Floral Biology and Visitors Behaviour of Caralluma Acutangula (Decne.) N.E.Br. in Jazan Region, Southwestern Saudi Arabia

Y.S.Masrahi* and H.A.Bosly

(*) Department of Biology, Faculty of Science, Jazan University, K.S.A.

Abstract

Caralluma acutangula (Decne.) N.E.Br. is one of the most succulent species of Asclepiadoideae(Apocynaceae) in the Tihama hill slopes of Jazan, Southwestern Saudi Arabia. The flowers of the plant attract many visitors, some of which are pollinators which are represented by Diptera, especially from families Muscidae, Sarcophagidae, and Calliphoridae. To attract the pollinators flowers use mimicry and deception for brood and food site (Sapromyophily) thus the female flies are the most frequent visitors. This mimicry with structure of flowers affects the behaviour of flies and leads to the attachment of pollinia to the proboscis and transfers them to receptors (guide rails). Other visitors are butterflies, represented only by Plain Tiger (*Danaus chrysippus* – Nymphalidae) whose larvae feed on flowers. Some predators of Thomisidae spiders hide between flowers to catch Diptera prey. This study sheds some light on a complex system between flowers and their visitors in arid habitats.

Keywords: *Caralluma acutangula*,Flowers,Diptera,Mimicry, Pollination,*Danaus chrysippus*, Thomisidae.Jazan,Saudi Arabia.

1. INTRODUCTION

The Asclepiadoideae (subfamily Apocynaceae) constitute a group showing complex floral structures and pollination in angiosperms (Kunze,1991; Albers and Meve,2002). Caralluma is a stem succulent genus of Asclepiadoideae, comprises about 60 species distributed in arid and semiarid regions of Africa and Asia (Bruyns,2000b; Müller and Albers,2002; Gilbert,2003). In Saudi Arabia, this genus is represented by 6 species, restricted to the southwestern part of the country (Müller and Albers,2002; Masrahi,2011).

Reproduction success in higher plants depends on the activity of pollinators in pollination. The flowers of many angiosperms have evolved many intricate mechanisms to attract pollinators including highly scented floral parts, mimicry of brood and food sites, colour patterns, and structural morphologies (Faegri and Van der Pijl,1979;Sakai,2002). On the other hand, some flowers represent sites to attract many kind of visitors vary in the behavior, some of them are pollinators,while others prey on the pollinators or even feed on the flowers itself (Dukas,2004).

No studies have been published on pollination and flower visitors of Caralluma, except some scattered observations (see Meve and Liede,1994), compared with other genera like Asclepias, Calotropis, and Ceropegia (Kunze,1991 and references within; Masinde, 2004).

This study documents floral biology and visitors behaviour in Caralluma acutangula,which represents one of the most succulent species of Asclepiadoideae in Southwestern Saudi Arabia.

(*)E-mail: ymasrahi@gmail.com ISSN: 6050-1658

2. MATERIALS and METHODS

Study species and sites

Caralluma acutangula is a perennial erect stem succulent, 0.4-1m tall. Flowers are crowded in terminal dark globose heads on stems. Flowers bloom after summer rain,from July- October. Field observations were conducted in rocky habitats (Tihama hill and slopes), 3 km east of Abu-Arish city,Jazan district,southwestern Saudi Arabia, between 100-400 m a.s.l. Plant distribution is patchy in these areas, where the plant grows in microhabitats between rocks and beneath shrubs. Average annual temperature is 32.3°C , whereas annual rainfall is between 186-328 mm . The study was carried out in the flowering stage of summer rainfall (July-October 2010).

Flower morphology

Flower morphology was described based on concepts of Asclepiadoideae (Liede and Kunze,1993; Meve and Liede,1994). Flowers were collected from the field and immediately transferred to the laboratory to be examined under stereomicroscope.

Flower visitors and their behaviour

Sampling (in total 104 flowers) was undertaken in the period (07:00 a.m. – 16:00 p.m.). At the same times, the behavior and movement of the visitors were observed closely. The frequency of visitors were recorded as (very frequent, frequent, infrequent) (Taroda and Gibbs,1982). Specimens collected were killed in chloroform tubes (insects bearing pollinia) and examined immediately under stereomicroscope or preserved in 70% ethanol for subsequent examination. Samples were identified by Amoudi(1997) in the case of flies ; Larsen(1984) in case of butterflies; Taher and Faragalla (1990); Hawkeswood (2003) in case of spiders (at family level).

Statistical Analysis

Data of visitors are represented as mean ± SE (visitors to N of flowers = 104). Statistical significance was evaluated using Student's t-test.

3. RESULTS

Flower morphology

Flowers of Caralluma acutangula are arranged in dark large globose heads,pseudumbles inflorescence (fig.1,A). Flowers emit fetid scents,resembling rotten meat or decaying organic matter. The single flower consists of five petals(corolla lobes). The surface of the corolla lobe is wrinkled. The corona (the centre of the flower) includes white coloured stigma head surrounded by five staminal coronas. Five pollination units, the pollinia,are located on the margins of the stigma head, just above guide rails. Guide rails represent narrow slits (to received pollinia)(fig.1,E). These guide rails produce droplets of nectar as seen under the microscope. The droplets drop and accumulate in the nectar cavity below the guide rail (fig.1,C).

Pollination and visitors behavior

C. acutangula flowers were visited mainly by insects in orders Diptera and Lepidoptera as well as Arachnoidae (Thomosidae-crab spiders).

Diptera were the most frequent visitors to flowers (table 1.) followed by Plain Tiger butterfly (as observed by larval stage feeding on flowers), and finally crab spiders (Thomisidae).

Diptera visitors belonged to three families: Muscidae, Sarcophagidae, and Calliphoridae. Female were more frequent than males ($P<0.001$) except Chrysomya marginalis which male and female were equall in percentage of visiting (fig. 2.).

The behavior of all fly species was almost similar whereby the fly lands on the flower attracted to the corona at the center of the flower. In order to reach the nectar cavities inside,the fly then extends its proboscis and probe the surface of these narrow chambers which are wide enough only for

the proboscis (fig. 1,B). This activity leads to attachment of the pollinia to the proboscis (fig.1,D). In all cases,pollinia were found attached only to the proboscis. Upon repeating this process with the nectar cavity of another flower, the pollinia enter the slit of guide rail and hence the flower ensures pollination (fig1, F). No pollinia were ever detected adhering to the bodies of other groups of visitors.

Other visitors to the flowers of C. acutangula were the Plain Tiger butterfly (Danaus chrysippus-Nymphalidae) and crab spiders (Thomisidae)(fig.3). Larvae of D. chrysippus were frequently found on flowers and feed on corolla lobes (fig.3,A). The duration of feeding behavior is not included in this study. On reaching maturity,the larvae left the flowers to search for suitable pupation sites (usually part of the stem just below the flowers-fig.3,B,C).

Thomisidae spiders were infrequently found on the flowers. They hide between flowers in inflorescence, waiting for Diptera prey (fig.3,D,E).

4. DISCUSSION

Faegri and Van der Pijl (1979) have distinguished two types of pollination syndrome for fly-pollinated flowers: myophily and sapromyophily. General features of myophily are simple structures ,light colours, imperceptible odour,easy access to nectar and exposed sexual organs (anthers and stigma). Sapromyophily is characterized by dark or brown-purple colour (or blotched dark spots), pollination units frequently have great depth, and odour resembling that of decaying organic matter. Attraction in sapromyophilous flowers is by deceit, with flies confusing the flowers for decaying organic matter as a suitable brood and food site (Faegri and Van der Pijl,1979; Dafni,1984; Jürgens et al.,2006). Typical examples of sapromyophily are found in the genera Stapelia (Apocynaceae-Asclepiadoideae), Arum (Araceae), Rafflesia (Rafflesiaceae), and some Orchids (Kevan and Baker,1983; Beaman et al.,1988; Albre et al.,2003).

On the basis of the above concepts,the flowers of Caralluma acutangula belong to sapromyophily syndrome since they have dark colour, pollination units not exposed, and odour resembling that of decaying organic matter.

In entomophillous flowers,structures vary and are adapted to fit the structure and behavior of insect pollinators. By analogy, flower-visiting insects have many modifications to get flower attractants (nectar and pollen) especially in the mouthparts (Krenn et al.,2005). Flowers of C. acutangula don't have easy access to nectar and pollinia, so they must have many adaptations in shape,colour and odour to attract pollinators. Pollinators of C. acutangula are flies from families Muscidae,Calliphoridae, and Sarcophagidae. These flies have a short proboscis. Most flower-visiting Diptera with a short proboscis take nectar from flowers with open and easily accessible nectarines (Brackenbury,1995; Krenn et al.,2005). On the other hand,flies of Muscidae,Calliphoridae, and Sarcophagidae,especially species visiting C. acutangula flowers, common in slaughter-

Table.1. Frequencies of visitors for flowers of ***C. acutangula***

Visitors	Frequency
Flies	Very frequent
Plain tiger butterfly	Frequent
Crab spiders	Infrequent

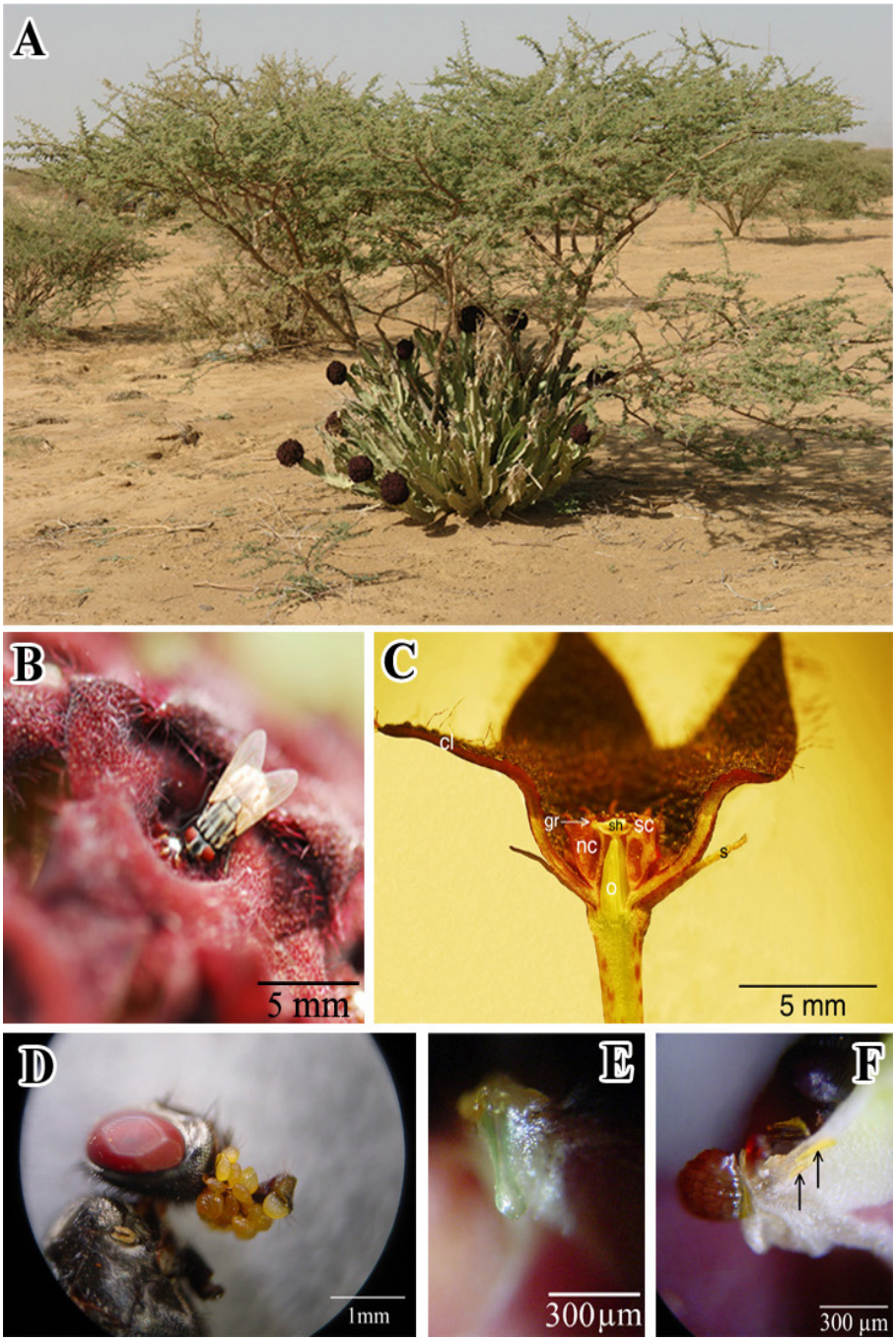

Fig.1. A. *Caralluma acutangula* in its natural habitat. **B.** *Musca domestica* on a flower. **C.** L.S. in the flower. **D.** Pollinia attached to *Musca domestica* proboscis. **E.** guide rail. **F.** Guide rail after entrance of pollinium (L.S) (arrows indicate germination tubes). (abbreviations in **C.** cl. Corolla lobe, gr. guide rail, sh. stigma head, nc. nectar cavity, sc. staminal corona, o. ovary, s. sepal).

houses and garbage dumps, being share in attracted to meat in which the eggs are deposited (Buttiker et al.,1979; Gadallah and Bosly, 2006). Flowers of C. acutangula with odour resembling rotten meat (or carcasses), and appearance with dark colour and wrinkled surfaces, mimic brood and food sites of these flies.

After the attraction and landing on the flowers, the fly may try to search for a suitable location to lay eggs(most of flies visiting are females). In the behaviour of laying eggs in females, choosing a site correlates to two stimulators: general stimulator to site (odour) and special stimulator to specific location (particular concentrations of cations in excretion decaying matter sensed by receptors on ovipositor of the flies) (Rice,1977; Byrd and Castner, 2001; Amendt et al.,2004). Therefore, fly females cannot lay eggs on dry decaying matter (Byrd and Castner,2001; Amendt et al.,2004). In our field observations,we did not observed eggs on the flowers, which may confirm the above mentioned. Flowers of C. acutangula seem to mimic general stimulator to brood site (odour), whereas the dry appearance of corolla lobes surfaces does not motivate the special stimulator to lay eggs.

Nectar in most succulents of Asclepiadoideae is found in the guide rail and flows to the bottom of the nectar cavity(Meve and Liede,1994; Bruyns,2000a). Nectar cavities of C. acutangula are narrow,and nectar is not easily accessible. In this case, the presence of nectar may be detected by taste sensory organs on the fly's labellae, maxillary palps and tarsi. Touching of these organs, especially tarsi, with flowing nectar stimulates the proboscis to extend and probe (Chapman,1971; Daly et al.,1978; Vogel,1983). On searching for nectar in the nectar cavity, the fly must extend its proboscis in this narrow chamber and probe cavity surfaces. This behavior leads to attachment of pollinium to the proboscis. On repeating this process with another cavity, the chance is suitable to entrance of pollinium into the guide rail, and thus the flower ensures pollination. The dependence on flies for pollination seems to be an adaptive strategy, because these insects are widespread, prefer high temperatures, and are present at all times of the year (Büttiker et al.,1979; Faegri et al.,1979).

Another visitor to the flowers of C. acutangula is the Plain Tiger butterfly (Danaus chrysippus-Nymphalidae). It is well known that butterflies of Danaus spp. feed exclusively on poisonous plants of Apocynaceae (especially Asclepiadoideae) which contain cardiac glycosides (cardenolides) (Larsen,1984; Zalucki and Brower,1992; Mebs et al.,2005). The larvae sequester these poisons and pass them to the adults in concentrated form. Small mammals and birds react with vomiting when they attempt to eat them (Mebs et al.,2005). The female of D. chrysippus lays eggs on the flowers. After hatching, larvae feed on corolla lobes. It is not known if the flowers of C. acutangula contain cardenolides or not. Some samples of D. chrysippus feeding on Apocynaceae plants do not contain cardenolides (Mebs et al.,2005) indicating a lack of them in eaten plant parts. On the other hand,some chemicals (like flavonol glycosides) in Apocynaceae plants act as oviposition stimulants for Danaus spp.,which means that recognition of host plants by these butterflies depends on the unique chemistry of these plants (Haribal and Renwick,1998). Existence of the larvae on the flowers of C. acutangula, not on any plant species in the same habitat, confirm the above mentioned.

Crab spiders (Thomisidae) are infrequently found on flowers (as compared with other visitors). This observation may be misleading, because these spiders hide in flowers (below petals), especially light colour species (Hawkeswood,2003). They sit

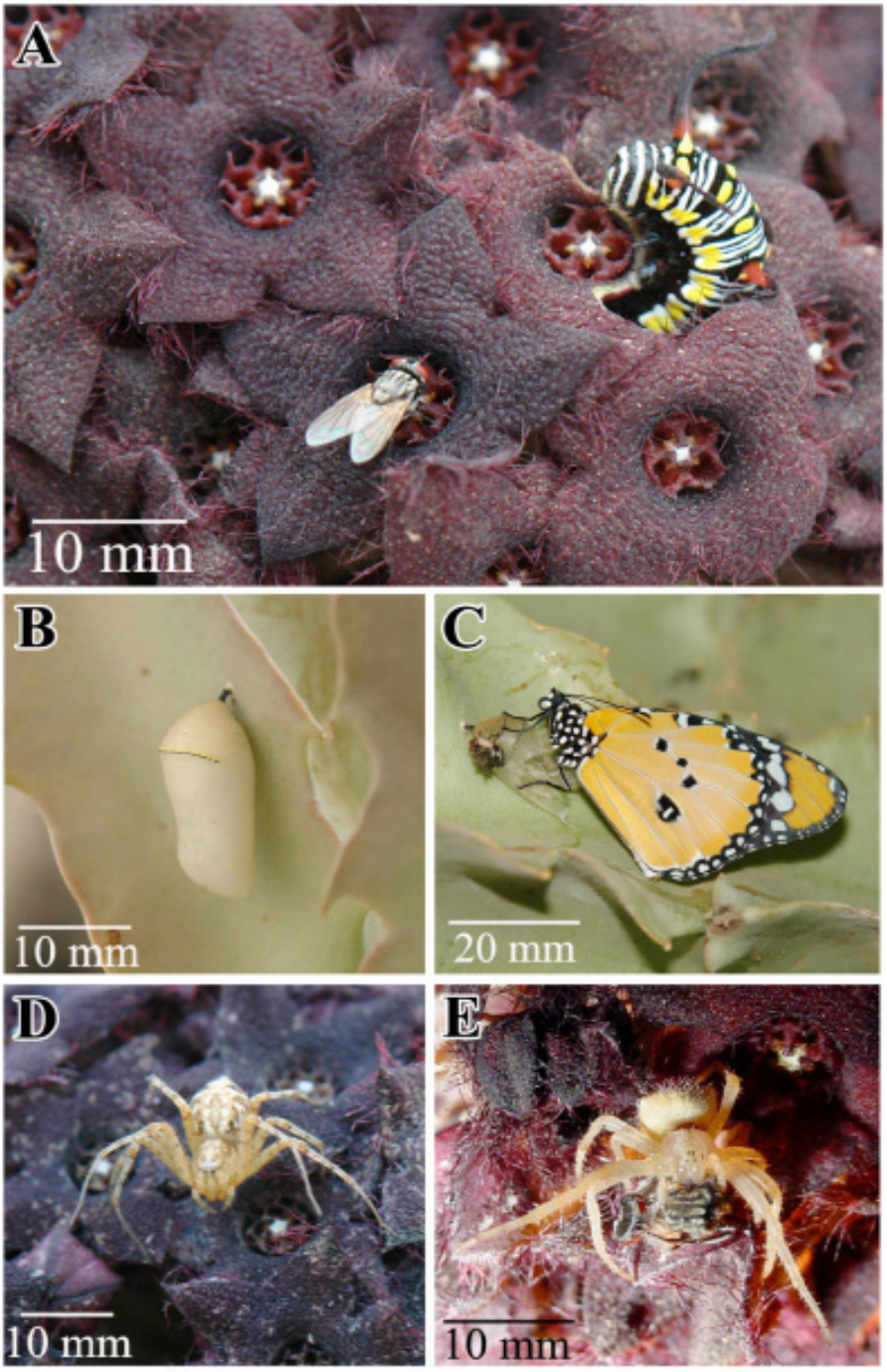

Fig. 3. A. Larva of *Danaus chrysippus* feeds on a flower of ***C. acutangula*** **. B.** Pupa on a stem of ***C. acutangula.*** **C.** The adult butterfly is shown minutes after it emerged from the pupa. **D,E.** Thomisidae spiders on the flowers (in E spider has caught and is feeding on *Musca domestica*).

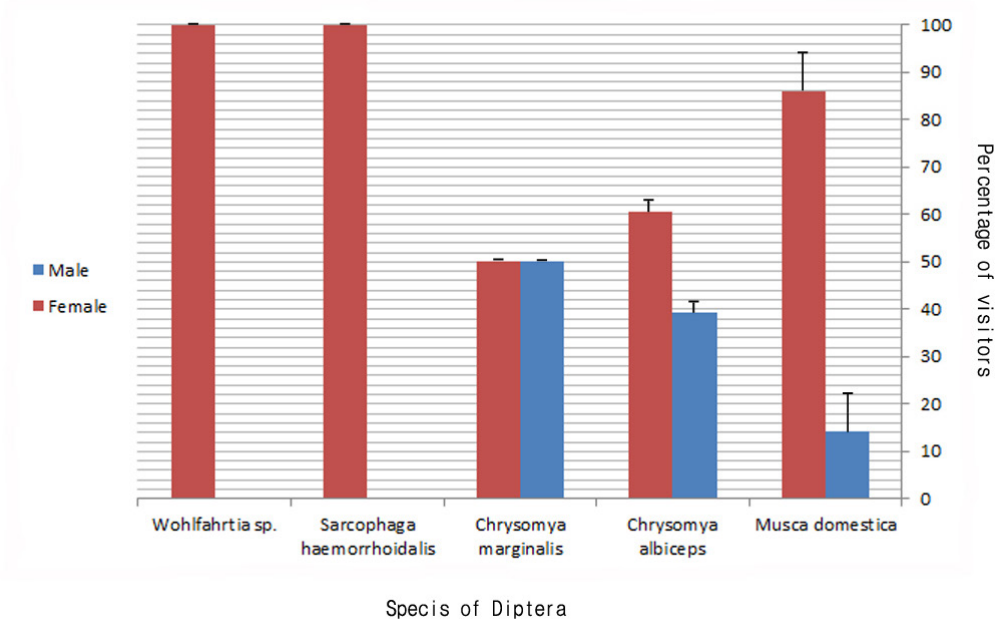

Fig.2. Percentage of sex in Diptera visiting to flowers of *C. acutangula*

motionless to wait for landing insects, and then seize them by strong front legs,bite and inject a rapidly acting poison (Foelix,1996). Crab spiders represent most frequent ambush predators that sit on or near the flowers (Dukas,2004). Crab spiders respond to the floral signals in the same manner as pollinators, including olfactory signals (Aldrich and Barros,1995; Heiling et al.,2004).

Flowers of C. acutangula represent three types of plant-visitors interactions :

1-Seduction and deception of Diptera for pollination,

2-Predation of flowers (larvae of D. chrysippus),

3- Act as an attractive microhabitat to insect predators (Thomisidae spiders).

These three types of interactions seem to share in the same manner of visitors attractants: olfactory and chemical signals, and we emphasize that further work is required.

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بيولوجيا الأزهار وسلوك الزائرات لنبات الغلفي في منطقة جازان،جنوب غرب المملكة العربية السعودية

يحيى سليمان مسرحي ، حنان أبو القاسم بُصلي
قسم الأحياء ، كلية العلوم ، جامعة جازان

المُلخّص

يعتبر نبات الغلفي أحد أكثر عصاريات تحت الفصيلة العشارية تواجداً في منحدرات سهول تهامة جازان،جنوب غرب المملكة العربية السعودية. تجذب أزهار النبات العديد من أنواع الذباب، خصوصاً ضمن فصائل الذباب المنزلي،ذباب اللحم، والذباب المعدني. لجذب الملقّحات تسلك الأزهار سلوك الخداع والمحاكاة لأماكن وضع البيض والغذاء؛ ولذا فإن إناث الذباب هي أكثر الزائرات تردداً. تؤثر المحاكاة التي تبديها الأزهار على سلوك الذباب مؤدية إلى التصاق الكتل اللقاحية بخرطوم الحشرة ونقلها إلى المستقبل الميسمي(الشق الموجّه). من الزائرات الأخرى للأزهار الفراشات، وتتمثل بنوع وحيد هو فراشة نمر السهول؛ حيث تتغذى يرقاتها على الأزهار. بعض أنواع العناكب(من فصيلة عناكب السرطان) تنجذب أيضاً للأزهار؛ حيث تختبئ بين الأزهار لاقتناص الفرائس من الذباب الزائر. تلقي هذه الدراسة بعض الضوء على العلاقة المعقدة بين الأزهار وزائراتها في البيئات الجافة.

كلمات مفتاحية: نبات الغلفي - الأزهار - الذباب المنزلي - ذباب اللحم - الذباب المعدني - جازان - المملكة العربية السعودية.