HAYATI Journal of Biosciences, December 2007, p 155-161 Vol. 14, No. 4
ISSN: 1978-3019

Diversity of Pollinator Insects in Relation to Seed Set of Mustard (*Brassica rapa* L.: Cruciferae)

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Received August 29, 2007/Accepted December 5, 2007

Pollinators provide key services to both natural and agricultural ecosystems. Agricultural productivity depends, in part, on pollinator populations from adjacent seminatural habitats. Here we analysed the diversity of pollinator insects and its effect to seed set of mustard (*Brassica rapa*) planted in agricultural ecosystem near the Gunung Halimun-Salak National Park, West Java. At least 19 species of insects pollinated the mustard, and three species, i.e. *Apis cerana*, *Ceratina* sp., and *Apis dorsata* showed a high abundance. The higher abundance and species richness of pollinators occurred at 08.30-10.30 am and the diversity was related to the number of flowering plants. Insect pollinations increased the number of pods, seeds per pod, seed weights per plant, and seed germination.

Key words: diversity, pollinator insects, social bees, solitary bees, seed set, *Brassica rapa*

INTRODUCTION

Pollinators provide key of ecosystem services to both natural and agro-ecosystems. Almost all flowering plant species in tropical lowland rain forests are pollinated by animals (Bawa 1990). Positive relationships between the richness and abundance of floral resources and pollinator diversity and activity have been found at the landscape level (Steffan-Dewenter *et al*. 2002; Klein *et al*. 2003). On sunflowers, wild bees may contribute more pollination services through enhancement than that of direct pollination, due to they concentrate on male flowers rather than female ones. Bees visiting only male flowers make no direct contribution to its pollination but do contribute through enhanced pollination (Greenleaf & Kremen 2006).

Animal pollinators are thought to contribute in 15 up to 30% of global food production (McGregor 1976; Roubik 1995) and bees are recognised to be the most important pollinating taxon (Delaplane & Mayer 2000). Farmers obtain adequate pollination services by bringing large numbers of honey bees to crop fields (Greenleaf & Kremen 2006). Single plant species, both wild and crops, may also receive a pollination service of higher quality and quantity as a result of this increased pollinator activity (Klein *et al*. 2003; Potts *et al*. 2004). In addition to the honey bee, *Apis mellifera* L., which is often advocated as the only practical pollinator, the use of solitary bees and flies has been proposed (Delaplane & Mayer 2000). Pollination is an ecosystem service of major economic and societal value, which is endangered by recent declines in pollinators (Daily 1997). Destruction and fragmentation of habitats adversely affect the diversity and abundances of solitary wild bees and bumblebees (Kremen *et al*. 2002; Steffan-Dewenter *et al*. 2002).

In this study, we used mustard species *Brassica rapa* L.: (Cruciferae). This species is an important crop in Asia (Rubatzkky & Yamaguchi 2000). Flowers of *B. rapa* are formed in the stem elongates after the leaf stop growing. The stem has many branches, small leaves, and bright yellow flower. Each flower has four petals and six stamens of which two stamens are shorter than the style but four others are longer. There is a single stigma at the tip of the style. Nectar is excreted at the bases of the short stamens and ovary. The flower is open for three days. Approximately, 95% of species of Crucifers require cross-pollination, although some cauliflower varieties are self-fruitful. Wind is not a good pollinator in *Brassica* spp. and bees play an important role in pollen vectors. Selfing in the absence of cross pollination generally reduces seed yield, seed size, and yield in subsequent generation (Delaplane & Mayer 2000). Two species of Cruciferae, *B. rapa* (syn. *campestris*) and *B. oleraceae* were identified as plants with Sporophytic Self-incompatibility (SSI) (Takayama & Isogai 2005). Self-incompatible plants require pollen transfer from plant to plant (Wallace *et al*. 2002). Earlier studies on the effects of pollinator insects to seed set of Cruciferae had been reported. In male sterile oilseed rape (*B. napus*), yields of the species were increased by honey bee pollination (Westcott & Nelson 2001; Steffan-Dewenter 2003). Similarly, in sarson (*B. campestris*), insects pollination increase the seed yield, caused formation of well-shaped, larger grain, and more viable seed (Khan & Chaudory 1995).

Here, we analysed the diversity of pollinator insects in relation to seed set of mustard (*B. rapa*). The diversity of pollinator insects was observed in relation to time and flower phenology. Effects of pollinator insects on reproductive success of *B. rapa* were quantified by measuring the number of pods, seeds, and seed viability.

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MATERIALS AND METHODS

Study Area. The study was conducted from December 2006 up to May 2007 in an agricultural landscape located in Cipeuteuy village, Kabandungan, Sukabumi District, West Java, in the margin of Gunung Halimun National Park at an elevation of approximately 845 m asl.

Observation of Pollinator Visitation. One hundred plants of mustard were planted in agricultural landscape for studied the pollinator diversity. Plants were planted three times, i.e. November 30, 2005, January 26, 2006, and March 16, 2006. The plants were fertilized by biofertilizer and no insecticide applications. Observations of pollinator insects were carried out using scan sampling (Martin & Bateson 1993) for 15 min per hour, starting from 07.30 h until 14.30 h on sunny days to measure abundance and species composition of floral visitors. Insect observations were conducted on January 12-February 9 (21 days), March 1-24 (16 days), and April 11-May 8 (16 days), 2006, respectively. Observations of flower-visiting insects were conducted from the start of flowering until approximate 95% of the flower faded. Samples of insect visitors were caught by sweep netting for species identification in the laboratory.

Measuring the Effects of Pollinator Insects to Seed Set. To measure the effects of pollinator insects on reproductive success of mustard, before flowering started, 100 plants of mustard were caged by insect screen of which pollinators had no access to flowers, and 100 plants were exposed to pollinators. Caging of plants was replicated three times. After the end of the fruiting period, we harvested 50 plants and counted the number of pods per plant, seeds per pod, seeds per plant, and seed weights per plant for each treatment. Seed viability was measured using the percentage of germinated seeds. One hundred of seeds were germinated in watered cotton in the plastic pans. Measurements were replicated 60 times for each treatment and the percentage of seed germination was measured.

Data Analysis. The number of species and individual of pollinator insects related to time of observation and the number of flowering plants were shown in graphics. Student's t test and Analysis of variance (ANOVA) were used to test for differences between two or more groups and group differences were established using the Scheffe test at the 95% level.

RESULTS

Diversity of Pollinator Insects. A total number of 5,955 pollinator insects associated with *B. rapa* were observed. They were belonged to 19 species and 4 orders (Hymenoptera, Lepidoptera, Coleoptera, and Diptera, for 95, 2.17, 2.07, and 1%, respectively). Three species of flower-visiting insects showed a high abundance i.e. *A. cerana* (43.1%), *Ceratina* sp. (37%), and *A. dorsata* (8.4%). Additionally, six species of Lepidoptera (*Nyctemera* sp., *Parnara guttata*, *Eurema hecabe*, *Potanthus* sp., *Jamides virgulatus,* and *Neptis hylas*), and one species of Coleoptera (*Papilia biguttata*) and Diptera (*Shyrphus balteatus*) visited mustard flowers, but they all accounted for less than 3% of the total number of observed pollinators (Table 1).

Diversity of Pollinator Insects Related to Time and Flower Phenology. Species richness of pollinator insects increased from 07.30 h and the highest species richness occurred at 10.30 h and subsequently decreased. The number of individual pollinators reached the peak at 08.30 h and decreased subsequently (Figure 1). Flowering of *B. rapa* were lasted for 20-25 days, and the peak flowering occurred at 10-15th days. The number of species relatively constants to the density of flowers (Figure 2), but the number of individual

Table 1. Species and individual number of pollinator insects on mustard flowers

Taxon	Species	Individual number				Percentage (%)			
		Jan-Feb	March	Apr-May	Total	Jan-Feb	March	Apr-May	Total
Hymenoptera	*Apis cerana*	1,468	733	366	2,567	50.57	46.16	25.00	43.11
Apidae, subfamily Apinae	*Apis dorsata*	5	493	0	498	0.17	31.05	0.00	8.36
	Trigona sp.	8	0	1	9	0.28	0.00	0.07	0.15
Apidae, subfamily Xylocopinae	*Xylocopa caerulea*	37	27	5	69	1.27	1.70	0.34	1.16
	X. confusa	28	21	20	69	0.96	1.32	1.37	1.16
	X. latipes	7	2	6	15	0.24	0.13	0.41	0.25
	Ceratina sp.	1,072	207	923	2,202	36.93	13.04	63.05	36.98
Colletidae, subfamily Hylaeinae	*Hylaeus* sp.	32	13	62	107	1.10	0.82	4.23	1.80
Halictidae, subfamily Nomiinae	*Nomia* sp.	67	0	21	88	2.31	0.00	1.43	1.48
Scoliidae	*Compsomeris lindenni*	0	1	0	1	0.00	0.06	0.00	0.02
Lepidoptera									
Arctiidae	*Nyctemera* sp.	25	0	2	27	0.86	0.00	0.14	0.45
Pieridae	*E. hecabe*	7	3	1	11	0.24	0.19	0.07	0.18
Lycaenidae	*J. virgulatus*	0	4	1	5	0.00	0.25	0.07	0.08
Nymphalidae	*N. hylas*	0	1	0	1	0.00	0.06	0.00	0.02
Hesperiidae	*P. guttata*	12	7	1	20	0.41	0.44	0.07	0.34
	Potanthus sp.	10	0	3	13	0.34	0.00	0.20	0.22
Coleoptera									
Scarabaeidae	*P. biguttata*	42	39	48	129	1.45	2.46	3.28	2.17
Diptera									
Syrphidae	*S. balteatus*	82	37	4	123	2.82	2.33	0.27	2.07
	M. argyrocephala	1	0	0	1	0.03	0.00	0.00	0.02
Total number		2,903	1,588	1,464	5,955	100	100	100	100

Jan: January, Feb: February, Apr: April