ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

DIVERSITY OF SUNFLOWER INSECT POLLINATORS AND THEIR FORAGING BEHAVIOR UNDER FIELD CONDITIONS

Saha Koşullarında Ayçiçeği Böcek Tozlaştırıcılarının Çeşitliliği ve Yayılma Davranışı

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ABSTRACT

To discover the pollinator community of sunflower (*Helianthus annuus* L.) and different aspects of behavior, activity and pollination effect of *Apis* and non *Apis* bees, an experiment was performed at the research farm of Arid Agriculture University, Rawalpindi, Pakistan. The insect pollinator community was composed of eighteen species belonging to seven families and three insect orders. *Apis mellifera* and *Xylocopa fenestrata* were the most frequent visitors comprising 44% and 14% with maximum activity observed during early day hours.Visitation frequency of these two pollinators significantly varied at early and late observation times with no significant differences observed during the mid-day. The study also covered other aspects including visitation rate and duration of a single visit on flower heads. These also contributed significantly in increase of head diameter, total number of seeds per head, filled seeds, seed filling percentage and seed weight when compared with self-pollination.Presence of wild pollinators with commercial bee keepers can help in increase of crop yields and their good seed potential due to improvement of crossing of gene pool.

Key Words: *Crop yield, Diversity, Foraging, Insect pollinators, Sunflower, Bees*

ÖZ

Bu çalışma Pakistan, Rawalpindi Arid Tarım Üniversitesinde araştırma çiftliğinde yapılmıştır.Çalışmada Ayçiçeği (*Helianthus annuus* L.) bitkisinde tozlaştırıcıların, Apis ve Apis cinsine bağlı olmayan arıların farklı davranış, faaliyet ve tozlaşma üzerine etkilerinin araştırılması ve keşfedilmesi amaçlanmıştır.Burada sözkonusu böcek topluluğu 18 tür olarak 7 aileye ve üç takıma aittir.*Apis mellifera* ve *Xylocopa fenestrate* günün erken saatlerinde %44 ve %14 azami faaliyet gösteren ve en sık görülen ziyaretçilerdir. Gün ortasında ziyaret sıklığı önemli olmazken bu iki türün erken ve geç saatlerde ziyaret sıklığı önemli derecede değişmektedir. Bu çalışma aynı zamanda ziyaret seviyesine ve bir çiçek tablasında geçen zamanıda kapsamaktadır. Tüm bu bulgular kendine tozlaşma ile karşılaştırıldığında tabla çapını, tabladaki toplam tohum sayısı, dolu tohumlar, tohumların dolgunluk yüzdesi ve tohum ağırlığının önemli derecede artmasına katkı sağlamıştır. Ticari olarak çalışan arıcıların arılarının yanı sıra yabanı tozlaştırıcıların varlığı verimin ve gen havuzunun çapraz tozlaşma ile karışması sonucu iyi tohum potansiyelinin artmasına yardımcı olabilir.

Anahtar Kelimeler: *Tarımsal üretim, Çeşitlilik, Yayılmacı,Böcek tozlaştırıcılar, Ayçiçeği, Arılar*

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

GENİŞLETİLMİŞ ÖZET

Amaç: Bu çalışma Pakistan, Rawalpindi Arid Tarım Üniversitesinde araştırma çiftliğinde yapılmıştır. Çalışmada Ayçiçeği (*Helianthus annuus* L.) bitkisinde tozlaştırıcıların, Apis ve Apis cinsine bağlı olmayan arıların farklı davranış, faaliyet ve tozlaşma üzerine etkilerinin araştırılması ve keşfedilmesi amaçlanmıştır.

Gereç ve Yöntem: Bu çalışmada ayçiçeğinin açık tozlaşan "Desi" varyetesi kullanılmıştır. Böcek tozlaştırıcıların kapan ile yakalanmış ve içinde potasyum siyanid bulunan kavanozlarda ölmeleri sağlanmış ve böcek müzesinde teşhisleri yapılmıştır. Haftada bir gün günde 3 defa saat 09.00, 13.00 ve 17.00 de her dakika için tesadüfi olarak seçilen 20 çiçekte ziyaretler kayıt edilmiştir. Tozlaştırıcıların yaygınlığı tesadüfi olarak seçilen 30 çiçek tablasında belirlenmiştir.Ziyaret sıklığı ise her dakika için her çiçekte 60 saniye içinde belirlenmiştir.Gözlemler saat 08:00, 10:00, 12:00, 14:00, 16:00 ve 18:00 de yapılmıştır.Çiçeklenme döneminde haftada bir ve tozlaştırıcı böcek çeşitliliği ise çiçek sıraları arasında 5 dakika yürüyerek farklı böceklerin belirlenip sayılması ile belirlenmiştir.Çiçek tablaları bez torbalar ile çiçekler açmadan kapatılıp her bir arı ziyaretinden sonra yeniden kapatılmıştır.Bu şekilde 30 çiçek bez torbalar ile kapatılırken 30 çiçek ise açık bırakılmıştır.Her torba farklı şekilde kodlanmıştır.

Bulgular: Burada sözkonusu böcek topluluğu olarak toplam 804 böcek tozlaştırıcı tespit edilmiş, 18 tür olarak 15 cins, 7 aileye ve üç takıma aittir. *Apis mellifera* ve *Xylocopa fenestrate* günün erken saatlerinde %44 ve %14 azami faaliyet gösteren ve en sık görülen ziyaretçilerdir.*A. mellifera* erken saatlerde 2-3 kez daha fazla ve yine digger zamanlarda *X. fenestrata*'dan önemli derecede daha fazla gözlenmiştir. *A. mellifera* 16:00-18:00 arasında dakikada her çiçek için 1.2 ve 0.88 ziyaret ile *X. fenestrate*'dan 0.38 ve 0.31 olarak daha fazla performans göstermiştir. (Figure 2). Tabla çapında veya genişliğinde sırası ile *A. mellifera* (17.67 cm), açık alanda tozlaşanlarda (16.70 cm) ve *Xylocopa* ile tozlaşma (15.10 cm) ve en az kendine tozlaşma ile elde edilmiştir (13.60 cm) (Tablo 2). Gün ortasında ziyaret sıklığı önemli olmazken bu iki türün erken ve geç saatlerde ziyaret sıklığı önemli derecede değişmektedir. Bu çalışma aynı zamanda ziyaret seviyesine ve bir çiçek tablasında geçen zamanıda kapsamaktadır. Tüm bu bulgular kendine tozlaşma ile karşılaştırıldığında arılar tozlaştırıcı olduğunda tabla çapını, tabladaki toplam tohum sayısı, dolu tohumlar, tohumların dolgunluk yüzdesi ve tohum ağırlığının önemli derecede artmasına katkı sağladığını göstermektedir.

Sonuç:*Apis mellifera* ile ayçiçeği bitkisinde toplam tohum miktarı, tohum doluluk yüzdesi ve tohum ağırlığı artmıştır. Apis cinsine ait olmayan arılar davranışsal etkileri ile dolaylı yoldan ürün veriminde mutemelen *A. mellifera*'nın etkinliğini artırmaktadır. Bu yüzden arıların ekilen kültür bitkilerinin yakınında artırılmasının, arıların korunması ve böcek öldürücülerden sakınılması ile ayçiçeği bitkisinde doğal olarak bulunan böcek tozlaştıcıları ile yükseltilmesi tavsiye edilmektedir. Ticari olarak çalışan arıcıların arılarının yanı sıra yabanı tozlaştırıcıların varlığı verimin ve gen havuzunun çapraz tozlaşma ile karışması sonucu iyi tohum potansiyelinin artmasına yardımcı olabilir.

INTRODUCTION

Pollination, a transfer of pollen grains, is very important for qualitative and quantitative fruit and seed production especially in cross pollinated plants like sunflower. Sources that help in cross pollination involve wind, insects and other animals. Insect pollination plays vital role in determining mating opportunities in plants and improves seed set percentage and quality of the produce like oil contents (Free, 1993). Seventy five per cent of the world agricultural crops depends on insect pollination for fruit set and seed development (Klein et al., 2007; Morse and Calderone, 2000). Share of pollinators to world food volume is 24-35% playing very importantly for supplying essential nutrients for the human subsistence (Gallai et al*.,* 2008; Klein et al., 2007).

Insects are the most efficient and important pollinators among other pollinating factors with almost 80-85% share in plant pollination services (Johannsmeier and Mostert, 2001; McGregor, 1976). Solitary bees, honeybees and bumblebees with certain morphological and behavioral characters like hairy bodies

and need of nectar and pollens to develop their progeny forcing them for flower foraging (Free, 1993; Maalik et al., 2013). Managed honeybee (*Apis mellifera* L.)pollination contribution in increasing crop yield and quality is estimated to be more compared to honey and wax production (Shrestha, 2004). Honeybees alone are responsible for 70-80% of all insect pollination (Johannsmeier and Mostert, 2001). In the United States, yield increased due to honeybee pollination varied from US $9.3 billion in 1989 to US $15.12 billion in 2009 with three fourth contribution of honeybees and one fourth with other native bees (Morse and Calderone, 2000; Calderone, 2012).

Sunflower (*Helianthus annuus* L.) is highly cross-pollinated and short duration crop grown twice a year in almost all parts of Pakistan (Shah et al., 2005). It is one of the important cultivated oil crops in the world after soybean, rapeseed and peanut with India the largest sunflower growing country in Asia (Anonymous, 2018; Gupta, 2011). After its introduction in Pakistan during early 1960s, it helped to bridge the gap between consumption and production of edible oils in the country (Burney et al., 1990). Now, it ranks second after cotton seed with 40-50% oil contents which can be used directly for cooking and contains up to 80% fatty acids (Khalil and Jan, 2002). In spite of great interest of government to enhance its productivity, its yield is still three times less here than other sunflower producing countries. Reasons for its low yield are less soil fertility, adverse climatic conditions, water stress, attack of pests and diseases (Mirza and Beg, 1983). One of the major factor that has still not given due importance that contributes in low yield is insufficient pollination (Free, 1999). Being highly open pollinated crop, it benefits from many pollinating agents for the transfer of pollens from one plant to another. As pollens of sunflower are sticky and heavy, therefore, wind cannot carry them and it is greatly dependent on insects for successful pollination (Yadav et al., 2002).

Sunflower gets benefit in terms of pollination from insects, visit flowers for nectar and pollens. Honeybees as a pollinator increased 30% seed yield and more than 6% of oil contents in hybrid sunflower (Furgalaet al., 1979; Jyoti and Brewer, 1999). In various parts of the world, honey bees are considered as the most important pollinators of the sunflower (Henning et al., 1992; Gordon et al., 1995; Hoffman and Buchmann, 1995; Nye and Mackensen, 1968; Olmstead and Wooten, 1987; Tanda, 1984). For instance in Viamao (Brazil), among all insect pollinators of sunflower, contribution of *A. mellifera* was found 96% (Hoffmann, 1994). Besides honeybees, non-*Apis* bees are also important visitors of this crop however, considered as ineffective and untrustworthy pollinators because of their low activity (Radford et al., 1979). These bees play vital but indirect role in pollination of sunflower by influencing and promoting *A. mellifera* due to some behavioral interactions like inter-specific competition environment for pollen and nectar (Greenleaf and Kremen, 2006; Hoffmann and Watkins, 2000). Presently no systematic information regarding pollinators of sunflower is available from this region and present study was, therefore, conducted to explore the insect diversity of local floral visitors of sunflower, best insect pollinator species for increasing crop yield and comparing the foraging activities of the different insect pollinators.

In order to evaluate the effect of different insect pollinator species and foraging behavior on yield of sunflower, following experiment was carried out.

MATERIALS AND METHODS

This study was performed at the University Research Farm, Chakwal Road located at latitude 233°06'N and 73°00'E at an elevation 1702ft under arid conditions. Wheat fields surrounded the experimental area to East and

West and honeybee colonies were present at North of experimental plot while land was barren Southwards. Open pollinated sunflower variety 'Desi' was cultivated on 9th February, 2012 on an area of 2.5 acres with drill in rows. Germination was completed within fourteen days after sowing. Row to row distance of 45cm and plant to plant distance at 30cm was maintained. Studied area comes under the Pothwar plateau (Latitude 32°10' to 34°9' N and Longitude 71°10' to 73°55' E) where agriculture depends solely on rainfall. The climate is semiarid and clay loam soil where rainfall mostly does not coincide with crop growth stages (Nizami et al., 2004).

Collection, identification and foraging behavior of insect pollinators

On onset of about 30% flowering (from May 12 to June 16, 2012), insect pollinators were collected with hand net and were killed in insect killing jar (having potassium cyanide). Pinning of those insect pollinators was done and brought to the Biosystematics Laboratory, Department of Entomology, Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi for their identification up to genus and species level. Voucher specimens were deposited at the Biosystematics Museum. Foraging behavior of different pollinators was recorded by observing visitation rate (number of the flower visited by different insect pollinators per minute) and stay time on twenty randomly selected flower heads by using stop watch. Time was counted when insect landed on flower excluding the time, it circled on flower. Data of foraging behavior was recorded three times (0900, 1300 and 1700 hours) in a day on weekly basis throughout the flowering season. Pollinator's abundance was determined during the flowering season on thirty randomly selected flower heads. Visitation frequency (no. of visits per flower per minute) of different insect pollinators was observed for 60 seconds on each flower with the help of stop watch. Observations were made at 0800, 1000, 1200, 1400, 1600 and 1800 hours on weekly basis during the flowering season. Diversity of insect pollinators was determined by counting various insects while walking in rows for five minutes.

Open, self and pollinator specific pollination for yield comparison

In order to check effectiveness in terms of seed setting by single visit of different insect pollinators, hundred flower heads were selected at random. Muslin cloth bags of one square feet were used to cover flower heads before flower opening and after a single visit made by a particular pollinator species (honey bee and carpenter bee) flower heads were covered again. Cloth bags were marked with different codes for easily discrimination of flower heads pollinated by various pollinating agents. Thirty flower heads were left covered with cloth bags for whole flowering period for yield assessment by self-pollination whereas thirty open pollinated flower heads visited by different insect pollinators were taken at maturity. Sunflower heads on which different pollination methods were applied were harvested with sickle and sun-dried after maturity. From flower heads, seeds were hand threshed. Hundred seeds from each pollination technique were picked at random and the weight was recorded in grams by using electrical balance. Head diameter of flower heads with different pollination methods was measured from one edge of the disc to the other in centimeters (cm). Thirty flower heads of each pollinating technique were threshed separately and numbers of filled and unfilled seeds were counted by visual observations. Seed filling percentage was determined by taking ratio of filled seeds to the total number of seeds (filled + unfilled) per head multiplied by hundred. 100 seed weight of each pollination technique was recorded.

Data analysis

The data of visitation rate, stay time, number of seed per head were subjected to statistical analysis using analysis of variance (ANOVA).

Means were compared by using Tukey's test at P = 0.05 in SPSS package.

RESULTS

Relative abundance of insect pollinators

A total of 804 insect pollinators belonging to three insect orders (Hymenoptera, Lepidoptera, Hemiptera) in 15 genera with 18 species were recorded from sunflower throughout the flowering period (Table 1). *A. mellifera* was the most abundant and dominant species with 44 % of all insect pollinators followed by *X. fenestrata* comprising 14 %.

Visitation pattern and frequency of *Apis mellifera* and *Xylocopa fenestrata*

Visitation pattern revealed significantly maximum visitation during early hours than later hours of the day (Figure 1). *A. mellifera* were 2-3 times more than *X. fenestrata* at early hours but remained significantly different at other observation times. Similarly, significant differences in visitation frequency (number of visits per flower per minute) of *A. mellifera* and *X. fenestrata* were observed throughout the flowering period on sunflower (Figure 2). Maximum activity of both was observed during 0800 hours with an average of 2.98 and 1.58 visits, respectively. During 1000 hours significant variations were resulted with 1.36 and 0.84 visits per minute and then 1200 and 1400 hours showed non-significant differences. *A. mellifera* showed better performance with 1.2 and 0.88 visits compared to *X. fenestrata* with 0.38 and 0.31 visits per flower per minute at 1600 and 1800 hours, respectively (Figure 2).

Table 1. Relative abundance of insect pollinators belonging to different insect orders on sunflower

Order	Insects species	Number counted	% age
Hymenoptera	*Apis mellifera*	353	43.90
	A. florea	14	1.74
	A. dorsata	33	4.10
	Xylocopa fenestrata	113	14.05
	X. aestuans	39	4.85
	Vespa orientalis	27	3.35
	Delta esuriens	8	0.99
	Polistes wattii	14	1.74
	Ropalidia brevita	8	0.99
	Amegilla cingulata	16	1.99
	Coelioxys sp.	18	2.23
	Megachile sp.	14	1.74
Lepidoptera	*Vanessa cardui*	13	1.61
	Colias croceus	32	3.98
	Danaus chrysippus	22	2.73
	Colitis etrida	5	0.62
	Belenois mesentina	54	6.71
Hemiptera	*Agonoscelis puberula*	21	2.61
	Total	804	100

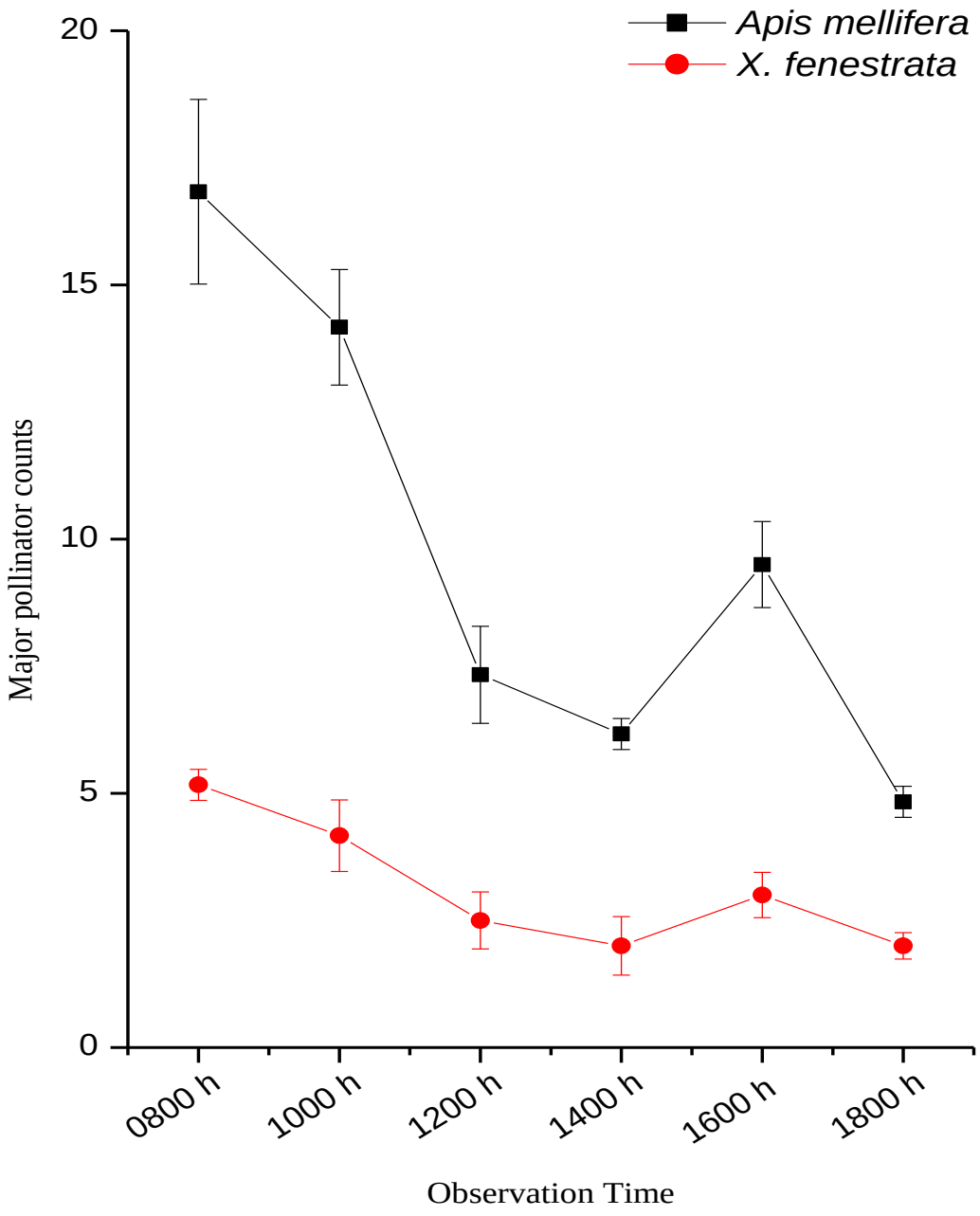

Figure 1. Visitation pattern of major insect pollinators on sunflower

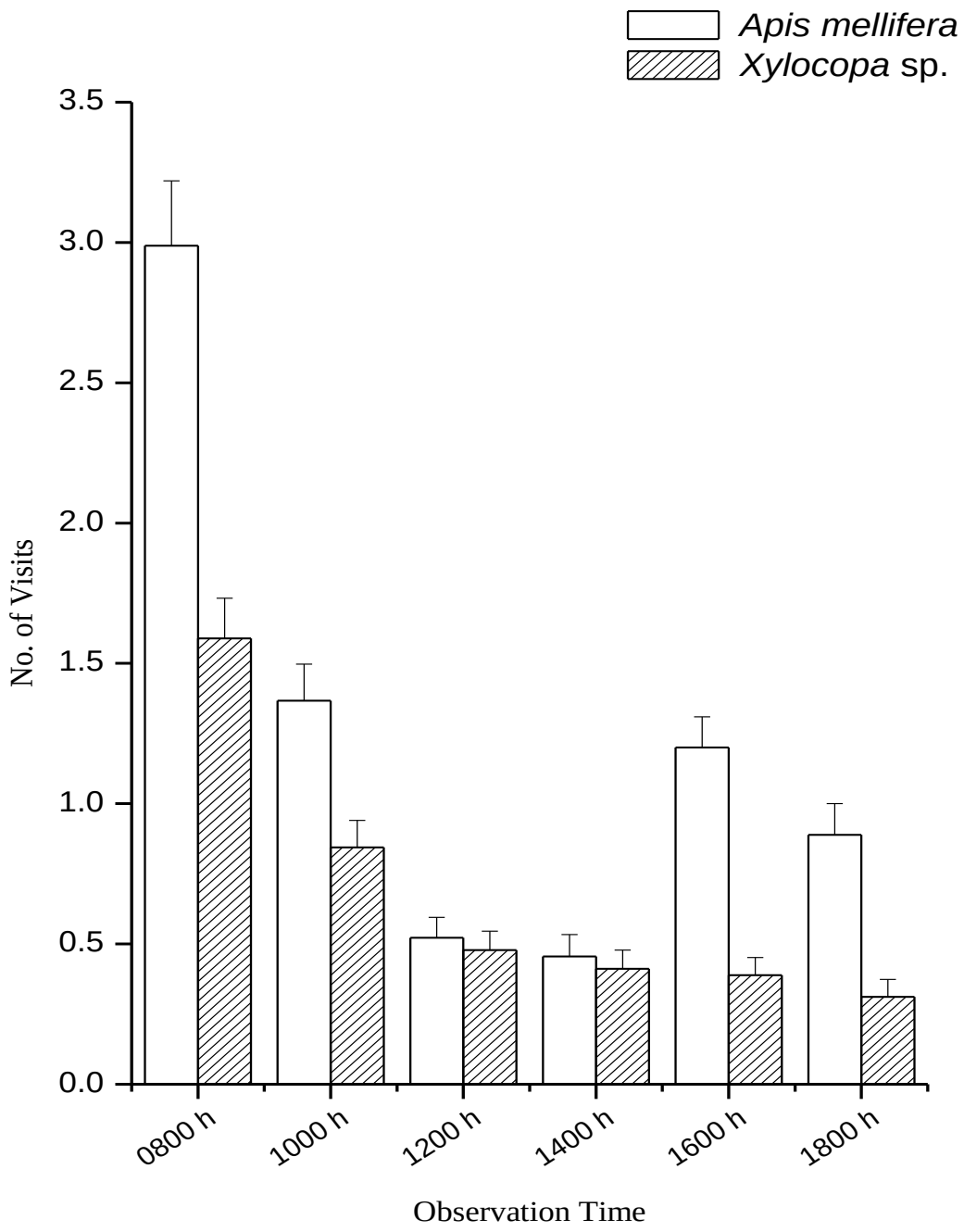

Figure 2. Visitation frequency (Mean ± SE) of *Apis mellifera* and *Xylocopa* sp. from May 12 to June 16, 2012on flowering of sunflower

Visitation rate of *Apis mellifera* and *Xylocopa fenestrata*

Visitation rate (number of flowers visited per minute) of *A. mellifera* and *X. fenestrata* showed significant variation in visitation rate during all observation times. During 0900 hour, *A. mellifera* visited more (3.53) flowers compared to *Xylocopa* spp. (1.85) with similar trends during 1300 and 1700 hours. *A. mellifera* showed reliable activity (2.11, 2.45) compared to *X. fenestrata* with 1.53, 1.78 flowers visited per minute, respectively (Figure 3).

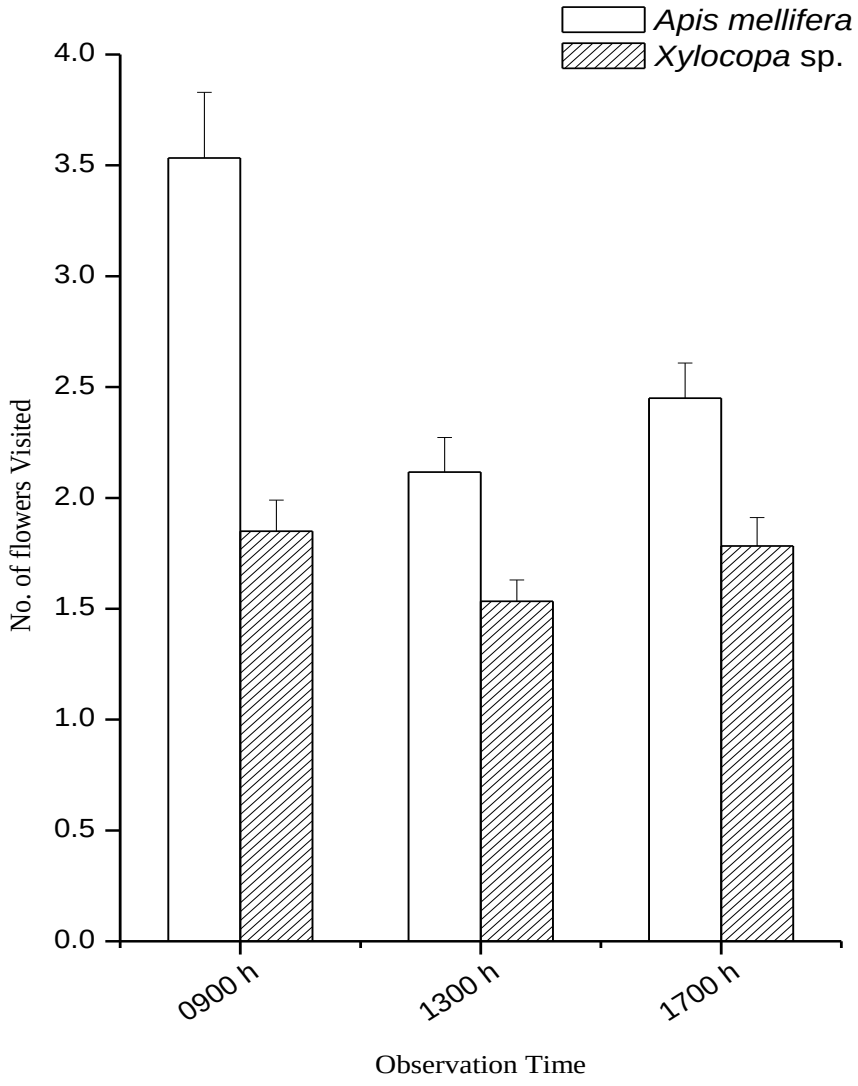

Figure 3. Visitation rate (Mean ± SE) of *Apis mellifera* and *Xylocopa* sp. from May 12 to June 16, 2012 on flowering of sunflower

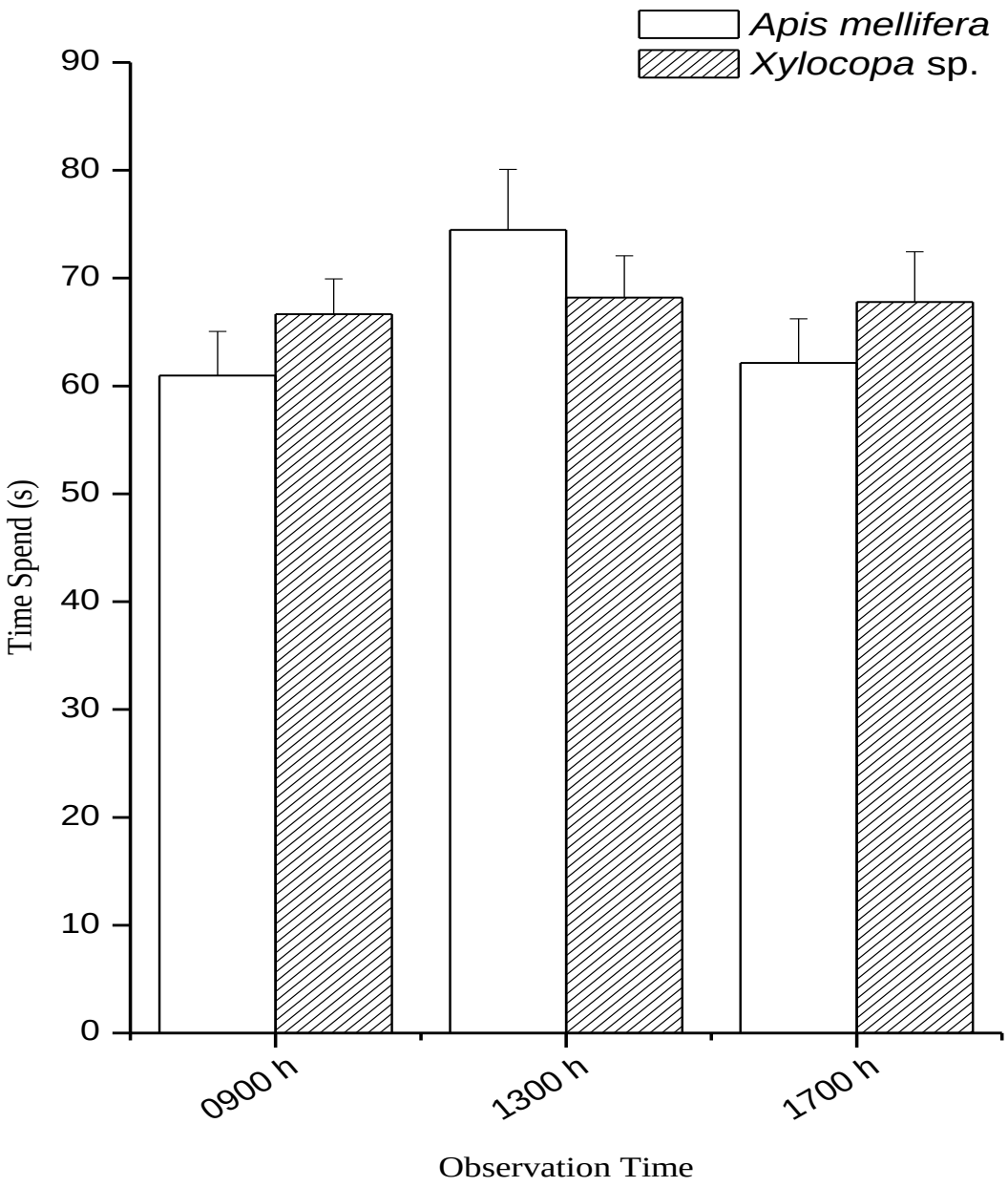

Figure 4. Time spent (Mean ± SE) of *Apis mellifera* and *Xylocopa* sp. from May 12 to June 16, 2012 on flowering of sunflower

Time spent by *Apis mellifera* and *Xylocopa fenestrata*

A. mellifera spent 60.97, 74.46, 62.12 seconds per flower during 0900, 1300 and 1700 hours compared to *X. fenestrata* (66.65, 68.19, 67.79 seconds) with significant variation in their stay time at all the times observed (Figure 4).

Head diameter, seed filling percentage and 100 seed weight

Significant differences existed in head diameter visited by *A. mellifera* (17.67 cm) and open pollination (16.70 cm) followed by *Xylocopa* pollination (15.10 cm) with minimum in self-pollination (13.60 cm) (Table 2). Similarly, total number of seeds produced was non-significant between *A. mellifera* (1162) and open pollination (1093). Minimum numbers of seeds resulted from *Xylocopa* pollination (916) which was non-significant with self-pollination (894). Maximum filled seeds were obtained from *A. mellifera* pollinated heads (1029) were followed by open pollination (962) and *Xylocopa* pollination (582) while minimum were recorded from self-pollination (297) and reverse was the case for unfilled seeds. The highest seed filling percentage was with honey bee pollination (88%) followed by open pollination and *Xylocopa* pollination (65%) whereas it was lowest in self-pollination treatment (33%). Maximum 100 seed weight was obtained from open pollinated heads (5.04g) followed by honey bee pollination (4.63g). However, significant differences existed in seed weight of *Xylocopa* (4.20g) and self-pollinated heads (3.30g).

DISCUSSION

Among the diverse flower visitors of sunflower at the research area, Insect pollinators comprise honeybees especially the commercial *A. mellifera* species was abundant and the most frequent pollinator of sunflower. It has been known to participate in its pollination with major share in flowers visitation and crop yield (Hoffman, 1994; Moretti et al., 1993). Nderitu et al. (2008) reported 14 species visiting sunflower with maximum contribution of *A. mellifera* (Hymenoptera) followed by the Lepidopteron species. Radford et al. (1979) found non-*Apis* bees as inefficient pollinators but their presence enhanced honeybee pollination efficiency. Hymenopterans crop pollinating insects are the most abundant with different *Xylocopa* species varying different in different locations. These carpenter bees are the most easily observable species due to their buzzing nature and large size with shinning bright colors. Previously pollinators from four insect orders including Hymenoptera, Lepidoptera, Diptera and Coleoptera has been reported whereas presently first three orders were observed (Nderitu et al., (2008). This variation might be due to spatial variation and most generally the coleopteran visitors are very small in size and often neglected by the observers. Maximum insect pollinators of sunflower have been from Hymenoptera, Lepidoptera and Diptera with sixty percent hymenopterans out of twenty visiting species (Arya et al., 1994; Satyanarayana and Seetharam, 1982; Vaish et al., 1978).

The number of *A. mellifera* and *X. fenestrata* visiting sunflower peaked during 0800 hours. Present and previous studies strongly showed relationship in *A. mellifera* activity at early and late hours of the day. This might be due to their activeness with temperature (Kumar et al.,1994; Morgado et al., 2002; Santana et al., 2002). They also observed the reduced foraging after 1000 hours of the day which regained in later day hours. However, the variation in bee density might be due to variation in different climatic environments in different parts of the worlds (Parker, 1981; Satyanarayana and Seetharam, 1982). Foraging behavior of honey bees varied during different times of the day as observed by du Toit (1988) that activity start at early morning and peak observed between 9:00-10:00 hours. Present results are also in confirmation with Nderitu et al. (2008) who reported peak activity of *Apis* and non-*Apis* bees between 1000 to

1400 hours. However, variation in foraging numbers at variable time of the day were also observed suggesting presence of nectar and pollen in flower heads and unfavorable high temperature (Free, 1964; Paiva et al., 2003; Schinohara et al., 1987) with variation in the most frequent visitors for pollination including *X. fenestrate, X. olivacea* and *Ceratinia laevifrons* and *Phaseolus vulgaris* (Kingha et al., 2012; Moalif and Al-Azzawi, 1989).

Present study showed that *A. mellifera* visited more number of flowers per minute compared to*X. fenestrate.* High visitation rate of both species has previously been observed and variation might be due to food availability, nectar content, temperature and relative humidity as well as rainfall (Sing et al., 1999). However, relative higher visitation rate (10.45 and 9.42 flowers per minute) of carpenter bee was observed by Kingha et al. (2012). This might be due to competition of various insects looking for same resources and the ability to carry the nectar and pollen load capacity.Higher visitation rate in bean flower compared to sunflower might be due to less available food resources in bean flower requiring more visitation than on sunflower heads (Tchuenguem et al., 2007).

Variable time spent by *A. mellifera* has been previously observed (Landrige and Goodman, 1974). Another indigenous honeybee species, *A. cerana* spent 52.98 seconds /sunflower head (Sing et al., 1999) and an important pollinator of brassica rapeseed (*Brassica campestris* L. var. toria) (Murell and Nash, 1981). Variation may be due to amount of nectar present in flower heads. Presently *X. fenestrata* spent 66.65 to 68.19 seconds on flower head during single visit lies in range of 1-5 minute observed by Glaiim et al. (2008). Flower size also has impact on visitation stay time suggesting food availability and flower size and orientation (Kingha et al., 2012).

This study showed that bee pollination has positive influence on head diameter, total number of seeds, seed filling percentage and 100 seed weight of sunflower confirm findings of previous studies indicating maximum number of seeds per head, seed weight, seed setting and filling %age and oil contents of sunflower from open and honeybee pollination compared to insect restricted sunflower heads (Calmasur and Ozbek, 1999; Hoffman and Wittman, 1987; Meynie and Bernard, 1997). Moreti et al. (1996) found higher number of seeds per head, seed weight and seed setting percentage (579.3, 41.2g and 82.4%) during first and (457.0, 23.4 g, 79.7%) second trial from sunflower heads having access of insect visitors than caged plants (81.5, 2.2 g ,1.2% and 111.9, 3.2 g, 28.5%) where insects were denied. Likewise, Kumar and Singh (2003) noticed maximum filled seeds per capitulum (728), seed filling percentage (75.5%) and 1000 seed weight (55.9 g) from hand plus insect pollinated heads compared to open and self-pollination.

CONCLUSION

Sunflower capitulum in bloom is highly attractive to various insect species especially those belonging to Hymenoptera and Lepidoptera. It is also evident that flower visitation by *A. mellifera* increased sunflower yield (total number of seeds, seed filling percentage, seed weight). Behavioral interaction of non-*Apis* bees has indirect effect on crop yield, possibly through improving efficiency of *A. mellifera*. Hence, conservation of bee species by encouraging increased forage crops in the vicinity of cropped areas and avoidance of insecticide application during flower head stage of sunflower to achieve the pollination services of naturally existed insect pollinators for higher crop yield is recommended.

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