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FLORAL VISITORS OF *ANANAS COMOSUS* IN GHANA: A PRELIMINARY ASSESSMENT

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Abstract—*Ananas comosus* var *comosus* (L.) Merr. is the third most important tropical fruit in the world production and the leading foreign exchange earner among fresh fruits exported from Ghana. A survey was conducted in pineapple farms in the Central region of Ghana to identify floral visitors and their activities on the flowers. Nectar concentration and energetics and effect of floral visitors on fruit production were determined. Fourteen species of butterflies and one ant species were the main insect floral visitors as well as four species of sunbirds. The mean nectar concentration was 23.3% (± 0.39, SE) and pollination limitation did not significantly affect fruit yield (weight: $p = 0.285$; length: $p = 0.056$; width: $p= 0.268$). The study showed that butterflies, ants and sunbirds are the main floral visitors on *A. comosus.* However their visits did not results in pollination and fruit production was not affected in any way by floral visitation. Still, it was found that *A. comosus* provides an important nectar resource for its foragers. Even if pollination is not crucial in pineapple cultivation, it is still essential in pineapple breeding programs to promote genetic diversity and conservation.

Keywords: Pineapple, nectar concentration, pollination limitation, butterflies, sunbirds, ants

INTRODUCTION

Pollinators provide an essential ecosystem service that result in the out-crossing and sexual reproduction of many plants (Kearns et al. 1998; Klein et al. 2007). They benefit society by increasing food security and improving livelihoods and by the role they play in conserving biological diversity in agricultural and natural ecosystems (Klein et al. 2007). Unfortunately, inappropriate agricultural development threatens many pollinators (Roubik 1989; Potts et al. 2010) and hence the conservation of pollinators has become an integral part of many biodiversity conservation efforts (Anon 2003). Currently, the evolving concept of good agricultural practices includes those that identify and conserve wildlife habitats and landscape features such as isolated trees in farmland and manage field margins with native vegetation or hedges that can support pollinators. Knowledge about pollinators and the plants that they pollinate is therefore important for pollinator conservation both in natural and in agro ecosystems.

Ananas comosus var *comosus* (L.) Merr. (Bromeliaceae, hereafter *Ananas comosus*), commonly known as pineapple, is a tropical, herbaceous, perennial monocot, approximately 1-2 metres tall and wide, with leaves arranged spirally (Bartholomew et al. 2003). It bears flowers on a terminal inflorescence, which form a large, edible fruit characterized by a tuft of leaves at its apex. *A. comosus* is the third most important tropical fruit in the world production after bananas and citrus (Bartholomew et al. 2003). It is the leading foreign exchange earner among fresh fruits exported from Ghana (WTO 2002). *A. comosus* is the most famous and economically important member of the family Bromeliaceae. It is the only bromeliad with edible fruit. Bromeliads typically are epiphytic and do not require mineral soil but do best living on bark or humus in the crotches of tree branches. In contrast, *A. comosus* is terrestrial and grows best in a mineral soil medium (Collins 1960). *A. comosus* is cultivated predominately for its fruits, which are consumed fresh or as canned fruit and juice.

A. comosus are pollinated by hummingbirds in the Americas although the crop is produced parthenocarpically (Westerkamp & Gottsberger 2000). Its cultivars are self-incompatible, forming fruits without seeds (Py et al. 1987). Different cultivars can be crossed and then form seeds (Leal 1989). Ghana has excellent *A. comosus* growing conditions capable of producing high quality and well-coloured fruit (Dixie & Sergeant 1998). This project was undertaken to identify floral visitors of *A. comosus* in the coastal part of Ghana to gain more insight into the interactions between *A. comosus* and its floral visitors.

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This paper reports the floral visitors on *A. comosus* and the effect of their visit on fruit production.

MATERIALS AND METHODS

Study area

The project was carried out in seven pineapple farms in Jira Akyinim (N05° 05.738', W001° 22.397') in Komenda Edina Eguafo Abirem (KEEA) district in the Central Region of Ghana from November 2009 to July 2010. The topology is hilly with an elevation of 40m. Pineapple farming is one of the main occupations of small holder farmers in this district and farms are located on top or across the slope of the hills. Small thickets of trees separate one farm from other and farms are mostly one to two acres in size.

Survey of floral visitors and nectar

Insects that visited pineapple flowers were collected from different study sites during the flowering period using an insect net. The activities of flower visitors were also recorded through direct observations for the whole period they stayed on the flowers. Sampling was conducted 3 days a week at different times of the day for 12 weeks to determine the type of floral visitors and their active period of visitation on flowers in the study sites. The collected specimens were identified and stored at the Entomological Museum of the University of Cape Coast. Survey and inventory of birds seen on the flowers were also taken. Bird identification and survey techniques followed Borrow & Demey (2001) and Bibby et al (1998). Binoculars were used to observe the activities of the birds during their visit on flowers.

Nectar was collected from 50 open flowers exposed to floral visitors at different times of the day between 0700hrs and 1200hrs. The time for nectar collection was chosen as a result of a preliminary survey on the active period of floral visitors and the temporal pattern of opening and closing of flowers of *A. comosus* as described in Purseglove (1972) and Bartholomew et al. (2003). Nectar collection days were divided into three sessions (0700-0800 hrs, 0900-1000 hrs and 1100-1200 hrs) and nectar was taken from an average of three flowers in each session per week for five weeks. Nectar concentration, total amount of sugar in the nectar and nectar energetics were measured. Nectar was taken from the plants with 1μL micro capillary tubes (Drummond, U.S.A) and nectar concentration was measured with a sugar refractometer modified for small volumes (Bellingham & Stanley, UK) as described in Kearns & Inouye (1993) and Galetto & Bernardello (2005). Distilled water was used to clean the refractometer which was dried with tissue paper after each use. Temperature and relative humidity during nectar collection were measured as close as possible to the flowers with a hand-held thermo hygrometer (Kestrel, U.S.A). Total amount of sugar was calculated from the equation below:

$$y = 0.00226 + (0.00937\,X) + (0.0000585\,X^2)$$

Where the value of X is the concentration (the reading of the refractometer) and y is quantity of sucrose (mg) per μL. For calculation of energetics: 1mg of sucrose = 16.8 joule (Galetto & Bernardello 2005).

Pollination limitation

In order to study visitation limitation on fruit yield, three experimental set ups were conducted.

(1) Completely covered pineapple plants: 15 plants were completely covered with muslin cloth sown into a bag and secured at the base. Florets were therefore not exposed to flower visitors.
(2) Partially covered pineapple plants: 15 plants were completely covered but exposed to flower visitors when 50% of the florets were flowering.
(3) Open pineapple plants: 15 plants were marked but not covered with all florets exposed to flower visitors.

Mature fruits from all the 45 plants were harvested and brought to the laboratory for examination. The weight, length, and width of fruits from fully covered and open flowers were measured and compared. Ten fruits from each group of plants were randomly selected and slit longitudinally into sections to find the presence of seeds in them. Pollination limitation was tested by counting the number of fruit set among flowers exposed to pollinators (unbagged flowers) versus fruit set in flowers partially or completely excluded from pollinators The differences among parameters from the three treatments were compared with one-way ANOVA using Minitab software package (version 16).

RESULTS

The whorl of flowers of pineapple started to open from the base of the inflorescence and about 5-15 florets opened daily. Flowers opened before 0600 hrs, began to whither in late afternoon, and closed at sundown. Flowers are hermaphroditic and flowering lasts for 10-20 days.

Flower visitors and their behaviour on flowers

Both birds and insects visited pineapple flowers for nectar and were very active on the flowers between 0800 hrs and 1100 hrs. Fourteen species of butterflies and one species of ants were the main insect floral visitors as well as four species of sunbirds (Tab. 1 & 2). *Apis mellifera adansonii* Linnaeus, *Xylocopa calens* Lepeletier and *Dactylurina staudingeri* Gribodo were seen in the pineapple farm collecting nectar from flowers of weeds and other plants but not foraging on pineapple flowers. In addition, *A. mellifera, Musca domestica, M. sorbens* and *Chrysomya* sp. were seen collecting juice from over-ripped and rotten fruits of *A. comosus.*

TABLE 1. Insects visiting *A. comosus* flowers in Central Region of Ghana

Order	Family	Scientific name
Lepidoptera	Nymphalidae	*Precis sophia* Suffert
		Charaxes tiridate Cramer
		Palla decius Cramer
		Danaus chrysippus Linnaeus
	Pieridae	*Melanitis leda* Linnaeus
		Mylothris chloris Fabricius
		Catopsilia florella Fabricius
		Belonois calypso Drury
	Papilionidae	*Appias sylvia* Fabricius
		Graphium adamastor Boisduval
	Acraeidae	*Graphium pylades* Fabricius
		Papilio demodocus Esper
		Acraea natalica Boisduval
		Acraea pharsalus Ward
Hymenoptera	Formicidae	*Lasius fuliginosus* Latreille

TABLE 2: Birds species found on *A. comosus* flowers in the Central Region of Ghana

Order	Family	Scientific name
Apodiformes	Nectariniidae	*Cinnyris sp*
		Anabathmis sp
		Cyanomitra sp
		Chalcomitra sp

Nectar survey

Temperature and relative humidity did not have any marked effect on nectar concentration (Fig. 1 & 2) and the mean ± SE nectar (sucrose) concentration from 0700hrs to 1200hrs was 23.3% ± 0.39 at an average temperature of 29.5°C and 77.5% relative humidity. However, there was a slight increase in concentration and nectar energetics as the temperature increased and relative humidity decreased through the day (Tab. 3; Fig. 1 & 2). Nevertheless, it was difficult to collect 1μl of nectar from a floret after 1200hrs.

Fruit set and pollination limitation

All the pineapple flowers (100%) exposed to or excluded from pollinators were able to set fruit and subsequently developed fully into fruits. No fruit had seeds in them. Fruit quality was similar in all the three treatments. There was no significant difference between the mean ± SE of weight (ANOVA, df = 2, F = 1.37, P = 0.285) and length (ANOVA, df = 2, F = 3.58, P = 0.056) of fruits developed from completely bagged flowers (375.7 ± 21.40g and 11.90 ± 0.30cm) and fruits developed from open flowers (332.4 ± 63.8g and 11.92 ± 0.82cm). Fruit width from the three groups of plants did not differ significantly from each other (ANOVA, df = 2, F = 1.45, P = 0.268) (Tab. 4). Thus pollination limitation did not significantly affect fruit yield, except that partially covered flowers resulted in the largest and heaviest fruits (Tab. 4). In conclusion, insect visitation did not have any effect on fruit quality or yield.

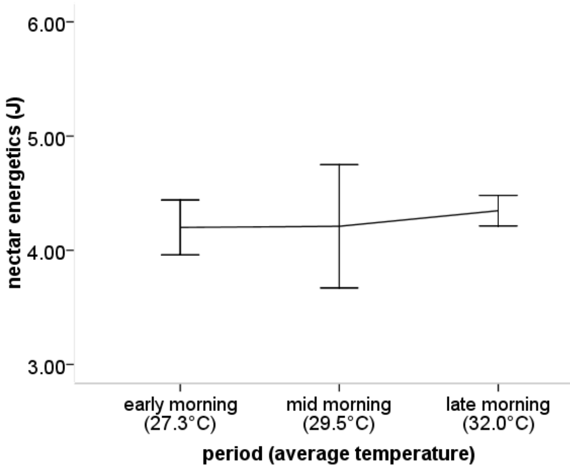

FIG. 1. Nectar energetic per 1μL of nectar of *A. comosus* at different times of the day with average temperatures. Error bars represent 2 SE.

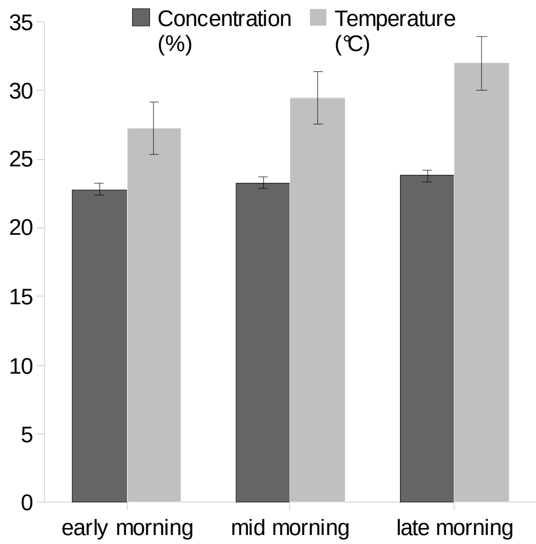

FIG. 2. Temperature (°C) and nectar concentration (%) of *A. comosus* at different times of the day. Error bars represent 2 SE.

TABLE 3. Temperature and relative humidity (± SE) at different times of the day have no effect on nectar concentration and total amount of sugar in 1μL volume of nectar produced by flowers of *A. comosus*.

Time of the day	Average temperature (°C)	Average relative humidity (%)	Sugar concentration (%)	Total amount of sugar (mg/μl)
Early-morning (0700-0800)	27.3 ± 0.60	95.8 ± 1.03	22.8 ± 0.63	0.2463 ± 0.00606
Mid-morning (0900-1000)	29.5 ± 1.00	77.5 ± 1.50	23.3 ± 0.50	0.2523 ± 0.00607
Late-morning (1100-1200)	32.0 ± 0.28	69.5 ± 0.50	23.8 ± 0.50	0.2584 ± 0.01801

TABLE 4. Mean (± SE) weight, length, and width of pineapple fruits produced from various treatment plants in Central Region of Ghana.

	Treatments			
Parameters	Fully bagged	Partially bagged	Unbagged	P value (ANOVA)
Weight (g)	375.70 ±21.40	438.60 ± 32.60	332.40 ± 63.80	0.285
Length (cm)	11.90 ± 0.30	13.84 ± 0.38	11.92 ± 0.82	0.056
Width (cm)	7.6 ± 0.20	7.84 ± 0.19	7.13 ± 0.42	0.268

DISCUSSION

The study showed that butterflies, ants and sunbirds are the main floral visitors on *A. comosus*. Pollination limitation did not significantly affect fruit yield. Knowledge about pollinators and the plants that they pollinate is needed in the management and conservation of both the pollinators and the plants, more so when there is loss or decline of pollinator communities in agro ecosystems and wild habitats (Buchmann & Nabhan 1996).

Sunbirds, butterflies and ants were observed collecting nectar from the flowers, however, their activities did not result in pollination. As a result seedless fruits were formed in both bagged and unbagged plants. This indicates that pollination is not required for fruit set in this plant. This is consistent with other studies that have shown that *A. comosus* flowers are normally self-sterile and fruit development is parthenocarpic (does not require fertilization) (Morton 1987; Py et al. 1987). Hummingbirds, which have similar feeding habits as sunbirds are the main principal pollinators of *A. comosus* in the Americas (Purseglove 1972; Free 1993). However, sunbird visit to *A. comosus* in the study area did not result in pollination. These floral visitors might have transferred pollen to stigma but this did not result in pollination due to the fact that pineapple cultivars are self-incompatible.

Nectar concentration of *A. comosus* was found to be diluted and it is therefore not surprising that butterflies and sunbirds were the main visitors rather than bee visitors. Diluted nectars are easy to imbibe and are preferred by long-tongued nectarivores such as lepidopterans and hummingbirds (Baker & Baker 1975, 1983). Nectar concentration has a major effect on several aspects of the behavior and ecology of nectarivores and temperature and humidity are also known to have marked effects on nectar concentration due to evaporation. However the effect was minimal on *A. comosus* flowers; thus nectar concentration remained fairly constant even when temperature increased during the day. The long corolla tubes of the flowers might have reduced the effect of temperature and relative humidity on the nectar. Experimental studies have shown that nectar concentration is directly affected by corolla depth: the concentration in flowers with long corolla tubes is lower than in flowers with short or without tubes (Corbet 1978; Galetto & Bernardello 2005).

Nectar production and nectar removal by floral visitors come with a cost to the plant and it becomes more costly when the plants receive no reward. The results from this study show that the interaction between *A. comosus* and its floral visitors only benefited the floral visitors but the plant was not disadvantaged, especially in terms of fruit development; the weight and the size of fruits from flowers exposed to floral visitors and those that were exempted from visitors did not differ significantly.

Interestingly, no member from the family Apidae was found visiting the pineapple flowers. *Apis mellifera, Xylocopa sp* and *Dactylurina sp,* the principal pollinators of most native plants and crops (Karikari & Kwapong 2007; Mensah & Kudom 2010), were not seen on *A. comosus* flowers. Instead they were found collecting nectar from flowers of weeds and other vegetation in and around the farm throughout the study period. In Australia, *Apis mellifera* and native bees were occasional visitors that feed on the nectar and play a relatively minor role in pollen dispersal and cross pollination (Purseglove 1972; Wee & Rao 1979). In this study *Apis mellifera* were rather seen collecting juice from over - ripe fruits of *A. comosus.* After juice collection fruits become prone to further attacks from other organisms such as aphids or saprophytic molds which lowers their economic value.

This and other (Westerkamp & Gottsberger 2000) studies have established that pollination is not important in pineapple cultivation. However, pollination is still an important process in pineapple breeding programs which makes knowledge on the interaction between *A. comosus* and its floral visitors very vital and worth studying. This study has shown potential pollinators of pineapple in Ghana which is useful information for programs that target sexual reproduction in pineapple especially for biodiversity and conservation purposes. Sexual reproduction via pollinators is known to increase seed production in pineapple (Klein et al. 2007). Pineapple cultivation is routinely carried out as monocrop. As a result the crop is susceptible to many fungal diseases. Genetic diversity of commercially used pineapple plants resulting from sexual reproduction can be one way to control such fungal diseases (Purseglove 1972; Bartholomew et al. 2003). Regarding the high diversity of floral visitors in pineapple farms, we recommend to combine pineapple cultivation with other crops in the form of intercropping, which can be beneficial to both plants. Intercropping has been found to improve fruit quality and yield in pineapple cultivation due to effective weed management (Eshetu et al. 2007). The other crops can also benefit through adequate pollination by the high abundance and diversity of pollinators in the farm. The abundance and diversity of pollinators have been found to improve the efficiency of pollination and fruit and seed production (Steffan-Dewenter et al. 2006).

CONCLUSION

Birds and insect floral visitors, comprising butterflies, ants and sunbirds were found to be frequent visitors of pineapple flowers. Flowers that were exempted from their visit were still able to produce fruits that were as good as the fruits that developed from flowers that received a lot of floral visitors and there were no seeds from either set of fruits. This study provides information about the interactions between *A. comosus* and its floral visitors offering a rich nectar source for its foragers. Since nectar removal by floral visitors has no effect on fruit development intercropping pineapple with other crops can be mutually beneficial. Improved weed management as a result of intercropping would increase fruit yield in pineapple while the other crops benefit through the abundance and diversity of pollinators. In addition, mature fruits can be harvested early to prevent secondary infection and ultimately lower economic value of fruits as a result of *Apis mellifera* feeding behaviour on the fruit.

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