rowell DM, Avilés L. 1995. Sociality in a bark-dwelling huntsman spider from Australia, *Delena cancerides* Walckenaer (Araneae: Sparassidae). Insectes Sociaux, 42(3): 287-302

Roth VD, Roth BM. 1984. A review of appendotomy in spiders and other arachnids. Bulletin-British Arachnological Society, 6(4): 137-146

Sango T, Yona AMC, Duchatel L, Marin A, Ndikontar MK, Joly N, Lefebvre JM. 2018. Stepwise multi–scale deconstruction of banana pseudo–stem (*Musa acuminata*) biomass and morpho–mechanical characterization of extracted long fibres for sustainable applications. Industrial Crops and Products, 122: 657-668

Schaefer M. 1976. An analysis of diapause and resistance in the egg stage of *Floronia bucculenta* (Araneida: Linyphiidae). Oecologia, 25(2): 155-174

Schmitz OJ. 2008. Effects of predator hunting mode on grassland ecosystem function. Science, 319(5865): 952-954

Taylor PW, Jackson RR. 2003. Interacting effects of size and prior injury in jumping spider conflicts. Animal

Behaviour, 65(4): 787-794

Taylor PW, Roberts JA, Uetz GW. 2006. Compensation for injury? Modified multi-modal courtship of wolf spiders following autotomy of signalling appendages. Ethology Ecology and Evolution, 18(2): 79-89

Tinzaara W, Gold CS. 2008. Banana pests and their management. In: Encyclopedia of Entomology (Capinera JL, ed). 359-369, Springer

Uetz GW, McClintock WJ, Miller D, Smith EI, Cook KK.1996. Limb regeneration and subsequent asymmetry in a male secondary sexual character influences sexual selection in wolf spiders. Behavioral Ecology and Sociobiology, 38(4): 253-257

Vetter RS, Crawford RL, Buckle DJ. 2014. Spiders (Araneae) found in bananas and other international cargo submitted to North American arachnologists for identification. Journal of Medical Entomology, 51(6): 1136-1143

Vetter RS, Rust MK. 2010. Periodicity of molting and resumption of post-molt feeding in the brown recluse spider *Loxosceles reclusa* (Araneae: Sicariidae). Journal of the Kansas Entomological Society, 83(4): 306-313

Villanueva-Bonilla GA, Onody HC, Santos BF, Vasconcellos-Neto J. 2016. First record of egg sac predation on a wall crab spider Selenopidae (Araneae) by the wasp *Camera lunavenatrix* sp.n. (Ichneumonidae, Cryptinae). Journal of Hymenoptera Research, 66: 15

Wrinn KM, Uetz GW. 2007. Impacts of leg loss and regeneration on body condition, growth, and development time in the wolf spider *Schizocosa ocreata*. Canadian Journal of Zoology, 85(7): 823-831

Yip EC. 2012. Costs and Benefits of Group Living in An Unusual Social Spider, *Delena cancerides*. Dissertation. Cornell University, USA

Yip EC, Rayor LS.2011. Do social spiders cooperate in predator defense and foraging without a web? Behavioral Ecology and Sociobiology, 65(10): 1935-1947.

Yu D, Huang P, Chen Y, Lin KS, Akutse Y, Lan H, Wei H. 2018. Effects of flower thrips (Thysanoptera: Thripidae) on nutritional quality of banana (Zingiberales: Musaceae) buds. PloS one, 13(8): e0202199