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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

FORAGING ECOLOGY AND ABUNDANCE OF NATIVE POLLINATORS IN BITTER GOURD

Acı Kabakta Yerel Tozlayıcıların Yayılma Ekolojisi ve Bolluğu

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ABSTRACT

An experiment is conducted in bitter gourd cropping system at Coimbatore district in India, to study bitter gourd floral character, the foraging ecology of native pollinators and their modes of pollination. Bitter gourd is a monoecious plant bears separate male and female flowers. Male flower blooms early followed by female flowers. Stigma receptivity of pistillate flowers was confirmed on 4th day old flower showed yellowish-green stigma with shining stigmatic exudation. The stigma receptivity lasts up to 24 hours after anthesis. Pollen viability test done with 2 per cent acetocarmine solution indicated that pollen collected during morning hours (06:00 h) were more viable and were deeply stained, whereas pollens collected at evening hours (17:00 h) remained unstained and considered as nonviable. The foraging activities of *Apis cerana indica* Fabricius and *Tetragonula iridipennis* begin at 06:00 h and 06:30 h respectively and ceased by evening 17:00 h. *T. iridipennis* foragers spent more time in pollen collection (31.1 seconds/ flower) and nectar collection (26.14 seconds/ flower) whereas, *A. cerana indica* spent less time in pollen collection (8.62 seconds/ flowers) and nectar collection (3.56 seconds/ flower) respectively. A total of 17 pollinator species belongs to four orders *viz.,* Hymenoptera, Diptera, Lepidoptera and Coleoptera have been documented and grouped based on their mode of foraging in bitter gourd flowers.

Key words: Abundance, Bitter gourd, Foraging ecology, Pollination

ÖZ

Acı kabak çiçek karakterini, yerli tozlayıcıların yiyecek arama ekolojisini ve bunların tozlaşma biçimlerini incelemek amacıyla Coimbatore Bölgesi'nde acı kabak yetiştirme alanında bir çalışma yapılmıştır. Acı kabak, ayrı erkek ve dişi çiçekler taşıyan monoik bir bitkidir. Erkek çiçek, dişi çiçekten daha erken açmaktadır. Stigmanın polen kabulu pistillat çiçekler 4 günlükken stigmatik eksüdasyon sonucu çiçek stigmaları sarımsı-yeşil hal aldığında başlamaktadır. Stigma alıcılığı, antezden sonraki 24 saate kadar sürer. % 2'lik asetokarmin çözeltisi ile yapılan polen canlılığı testi, sabah saatlerinde (06:00 saat) toplanan polenlerin daha canlı ve derin boyanmış olduğunu, akşam saatlerinde (17:00

saat) toplanan polenlerin ise lekesiz kaldığını ve cansız olarak kabul edildiğini göstermiştir. *A. cerana indica* ve *T. iridipennis*'in yiyecek arama aktivitesi sırasıyla 06:00 ve 06:30'da başlar ve akşam 17:00'de sona erer. *T. iridipennis* toplayıcıları polen toplama (31,1 saniye/çiçek) ve nektar toplama (26,14 saniye/çiçek) için daha fazla zaman harcarken, *A. cerana indica* sırasıyla polen toplama (8,62 saniye/çiçek) ve nektar toplama (3,56 saniye/çiçek) için daha az zaman harcamıştır. Hymenoptera, Diptera, Lepidoptera ve Coleoptera olmak üzere dört takıma ait toplam 17 böcek türünün acı kabak çiçeklerini ziyaret ettiği belirlenmiş, bunların beslenme tarzları izlenmiştir.

Anahtar kelimeler: Bolluk, Acı kabak, Yayılma ekolojisi, Tozlaşma

GENİŞLETİLMİŞ ÖZET

Çalışmanın amacı: Çalışmanın amacı, Hindistan'daki acı kabak yetiştirme sistemindeki yerli tozlayıcıların çiçek karakterinin, yiyecek arama ekolojisinin ve tozlaşma biçimlerinin incelenmesidir.

Gereç ve yöntem: Bu çalışma acı kabak çiçek karakterini, polen canlılığını ve tozlayıcıların çeşitliliğini incelemek için Coimbatore, Telugupalayam bölgesinde yapılmıştır Acı kabak çiçeklerini ziyaret eden tozlayıcılar 15 gün arayla kaydedilmiştir. Parlayan stigmatik salgıya sahip sarımsı-yeşil stigma, alıcılığın bir işaretiydi. Dört günlük (toplam 10 çiçek/gün) çiçeğin stigmatik yüzeyi el merceği ile görsel olarak incelenmiş ve gözlemler kaydedilmiştir. Açmadan bir gün önce 10 çiçek toplanmış ve laboratuvar koşullarında oda sıcaklığında bir petri kabında saklanmıştır. Polen canlılığı, %2 asetokarmin solüsyonu kullanılarak değerlendirilmiştir. Asetokarmin yalnızca sağlıklı canlı polen tanelerini boyayabilir.

Arıların acı kabak çiçeklerinde nektar ve polen toplama faaliyetleri gözlemlenmiştir. Tozlayıcı arıların anter veya stigma ile vücut teması üst çalışma ve yan çalışma olarak nitelendirilmiştir. Acı kabak çiçeğini ziyaret eden her türün bireyleri ve yiyecek arama biçimleri aşağıdakilere göre kaydedilmiştir: Üst işçi/yan işçi, Nektar toplayıcı veya polen toplayıcı, Hem nektar hem de polen toplayıcı. Çiçek işleme süresi, bireysel arı tozlayıcıları tarafından ürünlerin, yani polen ve nektarın toplanması için hem erkek hem de dişi çiçekler üzerinde harcanan süre, çiçek/dakika bir sayaç kullanılarak kaydedilmiştir. En yüksek çiçeklenme döneminde rastgele seçilen günde dört gözlem yapıldmıştır.

Bulgular ve tartışma: Parlayan stigmatik salgıya sahip sarımsı-yeşil stigmalı dişi çiçekler, stigmanın polen kabul etmeye hazır olduğunu göstermektedir. Canlı ve cansız polenleri ayırt etmek için %2'lik asetokarmin solüsyonu ile yapılan polen canlılık testi gözlemlenmiş ve canlı polenlerin koyu boyandığı canız polenlerin ise ya hiç boyanmadığı ya da zayıf bir şekilde boyandığı gösterilmiştir. Toplayıcılık dönemi ve çiçek tutumuna ilişkin gözleme göre *A. cerana indica* ve *T. iridipennis* acı kabakta en fazla bulunan tozlayıcılar oldukları belirlenmiş olup *A. cerana indica* ve *T. iridipennis*'in yiyecek arama faaliyeti sabah 06.00 ve 06.30'unda başlamış ve akşam 17.00'de durmuştur. *T. iridipennis* işçi arıları polen toplamada (31,1 saniye/çiçek) nektar toplamadan (26,14 saniye/çiçek) daha fazla zaman harcamışlardır. Ancak *A. cerana indica*, polen toplama (8,62 saniye/çiçek) ve nektar toplama (3,56 saniye/çiçek) için *T. iridipennis*'ten daha az zaman harcamıştır. Coimbatore ilçesi, Telugupalyam köyünde yetiştirilen acı kabak bitkisinde toplam 17 böcek türünün bu bitkiyi ziyaret ettiği belirlenmiştir. Bu türler, Hymenoptera, Diptera, Lepidoptera ve Coleoptera takımlarına ait 10 familyadan oluşmaktadır.

INTRODUCTION

Pollinators play a vital role in regulating the pollination services by transferring pollen grains from anther to stigma, which warrants productivity (Delaplane, et al., 2000). In cucurbits, pollination is a major problem due to the monoecious flowering habit and huge variance in male and female flower ratio. These factors lead to insufficient pollination and poor fruit set, which permits an agent as pollinator for fruit sets.

Bitter gourd (*Momordica charantia* L.) is grown well in tropical and subtropical regions of India, China, Japan, Thailand, Brazil, Central, and South America *Momordica charantia* is often called Bitter melon, Ampalaya, Balsam pear and Karela (Walters and Decker-Walters, 1988; Shan *et al.*, 2012) belongs to Cucurbitaceae family, which comprises of 130 genera and 900 species (Jeffrey, 1980). Apart from *Momordica dioica* wild species, all are monoecious

(Shrivastava, 1990). Male flower (staminate) blooms first followed by female flowers (Pistillate) in the ratio of 19:1 (Deyto and Cervancia, 2009) or 25:1 (Palada and Chang, 2003). Staminate flowers were bright yellow, solitary, perfect, actinomorphic, anthers are bell-shaped and sweetly scented at the time of anthesis. Pistillate flowers were confessed by the presence of an ovary that resembles the small fruit, a stronger scent than a staminate flower. The bright yellow color flower fascinates the pollinators

Cucurbit flowers were widely visited by insect pollinators like bees, butterflies, wasps, flies, beetles and bugs. Bees are the most reliable and exploited pollinators in bitter gourd. Bee pollinators observed in the bitter gourd cropping system were *Apis cerana indica* Fabricius*, Tetragonula iridipennis* Smith*, Apis mellifera* Linnaeus*, Apis florea* Fabricius*,* and *Apis dorsata* Fabricius*.* The most abundant non-*apis* pollinators were *Halictus* sp., *Xylocopa violacea* Linnaeus*, Amegilla cingulate* Fabricius*, Episyrphus balteatus* De Geer*, Aulacophora* sp., and *Eristalinus tabanoides* Jaennicke observed (Yogapriya *et al.*, 2019). Present study was conducted to study the floral character of bitter gourd and to record the ecology and abundance of native pollinators in bitter gourd cropping system.

MATERIALS AND METHODS

Field research was conducted at Telugupalayam area of Coimbatore district, to study the bitter gourd floral character, pollen viability and diversity of pollinators

Floral character studies: The following floral characters were studied in both the field and laboratory condition (Fig. 1).

Stigma receptivity

Yellowish-green stigma with shining stigmatic exudation was a symbol of receptivity. The stigmatic surface of 4day aged flower, (totally 10 flowers/day) were visually inspected with a hand lens and observations recorded. Dull and dark brown colour stigma was considered as non-receptive.

Pollen viability-Preparation

Two percent acetocarmine solution was prepared by dissolving 2g of carmine powder in 95ml of Glacial acetic acid and volume make up to 100 ml by adding distilled water. The solution was boiled, cooled, and filtered. Two to three drops of stain were placed on the centre of the slide and pollen grains were dusted and covered with coverslip and kept for 5 to 10 minutes (Fig. 3) and observed under stereo zoom leica microscope. Deeply stained were viable pollen and inadequately stained or unstained were considered as non-viable pollen.

Foraging ecology of pollinators

The foraging activity of pollinators was observed in 10 randomly selected plants. In each selected plants three flowers were tagged and observations documented.

Initiation and cessation time of foraging

Initiation and cessation time of foraging activity of bee pollinators were recorded on selected flowers and the total working hours of pollinators were calculated for 10 days daily during the peak flowering period and mean was worked out.

Flower handling time

The time spent by individual bee pollinators/ flower/ minute on both male and female flowers for collection of rewards *viz.,* pollen and nectar were recorded by means of a stopwatch. Four observations were recorded at randomly selected day during the peak flowering period.

Foraging modes of pollinators and flower visitors

Foraging activity of bees and flower visitors on flowers for nectar and pollen gathering was observed. The body contact of the pollinators with anther or stigma was documented as a top worker and side worker.

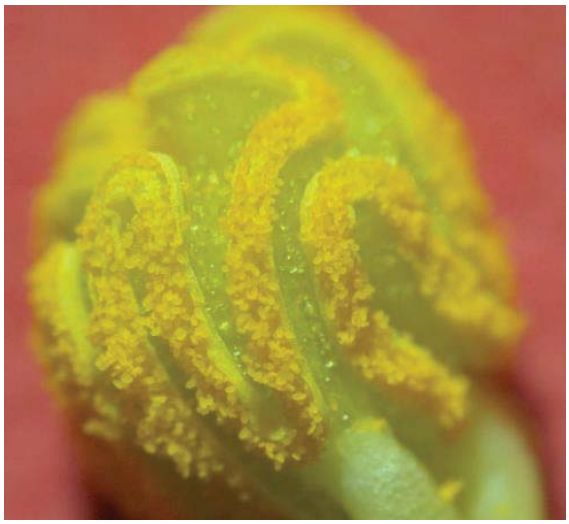
Top worker: Pollinators land on the anther of a flower and collect the pollen grains with the help of their foragial legs and body hairs.

Side worker: Pollinators stand on the petal with their meso and metathoracic legs and push their tongue towards nectarines to sip the nectar. Individuals of each species visiting bitter gourd flower and their modes of foraging were recorded based on:

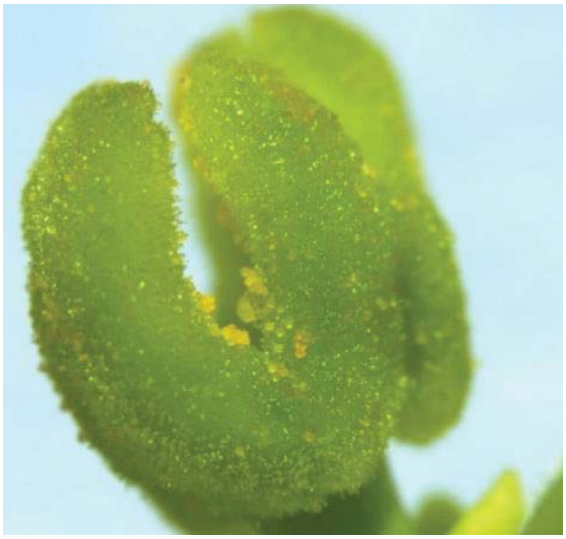
1. Top worker/side worker
2. Nectar collector or pollen gatherer
3. Both nectar and pollen gatherer.

1a. Male flower

2b. Female flower



1c. Anther



1d. Stigma

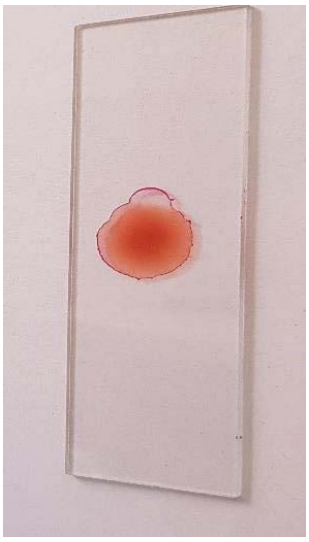
Figure 1. Floral character of bitter gourd

Receptive stigma - Yellowish-green Stigma with shining stigmatic exudation

Non receptive stigma- Dark brown colour stigma

Figure 2. Stigma receptivity Test

3a. Preparation of 2% acetocarmine



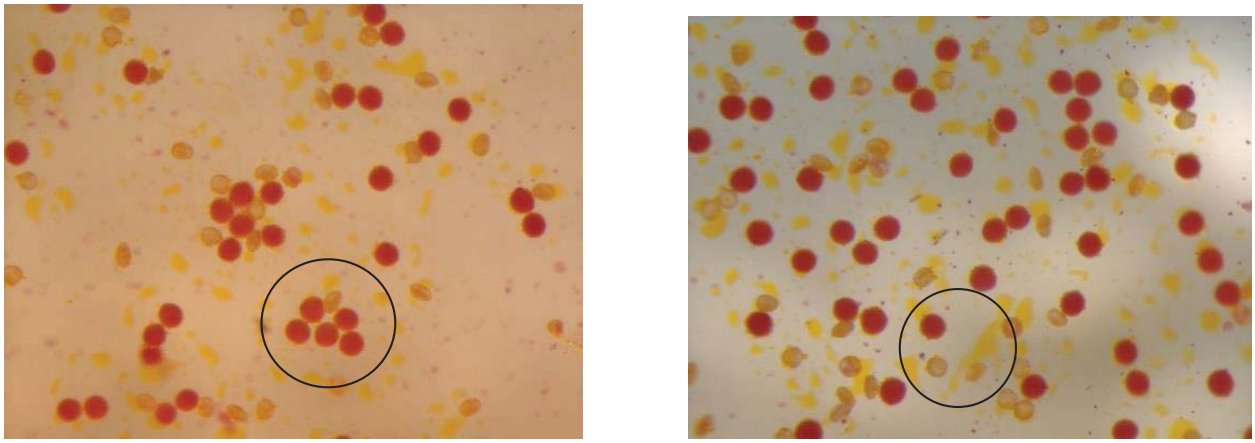
3b. Drops of stain on glass slide dusted with pollen grains

Figure 3. Preaparation of acetocarmine for pollen viability test

Table 1. Initiation, cessation period and flower handling time of *A. cerana indica* and *T. iridipennis* in bitter gourd flowers.

Species	Flower handling time*(sec)		Foraging time	
	Nectar	Pollen	Initiation	Cessation
A. cerana indica	3.56±1.05	8.62±1.47	0600 h	1700 h
T. iridipennis	26.14±4.5	31.1±2.70	0630 h	1700 h

Mean of 10 days observation, * time spent by a forager/ flower



Deeply stained – viable pollen

Unstained – non-viable pollen

Figure 4. Pollen viability Test

Table 2. Pollinators in bitter gourd crop and their foraging modes

Pollinators	**Family**	**Role**		**Foraging mode**
		Nectar	**Pollen**	
Hymenoptera				
Apis dorsata	Apidae	+	+	Top & Side worker
Apis cerana indica	Apidae	+	+	Top & Side worker
Apis florea	Apidae	+	+	Top & Side worker
Tetragonula iridipennis	Apidae	+	+	Top & Side worker
Amegilla cingulate	Apidae	+	+	Top & Side worker
Nomia melandari	Apidae	+	+	Top & Side worker
Halictus sp.	Halicitidae	+	+	Top & Side worker
Diptera				
Syrphus ribesii	Syrphidae	-	+	Top worker
Eristalinus tabanoides	Syrphidae	-	+	Top worker
Ischiodon scutellaris	Syrphidae	-	+	Top worker
Chrysomya sp.	Calliphoridae	-	+	Top worker
Lepidoptera				
Eurema hecabe	Nymphalidae	+	-	Side worker
Diaphania indica	Pyrallidae	+	-	Side worker
Pelopidas mathias	Hesperiidae	+	-	Side worker
Lampedes boeticus	Lycaenidae	+	-	Side worker
Coleoptera				
Aulacophora foveicollis	Chrysomelidae	+	-	Side worker
Henosepilachna vigintioctopunctata	Coccinellidae	+	-	Side worker

Apis cerana indica

Tetragonula iridipennis

Apis florea

Halictus sp

Figure 5. Foraging modes of bee pollinators, (Top workers)

Other flower visitors: Pollen gatherers

Amegilla cingulate (Side workers)

Nomia melandari

Apis cerana indica

Tetragonula iridipennis

Apis florea

Halictus sp

Eristalinus tabanoides

Ischiodon scutellaris

Chrysomya sp.

Aulacophora sp.

Henosepilachna vigintiopunctata

RESULTS

Study on bitter gourd floral character

a) Stigma receptivity

Female flowers exhibited that the yellowish-green stigma with shining stigmatic exudation facilitates the adhering of pollens as soon as the stigma becomes receptive which preceding for 24 h after anthesis (Fig.2).

b) Pollen viability

Pollen viability test conducted with 2% acetocarmine solution to distinguish the viable and non-viable pollen grains. The observation specified that viable pollen was deeply stained (Fig. 3), whereas non-viable pollen grains remained unstained or weakly stained. Pollen collected during morning hours 06:00 h were more viable than pollen collected in evening hours (17:00 h) (Fig. 4).

Foraging ecology of major pollinator in bitter gourd.

Initiation and cessation time of foraging activity

The observation on the foraging period and flower handling are given in (Table 1). *A. cerana indica* and *T. iridipennis* are the most abundant pollinators in bitter gourd. The foraging activity of *A. cerana indica* and *T. iridipennis* instigates at 06:00 h and 06:30 h of the day, and the foraging activity was totally stopped by evening 17:00 h.

The flower handling time of *A. cerana indica* and *T. iridipennis* depend on the type of floral rewards, they collect. Generally, bees spent more time in pollen collection than for nectar. The workers of *T. iridipennis* spent more time in pollen collection (31.1 seconds/ flower) than for nectar collection (26.14 seconds/ flower). But *A. cerana indica* spent less time than *T. iridipennis* for pollen collection (8.62 seconds/ flower) and nectar collection (3.56 seconds/ flower).

Foraging modes of pollinators and flower visitors

A total of 17 pollinator species have been recorded in bitter gourd crop raised in Telugupalyam village, Coimbatore district (Table 2). These pollinators encompassing 10 families belongs to four orders *viz.*, Hymenoptera, Diptera, Lepidoptera and Coleoptera. Based on their flower handling behaviour they were grouped as Side worker (nectar gatherer), Top worker (pollen gatherer) and Top side worker (both nectar and pollen gatherers) (Fig. 5).

Among these 17 pollinators *Apis dorsata, A. cerana indica, A. florea, Tetragonula iridipennis*. *Amegilla cingulate, Nomia melandari* and *Halictus* sp. were found collecting both nectar and pollen. whereas *Syrphus ribesii, Eristalinus tabanoides, Ischiodon scutellaris, Chrysomya* sp. were involved in pollen gathering alone and *Eurema hecabe, Diaphania indica, Pelopidas mathias* and *Lampedes boeticus, Aulacophora foveicollis* and *Henosepilachna vigintioctopunctata* were found gathering nectar from bitter gourd flowers.

DISCUSSION

Study on bitter gourd floral character - Stigma receptivity and pollen viability test in bitter gourd flower

The stigma receptivity was confirmed during morning hours with yellowish-green stigma and shining stigmatic exudation favours attachment of pollen grains. Delaplane *et al.* (2000) also described that the stigma receptivity of cucurbits observed during the time of anthesis (06:00 h to 14:00 h) of the day.

The pollen viability of bitter gourd was maximum in pollen collected during morning hours (06:00 h) than pollen collected in evening hours (17:00 h). Correspondingly, Nepi and Pacini (1993) recorded that pollen viability was higher in newly opened flower at 07:00h (92%) and very low (10%) during 12:00 h of the day.

Foraging ecology of *A. cerana indica* and *T. iridipennis* - Initiation and cessation time of foraging

The foraging activity of *A. cerana indica* and *T. iridipennis* in bitter gourd flowers started at 06:00 h and 06:30 h respectively and found declining from 12:30h and completely terminated by 17:00 h (Table 1). Peak activity of bees in morning hours might be due to the anthesis time of the bitter gourd flowers which commenced by 05:30h. The opened flower starts drying at 12:30 h and by evening anthers dried at 17:00 h and flowers partly curled and fell off. The findings are in accord with the results of Deyto and Cervancia (2009) who have reported that foraging activity of *A. cerana indica* and *T. iridipennis* starts at 0600h and 06:30 h respectively. In the same way, they recorded maximum foraging activity of *A. cerana indica* and *T. iridipennis* at 06:00 – 08:00 h and lasted upto 16:00 h in bitter gourd. Vijayan *et al.* (2018) and Lintu *et al.* (2020) also opined similar views that the foraging activity of *T. iridipennis* starts after anthesis of flowers by 07:50 h.

Bees spent more time in pollen collection than nectar foraging in bitter gourd. The nature and size of pollen grains of bitter gourd are suitable for insect foraging.

Foraging modes of pollinators and flower visitors

The bitter gourd flowers were recurrently visited by 17 pollinators during the study period and they were regarded as, based on their mode of foraging *viz.,* nectar gatherer, pollen gatherer and both pollen and nectar gatherers (Table 2). These results are in agreement with the discoveries of Yogapriya *et al.* (2019) who has reported 11 species of pollinators in bitter gourd. Among them *A. cerana indica, A. dorsata, A. florea, T. iridipennis, Amegilla zonata, Xylocopa violacea, Halictus* sp. were nectar and pollen foragers. *Syrphus ribesii, Danaius chrysippus, Tirumala limniace* and *Aulacophora* sp. were nectar foragers.

Similarly, Bisui and Layek (2020) listed 21 species of flower visitors in bitter gourd flower found to collect both flower rewards and they belongs to four orders *viz.,* Hymenopteran, Diptera, Lepidoptera and Coleoptera. Balina *et al.* (2012) also observed that the peak activity of pollen foragers starts from 08:00 to 10:00h, higher population of *Halictus* sp. (21 bees) at 08:00 – 10:00 h followed by *A. dorsata* (16 bees) at 06:00 – 08:00 h and *Megachile* sp. (14 bees) at 08:00 – 10:00 h. The activity of nectar foraging was maximum in *Halictus* sp. was (9 bees) at 10:00 – 12:00 h and minimum in *A. dorsata* and *Megachile* sp. was (8 bees) at 10:00 – 12:00 h.

Conclusion

Monoecious nature of bitter gourd crop results in discrepancy yield. To overcome the issue of lower yield in bitter gourd our present research exposed that among 17 pollinators identified in bitter gourd cropping system *A. cerana indica* and *T. iridipennis* were the most active pollinators in bitter gourd. Hence, this research will help beekeepers in managing controlled bee pollinators in the ecosystem of bitter gourds, increasing crop yield and honey production.

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Data availability: Data available on request from the authors.

Ethical issue: The research on honey bees have no ethical issues.

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