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Preliminary Test of Agri-Environmental Scheme Implementation in Farmland in Northern Slope of Mount Slamet

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ABSTRACT

An Agri-Environmental Scheme (AES) was designed to enhance flower availability in crops using local wild plants. The goals of this research were to determine the impact of four wild plants on three cash corps, focusing on the diversity and abundance of insect pollinators, and to test the efficacy of this scheme using farmland on the northern slope of Mount Slamet. This research was done using a split block design, with the three cash crops as blocks (strawberry [*Fragaria x ananassa* Duchesne], chili pepper [*Capsicum* spp.], and tomatoes [*Solanum lycopersicum* L.]) and four wild plant species as treatments (*Cleome rutidosperma*, *Borreria laevicaulis*, *Euphorbia heterophylla*, and *Tridax procumbens*) at different precentages (0, 5, 10, and 15 %) of cash crop plant density. The results show that growing wild plants with cash crops enhanced the abundance and diversity of insect pollinators. Moreover, the addition of wild plant species to the crops at four densities had significantly different effects on insect pollinators in terms of abundance and diversity. The combination of 15 % *C. rutidospermae* and tomatoes had the largest population of insect pollinators. From the experiments it concluded that an AES could be implemented in farmland on the northern slope of Mount Slamet.

Keywords: abundant, Agri-Environmental Scheme, diversity, insect pollinators, wild plant

INTRODUCTION

Numerous vegetable crops, including strawberry (*Fragaria x ananassa* Duchesne), tomatoes (*Solanum lycopersicum* L.) and chilli (*Capsicum* spp), are grown on the highland area of the northern slope of Mount Slamet and adjacent areas. To achieve maximum productivity, farmers in this area implement intensive farming practices involving the application of pesticides (insecticides, herbicides, and fungicides), monoculture farming, and a land management system that simplifies the agroecosystem and has an impact on the insect pollinators species richness and populations. Declines in the species richness and populations of insect pollinators have been strongly influenced by the development of agricultural ecosystems that reduce the diversity of plant species required by the insect pollinators (Batáry et al., 2010). Recent research in this area by Widhiono & Sudiana (2015a) revealed that 15 species of insect pollinators were in relatively small populations. Depaurete of insects pollinators in an agroecosystem will cause the failure of fruit production and economic losses for farmers. Because 70 % of the 124 main crops, are dependent on insect for pollination prosess (Klein et al, 2007). In that wild pollinators, in particular wild bees, serve as ecosystem services and contribute to pollination success of a large crop array (Gallai, Salles, Settele, & Vaissière, 2009; Bartomeus et al., 2014).

The roles of insects in vegetable crop pollination and productivity are influenced by their diversity and abundance (Steffan-Dewenter, et al. 2005), which are highly dependent on the numbers and types of flowering plants and on flowering phenology (Batáry et al., 2010). AES's (Agri-Environment Schemes) were introduced to agroecosysytems in Europe in the 1990s to maintain and restore farmland biodiversity, especially for insect pollinators. AES's are designed to protect and restore agrobiodiversity, thus securing or even enhancing pollination process as ecosystem services (Buri, Humbert, & Arlettaz, 2014).

To increase the agricultural productivity of plants dependence on insect pollination, insect pollinator conservation practices must be implemented. AES's can effectively enhance

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species richness for some insects over time (Roth, Amrhein, Peter, & Weber, 2008). The selection of model-based habitat conservation methods for insect pollinators are based on the theory that diversity and abundance of pollinating insects depend on the size of the habitat, habitat quality, and the potential for positive interaction with other habitats (Hodgson, Grime, Wilson, Thompson, & Band, 2005). Among these factors, the most important are habitat quality and the number and diversity of wild flowering plants as food supply for pollinating insects throughout the year. One approach to manage floral diversity and optimize pollination involves cultivating the most suitable flower species for targeted insects, as wild flower plantings could provide pollen and nectar resources when the crop is not in bloom (Carvell, Meek, Pywell, Goulson, & Nowakowski, 2007). Larger plantings of flowers could support greater diversity and an increased abundance of insect pollinators; therefore, conservation methods for insect pollinators on agricultural land are based on the concept of species enrichment and density of wild plants as food resources for these insects (Rollin et al., 2013).

One AES's that focuses on pollinators is referred to as a resource-oriented scheme (Dicks, Showler, & Sutherland, 2010). This resource-oriented approach consists of increasing the amount of specific floral resources by planting attractive flowers (Decourtye, Mader, & Desneux, 2010). The value of wild plants, which are often regarded as weeds within the context of agro-ecosystems, is very high to insect pollinators as they forage plants, especially in situations where such alternative forage has been eliminated or reduced in abundance due to the intense weed control practices. Weeds usually provide alternative food resources, thus facilitating the survival of pollinator populations (Nicholls & Artieri, 2012). However, not all flowering weeds that visited by insect pollinators provide alternative food resources, even for generalist pollinators. Among the weeds found in this area, only four (*Cleome rutidosperma*, *Borreria laevicaulis*, *Euphorbia heterophylla*, and *Tridax procumbers*) are visited by more than three insect pollinators (Widhiono & Sudiana, 2015b). We adopted an AES designed to specifically promote pollinating insect diversity and population size. We tested four local wildflowers, which were planted with three crops.

The goals of this research were to determine the effects of planting four wild plant species on a vegetable farm in terms of the diversity and population size of insect pollinators and to determine the potential to adopt this scheme at a research location.

MATERIALS AND METHODS

Study Area

This research was conducted from May to October 2012 in the village of Serang, subdistrict Karangreja, Purbalingga regency, Central Java, Indonesia. Geographically, this location is located at 7° 14´ 44´´ S and 109° 17´ 03´´, 61 E, with an elevation of 1140 m above sea level (Figure 1).

Procedure

The effects of four wild plant species planted at four different densities (0, 5, 10, and 15 %) among cash crops on the diversity and population size of insect pollinators were tested in a split block experimental design. The blocks were three cash crops (chilli, strawberry, and tomato), with each block being 40 m^2 in size. The treatments (four wild plant species: *C. rutidosperma*, *B. laevicaulis*, *E. heterophylla*, and *T. procumbens*) were applied with three replicates. Wild plants used have previously been identified by experts in plant taxonomy laboratory, Faculty of Biology Jenderal Soedirman University. Data collection began at the start of flowering of the cash crops and wild plants. The species of pollinating insect that visited flowers of each treatment and its respective population size were recorded weekly during the daytime (6:30–9:30 and 13:30–16:30 local time) by scan sampling (Martin & Bateson, 1993). For identification purposes, pollinating insects preserved and sent to the Indonesian Institute of Sciences Bogor, Indonesia.

Figure 1. Reseach location at Serang, Karangreja, Purbalingga Regency, Central Java

Data Analysis

A series of three-factor analysis of variance computations were used to determine the effects of wild plants, cash crop densities, and cash crops on the numbers and diversity of insect pollinators using SPSS software. The diversity of insect pollinators was analyzed using a variety of insect diversity indices (Shannon, Alpha, and Simspon), an equitability index (J), and an index of similarity (Morisita) with PAST software. To investigate the possible implications of our results for AES planning, we recorded data on the species and numbers of insect pollinators.

RESULTS AND DISCUSSION

A total of twelve insect pollinator species visited flowers of the four wild plant species in three crops. The pollinators belonged to the following three orders: Hymenoptera (seven species), Lepidoptera (four species), and Diptera (one species; Table 1). Hymenopteran visitors belonged to the families Apidae (five species), Halictidae (one species), and Vespidae (one species). From the Apidae family, honey bees (*Apis cerana javana*), stingless bees (*Trigona laeviceps*), and blue-banded bees (*Amegilla cingulata*) were observed on flowers of all four wild plant species and all crops. Small carpenter bees (*Ceratina dupla*; Apidae family, Xylocopinae subfamily) were only observed in *T. procumbers* and *E. heterophylla* in strawberries. The tropical carpenter bee (*Xylocopa latipes*; Apidae family, Xylocopinae subfamily) was only observed in *T. procumbers, C. rutidospermae*, and *E. heterophyla*, and not in *B. laevicaulis*. One species (*Polytes fuscata*) from the Vespidae family and one species (*Lassioglossum malachurum*) from the Halictidae family were found in all wild plants and all crops.

From the Lepidoptera order, consisting of moths and butterflies, one-spot grass yellow (*Eurema andersoni*; Pieridae family), common emigrant (*Cathopsylla pomona*; Pieridae family), and painted lady (*Vanessa cardui*; Nymphalidae family) butterflies were only observed on *T. procumbers* in strawberries, while the rice swift butterfly (*Borbo cinnara*; Hesperidae family) was observed on all wild plants and crops. From the Diptera order, only one species, the marmalade hoverfly (*Episyrphus balteatus*; Syrphidae family), was observed on all wild plants and crops.

The levels of species diversity among the wild plant species combined with cash crops were not significantly different ($F_{3.15}$ =3.44, p > 0.05 = 0.953); *T. procumber* had the highest species diversity of insect pollinators (H = 2.185, E = 0.7412, 1/D = 0.8731; Table 2).

The pollinator composition in this study was quite high compared to the results of a previous study that involved seven cash crops (Widhiono & Sudiana, 2015a), which reported ten species of insect pollinators and the lowest species diversity in chillis and tomatoes. Their results might be due to the restriction of insect pollinators on crops not receptive to the insects (Raw, 2000; Silva-Neto et al., 2013). Insect pollinator diversity was significantly different with the addition of wild plants and among wild plant densities. This might be due to the enhancement of resource-poor environments, such as the addition of flowering wild plants to a monoculture to attract beneficial insects (Iler & Goodell, 2014).

Table 1. Species diversity and abundance of insect pollinators for all combinations of wild plants and cash crops

Order	Family	Genus and species	Tp	Bl	Cr	Eh	Total	Relative abundance (%)
Hymenoptera	Apidae	*Apis cerana*	95	159	118	228	600	23.41
Hymenoptera	Apidae	*Trigona laeviceps*	50	77	41	50	218	8.5
Hymenoptera	Apidae	*Ceratina dupla*	7	0	0	7	14	0.05
Hymenoptera	Apidae	*Amegilla cingulata*	70	41	64	98	273	10.65
Hymenoptera	Apidae	*Xylocopa latipes*	54	0	47	32	133	5.18
Hymenoptera	Halictidae	*Lassioglossum malachurum*	82	77	71	93	323	12.60
Hymenoptera	Vespidae	*Polytes fuscata*	77	76	32	66	251	9.70
Lepidoptera	Pieridae	*Eurema andersoni*	11	0	0	0	11	0.04
Lepidoptera	Pieridae	*Catopsyla pomona*	4	0	0	0	4	0.01
Lepidoptera	Nymphalidae	*Vanessa cardui*	9	0	0	0	9	0.03
Lepidoptera	Hesperidae	*Borbo cinnara*	51	52	45	63	211	0.82
Diptera	Syrphidae	*Episyrphus balteatus*	132	155	140	89	516	20,13
			642	637	558	726	2563	

Remarks: Tp = *Tridax procumbers*; Bl = *Borerria laevicaulis*; Cr = *Cleome rutidospermae*; Eh = *Euphorbia heterophylla*

Table 2. Diversity parameters of insect pollinators for four different wild plants in combination with cash crops

Diversity parameters	*T. procumbers*	*B.laevicaulis*	*C.rutidospemae*	*E.heterophylla*
Number of Species	12	7	8	9
Number of Individuals	642	637	558	726
Dominance index	0.1269	0.1758	0.1593	0.1709
Shannon index (H)	2.185	1.836	1.953	1.951
Simpson index (1-D)	0.8731	0.8242	0.8407	0.8291
Evenness index E	0.7412	0.8958	0.8816	0.782
Equitability_J	0.8795	0.9435	0.9394	0.8881
Margalef	1.702	0.9293	1.107	1.214
Menhinick	0.4736	0.2774	0.3387	0.3346

Table 3. The numbers of insect pollinators observed for all combinations of wild plants and cash crops at different wild plant densities

Crops	*Tridax procumbers*				*Borerria laevicaulis*				*Cleome rutidospemae*				*Euphorbia heterophylla*			
Densities	0%	5%	10%	15%	0%	5%	10%	15%	0%	5%	10%	15%	0%	5%	10%	15%
Strawberry	28	49	70	80	26	52	70	98	16	32	71	86	24	44	83	94
Chilli	19	33	25	38	17	23	27	55	17	34	40	54	18	46	52	68
Tomatoes	36	60	94	112	38	63	98	117	15	56	75	94	46	56	89	118

During the sampling periods, this research obtained 2,563 insect pollinator specimens, representing 12 species. The most abundant species was *A. cerana* (Apidae family), with 600 individuals (23.41 %), followed by *E. balteatus* (Syrpidae) with 516 individuals (20.13 %), *L. malachurum* (Halictidae family) with 323 individuals (12.60 %), and *A. cingulata* (Apidae family) with 273 individuals (10.65 %). The least abundant was *C. pomona* (Pieridae), with only four individuals (0.01 %; Table 1). The greater representation of *A. cerana* might be attributed to their need to store large amounts of food to sustain colony development, and their evolved social and behavioral habits to optimize foraging (Dyer, 2002; Dornhaus & Chittka, 2004).

The number of of *E. balteatus* (hoverfly) individuals might be caused by the adults feed mainly on the nectar and pollen of flowering plants in agroecosystems, and the hoverfly depends on weeds for pollen and nectar (Sadeghi, 2008). Hoverflies are probably the most significant among the anthophilous Diptera family members. They are important as pollinators of various fruit crops, including strawberries (Jauker & Wolters, 2008). *Lassioglossum malachurum* is attracted to a variety of flowers, but mainly yellow flowers, such as those of chilli and tomatoes (Polidori, Rubichi, Barbieri, Trombino, & Donegana, 2010). This species is important as a supplemental pollinator. An intermediate number of *A. cingulata* individuals are generally found because their population size fluctuates between seasons (Anbalagan, Paulraj, & Ignacimuthu, 2015). The total number of insect pollinators on different wild plants and wild plant densities in each cash crop are presented in Table 3.

An analysis of variance indicated that the wild plant densities were significantly different compared to the control in all staple crops. Wild plant density (0, 5, 10, and 15 %) significantly affected the populations of insect pollinators in all blocks of cash crops (strawwberry ($F_{3,12}$ = 66.13, p < 0.05 = 0.00); chilli $F_{3,12}$ = 8.70, p < 0.05 = 0.002; tomatoes $F_{3,12}$ = 11.76, p < 0.05 = 0.001). The smallest plant populations for the 0 % density treatment, compared to the 5, 10, and 15 % treatments, resulted in fewer insects. This supports the hypothesis that the loss of diversity and density of pollinator species due to the decline of floral resources such as in mono-culture farming (Ebeling, Klein, & Tscharntke, 2011; ller & Goodell, 2104).

The greatest number of insect pollinators was found for a wild plant density of 15 %. The combination of a 15 % density of wild plants and tomatoes resulted in the largest number of insect pollinators; however, for each of the staple crops the numbers of insect pollinators were not significantly different among the wild plant species (strawberry ($F_{3,12}$ = 0.944, p > 0.05 = 0.95; chilli $F_{3,12}$ = 0.103, p > 0.05 = 0.45; tomato $F_{3,12}$ = 0.265, p > 0.05 = 0.85). These results indicated that a higher diversity and density of flowering wild plants would increase the populations of wild pollinators, which require flower nectar and pollen as a primary food source (Carvell, Meek, Pywell, Goulson, & Nowakowski, 2007). The higher numbers of insect pollinator are expected in plant communities with abundant flowers (Ghazoul, 2006; Ebeling, Klein, Schumacher, Weisser, & Tscharntke, 2008; Blüthgen & Klein, 2011). The results of this research are in accordance with those from previous studies (Holzschuh, Dormann, Tscharntke, & Steffan-Dewenter, 2011; Blaauw & Isaac, 2014) that found mass flowering crops are intensively used by bees in agro systems. Solitaire wild bees need more diversified native floral resources to fill each cell in their nest with enough food for one larva to complete its life cycle.

CONCLUSION AND SUGGESTION

From this study, it can be concluded that four wild plant species would increase insect pollinator diversity and population size. The combination of four wild plant species and three cash crops enhanced the diversity and number of insect pollinators, and the combination of a 15 % wild plant density in all three cash crops resulted in the largest populations of insect pollinators. The results of this study suggest that the enrichment of cash crops farms with four wild plant species can be achieved on the northern slope of Mount Slamet, but additional research is needed on production and the implications for farmer income.

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