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Original Research Article

Evaluation of diversity and abundance of pollinating insects on oilseed rape in major planting area of China

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Oilseed rape is the second largest oil crop that sustains the human consumption of edible oil. Insect available on this plant could be an indicator that reflects the diversity and abundance in an area. We compared the differences of the diversity and abundance of pollinating insects between mountains, which retain the similar landscape as four decades ago, and plains in eight major planting regions of oilseed rape in China. The diversity index in mountains was 2.7492±0.25, which was significantly higher than 1.8325±0.27 in plains (P<0.05). The dominant concentration index in mountains was 0.1359±0.06, which was significantly lower than 0.3176±0.09 in plains (P<0.05), and the evenness in mountains was 0.8390±0.07, which was significantly higher than 0.6623±0.10 (P<0.05). These observations suggest that insect species were more abundant in mountain than those in plain region, of which hymenopteran and hoverflies were the dominant pollinators of oilseed rape. The decline of diversity and abundance of pollinators in plain areas might be due to the consequences of the large-scale monoculture model, machinery farming and extensive usage of pesticides.

Key words: Oilseed rape, diversity, abundance, pollinators

INTRODUCTION

Oilseed rape, an annual or biennial plant species of Cruciferae is one of the four important seed crops (soybean, rapeseed, peanut and sunflower) in China, and is widely distributed in eastern, central, southern, southwestern, northwestern and northeastern across China (Wu and Han, 2008). The annual yield of oilseed rape accounts for 18.9% of the total seed oil production in the world and approximately 50% in China (Yin et al., 2009), and it is the second largest oil seed crop that plays a vital role to sustain the human consumption of edible oil (Ye, 2011). Oilseed rape is a typical entomophilous plant which has three different varieties, e.g. *Brassica campestris*, *Brassica napus* and *Brassica juncea*. Although *B. napus* is considered to be a self-pollinating crop, it has been documented that the insect pollination could also increase its production (Hater and Cresswell, 2006; Morandin and Winston, 2005).

The yield of oilseed rape is tightly associated with the sort and amount of pollinators (Guan, 2001).The insect pollination could enhance seed yield and quality in oilseed rape (Bommarco et al., 2012). As early as 1981, bumble bees and honeybees were the main visitors of rapeseed (Eisikowitch, 1981). It is reported that the yield and quality of rapeseed increased significantly by pollination by honeybees and other insects of *B. campestris* var. *sarson.* It is therefore insect pollination is the most economic and efficient way to increase the yield of rapeseed (Tara and Sharma, 2010; Sushi et al., 2013). Several field investigations have reported that honeybee pollination on rape seed significantly elevates the pod set and productivity, which hymenopteran insects account for 92.3% of all the visiting insects, and 99.8% of which are *Apis mellifera* (Annelise et al., 2011; Shakeel and Inayatullah, 2013)

Although, rape seed production is around 50% of all seed oil production in China, few studies report the importance of honeybee pollination in rapeseed in the yield enhancement and quality(Shi et al., 2009; Sun et al., 2014). Only one report on the abundance of visiting insects of rapeseed is available but confined in one province (Bu et al., 2012).

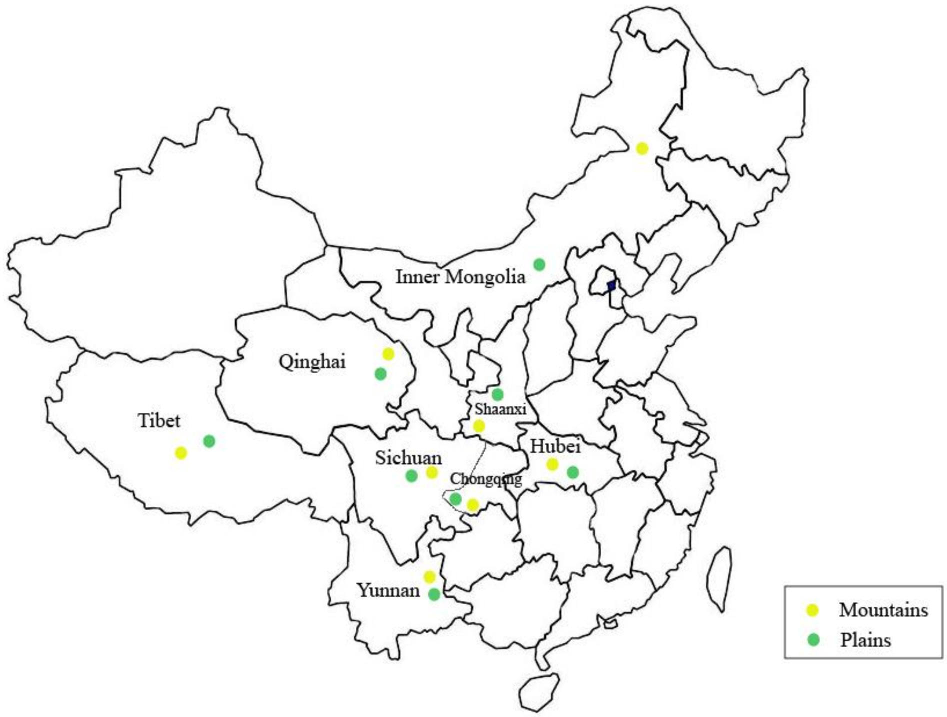

Figure 1: Map and schematic sample points of rape flower-visiting insects

Despite the importance for human edible oil consumption and diversity of eco-type in China, information regarding to the abundance and diversity of pollinating insects on rape seeds has not been reported yet. Diversity and abundance of wild insect pollinators play crucial roles in crop pollination, particularly for insect-pollinated crops. High levels of biodiversity are vital for enhancement of ecosystem function via interspecific facilitation (Cardinale et al., 2002).Conservation of pollinators' diversity is crucial to food production and the diversity of wild plants (Meffe, 1998; Batomeus et al., 2013). The large-scale agriculture is reported to reduce the diversity and abundance of wild insect pollinators in many agricultural landscapes (Tilman, 1999; Reen et al., 2005). To fill the knowledge gap of the abundance and diversity of pollinating insects during last four decades, we choose mountainous (landscape is almost similar to four decades ago) and plain areas in eight major planting areas to unravel the influence of agricultural landscape change on the diversity of pollinating insects on oilseed rape. This may be potentially helpful for conserving the dominant pollinators of oilseed rape, and also give the data resources for wild pollinators of oilseed rape of China.

MATERIALS AND METHODS

Sampling area

The survey was conducted on eight pairs of mountainous and plain areas selected in eight provinces of China, representing different eco-types. The geographical location was labeled on the map of China (Figure 1) and the geographical information is shown in Table 1.

The flower-visiting insects on oilseed rape were sampled by sweep-net to collect foraging insects as previously described (Jokimäki et al., 1998) during sunny and windless days in 2012-2013. At each site, insects were sampled from 7 am to 18 pm for two days. Collections started on the edge of the field to 50m transect until 50 sweeps directed towards insects that could be observed on flowers. Each sweep net sampling lasted approximately 60 s. The collected samples were counted, and pinned for later species identification.

Estimation of diversity (Shannon-Weaver index, H), dominance concentration (Simpson Index, C) and evenness (Equitability index, J) of insect species in each site was done by equations described previously.

(1) Simpson dominant concentration index:

$C=\Sigma\ (Ni/N)^2$, Ni indicates the individual number of each species, N is the total number of individuals(Simpson, 1949).

(2)Shannon-Wiener diversity index:

$H'=-\Sigma pilnpi(i=1,2\ldots.)$, Pi is the ratio of the number of individuals of i species to the total number of individuals in the sample(Krebs, 1989).

(3) Evenness (J):

$J=H'/\ H'max=H'/\ln\ S$, S is the total number of species (Pielou, 1975; Heip, 2009).

Data Analysis

All data were subjected to statistical analysis to compare the

Table 1. Eight sampling provinces and their natural conditions across China

Province	Sampling site	Farmland[1)]	Sampling date	A/W[2)]
Chongqing	Nanchuan (107°18′′E, 29°0′N)	M	2013.2.26-28	1.1029
	Rongchang (105°33′′E, 29°23′N)	P	2013.3.20-22	
Yunnan	Shizong (104°15'E, 24°47'N)	M	2013.2.23	0.2567
	Luoping (104°21'E, 24°55'N)	P	2013.2.24	
Sichuan	Shifang (104°01'E, 31°17'N)	M	2013.3.4	0.1760
	Shifang (104°08'E, 31°04'N)	P	2013.3.5	
Hubei	Yidu (111°24'E, 30°18'N)	M	2013.3.20	0.7637
	Gongan (112°15'E, 30°02'N)	P	2013.3.18	
Shaanxi	Hanzhong(106°51'E, 33°22'N)	M	2012.4.6	0.6040
	Tongchuan(108°34'E, 34°50'N)	P	2012.4.24	
Tibet	Duilongdeqing (88.82°E, 29.32°N)	M	2013.6.21	0.0047
	Dagzê(91°22'E, 29°39'N)	P	2013.6.22	
Qinghai	Menyuan (101°29'E, 37°31'N)	M	2012.7.10	0.0126
	Datong (101°43'E, 36°45'N)	P	2012.7.11	
Inner Mongolia	HulunBuir (120°14'E, 49°15'N)	M	2013.7.19	0.0760
	Wuchuan(111°45'E, 41°10'N)	P	2013.7.21	

Note: [1)] M=mountains, P=plains; [2)] A/W=Ratio of arable land to woodlot

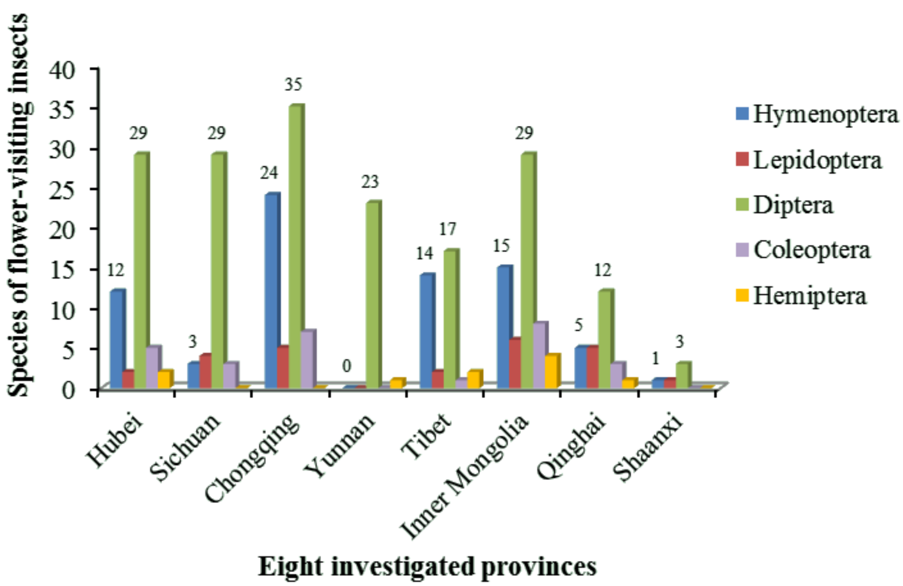

Figure 2: Distribution of rape flower-visiting insects in different provinces

abundance and diversity of pollinating insects in different provinces and geographic locations. Analysis of variance was also done to compare the means of insect diversity between the mountainous and plain areas.

RESULTS

Distribution of flower-visiting insects of oilseed rape in different provinces

As shown in Figure 2. dipteran and hymenopteran insects were the major pollinators found in 8 sampling sites. There were 24 hymenopteran and 35 dipteran species identified in Chongqing, the region found the most diverse insect species. However, there were only 5 species found in Shaanxi province, and 23 species found in Yunnan province where hymenopteran or lepidopteran insects were not observed.

On the basis of 8 sampling sites, they can be assigned to 5 geographic regions as shown in Figure 3. In all, 41 hymenopteran and 74 dipteran of insect species were found in southwestern China, the highest insect species among the 5 regions. The second most species abundant region was northwest, followed by central region. The lower insect abundant regions were northern and northeastern China. The hymenopteran and dipteran accounted for more than 50% of all visiting insects, representing the most abundant

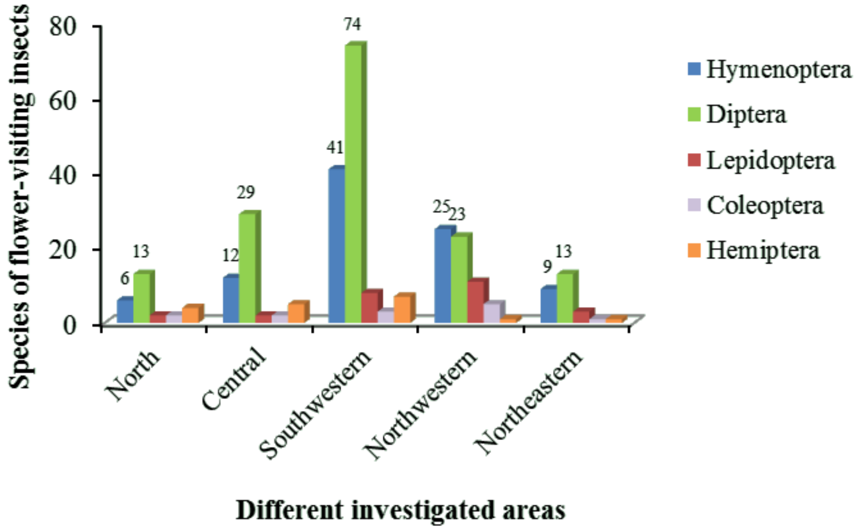

Figure 3: Distribution of rape flower-visiting insects in different geographical regions

Table 2. Analysis of diversity of insect community of different investigating points

Investigating areas	Indexes of insect community				
	Species number (S)	Individual number (N)	Dominant concentration index1) (C)	Diversity index2) (H')	Evenness3) (J)
Menyuan county, Qinghai (mountains)	16	26(honeybees:12)	0.0976	2.5224	0.9315
Datong county, Qinghai (plain)	10	18(honeybees:10)	0.2778	1.7918	0.7782
Shizong county, Yunnan (Mountains)	14	22(honeybees:0)	0.0950	2.5001	0.9474
Luoping county (plain)	12	14(honeybees:0)	0.1020	2.4036	0.9673
Duilongdeqing county, Tibet (mountains)	24	37(honeybees:2)	0.0475	3.1097	0.9785
Deqing town, Dagzê county, Tibet (plain)	10	16(honeybees:2)	0.1250	2.1873	0.9499
HulunBuir city, Inner Mongolia (mountains)	30	43(honeybees:3)	0.0514	3.1967	0.9399
Wuchuan county, Inner Mongolia (plain)	34	298(honeybees:157)	0.3576	1.6181	0.4588
Yinghua town, Shifangcity,Sichuan (mountains)	27	58(honeybees:10)	0.0713	2.9940	0.9084
Majing town, Shifangcity,Sichuan (plain)	16	32(honeybees:2)	0.1170	2.4971	0.9007
Yaojiadian town, Yidu county, Hubei (mountains)	43	91(honeybees:10)	0.0499	3.3922	0.9019
Gongan county, Hubei (plain)	23	81(honeybees:18)	0.1065	2.6007	0.7149
Hanzhong city, Shaanxi (mountains)	20	240(honeybees:179)	0.5677	1.1530	0.3849
Tongchuan county, Shaanxi (plain)	7	196(honeybees:182)	0.8645	0.3449	0.1773
Dayou town, Nanchuan district, Chongqing (mountains)	77	289(honeybees:69)	0.1070	3.1258	0.7196
Rongchang county, Chongqing (plain)	32	284(honeybees:219)	0.5904	1.2162	0.3509

Notes: 1) $C=\Sigma (Ni/N)^2$, Ni ,the individual number of i species; N, the total number of individuals; 2) $H'=-\Sigma PilnPi$, $Pi=Ni/N$; 3) $J=H'/H'max=H'/lnS$, S; the total number of species

flower-visiting insects.

Analysis of diversity of insect community of different investigating points

As shown in Table 2, the diversity indexes of mountains were higher than that in plain areas, which indicates a higher abundance and richer insect species. The diversity index of Duilongdeqing county, HulunBuir city, Yaojiadian town and Dayou town were all higher than 3, suggesting that the insect species was diverse. On the other hand, in Datong county, Wuchuan county, Hanzhong city and Rongchang county, the diversity indexes were less than 2, implying less species.

Based on Table 3, the diversity index in mountains was 2.7492 which was significantly higher than 1.8325 in plains ($P<0.05$), the dominant concentration index in mountains was 0.1359 which was significantly lower than 0.3176 in plains ($P<0.05$), and the evenness in mountains was 0.8390 which was significantly higher than 0.6623($P<0.05$) in plains. All the data represented indicated that mountain areas had richer insect species and higher abundance than

Table 3. Significant analysis of diversity indexesof investigated mountain and plain areas

Groups	Dominant concentration index (C)	Diversity index (H')	Evenness (J)
Mountains	0.1359±0.06a	2.7492±0.25a	0.8390±0.07a
Plains	0.3176±0.09b	1.8325±0.27b	0.6623±0.10b

(Paired-samples t-test, Mean±SE, P<0.05)

Table 4. List of main hymenopteran visiting insects in different geographical regions

Regions	Main hymenopteran insects
Northern	*Apis mellifera*; *Andrena thoracica*; Chrysididae sp.01
Central	*Apis mellifera*; *Apis cerana cerana*; *Andrena thoracica*; Tenthredinidae sp.02; Ichneumonidae sp.01
Southwestern	*Apis mellifera*; *Apis cerana cerana*; *Lasioglossum phoebos*; *Anthophora* sp.01; Andrenidae sp.01; *Tetralonia floralia*; *Anthophora* sp.02; *Anthophora melanognatha*; Megachillidae sp.01; *Xylocopa rufipes*; *Xylocopa nasalis*; *Xylocopa auripennis*; Halictidae sp.01; *Andrena speculella*; *Xylocopa sinensis*; *Bombus flavescens*; *Bombus breviceps*
Northwestern	*Apis mellifera*; *Andrena thoracica*; Bombidae sp.01; Bombidae sp.02; Tenthredinidae sp.01
Northeastern	*Apis mellifera*; *Andrena* (*Enandrena*) *subshawella*; *Andrena* (*Taeniandrena*) *ezoensis*; *Halictus quadricinctus*; *Colletes jankowskyi*; *Lasioglossum pollilomum*; Polislidae sp.01

Table 5. List of main dipteran visiting insects in different geographical regions

Regions	Main dipteran insects
Northern	*Eristalis tenax*; *Scaeva pyrastri*
Central	*Episyrphus balteatus*; *Eristalis cerealis*; *Melanostoma scalare*; *Xoprosopa globosa*; Anthomyiidae sp.01; Scathophagidae sp.01; Scathophagidae sp.02; Scathophagidae sp.03; *Lucilia sericata*
Southwestern	*Episyrphus balteatus*; *Syrphus vitripennis*; *Episyrphus ceretensis*; *Phalacrodira tarsata*; *Scaeva selenitica*; *Metasyrphus nitens*; *Metasyrphus corolla*; *Eristalis tenax*; *Eristalis cerealis*; *Scaeva pyrastri*; *Xylota ignova*; *Metasyrphus latifasciatus*; *Platycheirus albimanus*; *Syrphus ribesii*; *Chrysomya* (*Compsomyia*) *megacephala*; *Eristalis arbustorum*; *Melanostoma mellinum*; *Anthomyia plumiseta*
Northwestern	*Eristalis cerealis*; *Chrysotoxum octomaculata*; *Melanostoma univitatum*; *Mesembrius flaviceps*
Northeastern	*Eristalis cerealis*; *Scaeva selenitica*; *Sphaerophoria scripta*;

plain areas.

Main hymenopteran visiting insects in different geographical regions

As shown in Table 4, 17 species were observed and recorded. On the other hand, only 3 and 5 species of hymenopteran insects could be found in northern and northwestern China, respectively. Moreover, there were 5 and 7 species captured in central and northeastern China, respectively. Among all the identified insects, *A.mellifera* was the most abundant one for oilseed rape, followed by the genus *Andrena*, wild pollinated hymenopteran of oilseed rape.

Main dipteran visiting insects in different geographical regions

As shown in Table 5, the main dipteran insects visiting rape were from Syrphidae, which was abundant in southwestern but was rarely seen in northern and northeastern China. The hover flies of the genus *Eristalis*, e.g. *Eristalis cerealis* and *Eristalis tenax* were richest in all geographical regions investigated.

DISCUSSION

Pollinators are the work horses of modern farms, which rely on the insects to pollinate crops. Pollinators are known to be affected by environmental shifts, including habitat loss and climate change, especially for honeybees (Klein et al., 2007; Potts et al., 2010). Given the fundamental agricultural landscape changed in China since implementation of new agricultural policy in 1978, we evaluated the diversity of pollinators on oilseed rape in different eco-types across China in both mountain and plain areas. We found that diversity index in mountains are higher than plain areas, significant higher number of insects species and population found in mountain also higher than in plain. This may be the consequence the mountain regions retain almost same landscape as four decades ago. In contrast, the large-scale monoculture model, agricultural mechanization and the extensive use of pesticides in plain areas on crops to increase productivity may significantly influence the diversity and abundance of pollinators.

Biodiversity is paramount important for the agroecosystem, particularly the abundance of insects for crop pollination (Altieri, 1999). The types of landscapes influence the biology of arthropods. The typical modern agriculture is featured by the large size and the monoculture model of production, which directly results in the decline of natural enemies for pests. At current stage about 1.3 million tons of agrochemical are applied on crops in China, 2.5 time higher than the global values. The extensive usage of pesticides on the arable land definitely threats the viability of beneficial insects, especially the survival of the pollinators. The decline of pollinators is tightly associated with the biodiversity of agroecosystem and the yield reduction of the insect-pollinated crop (McLaughlin and Mineau, 1995).

The diversity index represents the complexity of insect community; the higher value indicates that the species of the community is more in diversity. The higher dominant concentration index refers that the species number of the insect community is lower, the evenness index is tightly associated with the species diversity, the higher evenness index indicates the species number of the insect community is more in diversity(Wu, 2006). In this work we found that all mountains sites investigated have higher diversity index, lower dominant concentration index and higher evenness index. On the contrary, all plain sites investigated have lower diversity index, higher dominant concentration index and lover evenness index. These observations suggest that modernized farming activity since 1978 has tremendous transformed the agroecosystem and inhabits of pollinating insects in China, which is in concordance with the findings that the diversity index is higher in mountains or less-human areas than in agricultural lands (Biesmeijer et al., 2006). A wide plethora of insect species observed on oilseed rape manifests the fact that relationships with mutualistic organism that pollinate the plants are often necessary for the establishment and persistence of self-incompatible and out-crossing of the foreign flora that depends on animal pollination (Morales and Aizen, 2002; Parker, 1997). Of the eight investigated provinces, the most abundant insect species and biodiversity observed in Chongqing (from Table 2, mountain 77 species, 289 individual number; plain 32 species, 284 individual number) agree with the landscape and climate, where it is subtropical monsoon climate and almost 89% of the lands are mountain regions. Thus, the agriculture is different from the large scale in plain areas, thus this provides good inhabitation for the pollinating insects. The lowest insect species found in Shaanxi may be the consequence that its land is covered by only 36% of mountain and 64% is loess plateau where the oilseed rape is the top economic plant. The large scale, mechanization planting, and pesticide utilization on rape seeds to increase the production may influence the inhabitation of pollinating insects, thus in turn reducing the insect species and biodiversity in this area. Noticeably, only dipteran and hemipteran observed in Yunnan province, the results need to be investigated further in our later research through adding the sampling sites in Yunnan province.

Honeybees are the good indicators of environmental quality because their intense foraging activity brings them into contact food abundance within 3 km around the hive. Here, although hymenopteran and dipteran were the dominant pollinators, honeybees are most abundant insect for the oilseed rape. Of the honeybees, *A. mellifera* and *A. cerana* are the most abundant. This suggests that honeybees play key roles in pollinating the oilseed rape. To be noted, China has over 8 million of bee colonies (FAOSTA, Food and Agriculture Organization of the United Nations Statistics Division，2012). However, the abundance of *A. mellifera* cannot represent the environment health of the area the oilseed rape planted due to the most Chinese beekeepers are migratory and move their bees to forage honey and pollen. The large number of *A. mellifera* as the most abundant species found in Shaanxi where large area of oilseed rape planting province suggest that modernized farming activity is detrimentally impact on the agroecosystem. Moreover, the observed hoverflies and the insects of the genus *Eristalis* as the major pollinators suggest they may play complementary roles on bees of oilseed rape pollination. This is in line with hoverflies are the most efficient anthophilous dipteran of oilseed rape (Larson et al., 2001; Jauker and Wolters, 2008), and *Eristalis tenax* of hoverflies is possible efficient pollinator of various fruit crop (Solomon and Kendall, 1970; Kendall et al., 1971; Nye and Anderson, 1974). In all, our data offers the potentially valuable information about pollinators in China, and may be useful for policy maker to protect the pollinators and agriculture of China.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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