HAYATI
Journal of Biosciences

Vol. 31 No. 6, November 2024 1050-1060
DOI:10.4308/hjb.31.6.1050-1060
ISSN: 1978-3019
EISSN: 2086-4094

Comparing Effectiveness of Hand Pollination, Wild Insects and Local Stingless Bees (*Tetragonula laeviceps*) for Pollination of Exotic Mauritius Raspberry (*Rubus rosifolius*)

Ramadhani Putra[1*], Rezha Tanu Dewangga[1], Endang Hermawan[2], Ida Kinasih[3], Rika Raffiudin[4], RC Hidayat Soesilohadi[5], Hery Purnobasuki[6]

[1]*Biology Study Program, School of Life Science and Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia*
[2]*Biomanagement Study Program, School of Life Science and Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia*
[3]*Department of Biology, Islamic State University Sunan Gunung Djati, Bandung Indonesia*
[4]*Department of Biology, Faculty of Mathematics and Natural Science, Institut Pertanian Bogor, Bogor 16680, Indonesia*
[5]*Biology Faculty, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia*
[6]*Department of Biology, Faculty of Sciences and Technology, Airlangga University, Surabaya 60115, Indonesia*

ARTICLE INFO

Article history:
Received February 6, 2023
Received in revised form April 9, 2024
Accepted May 22, 2024

KEYWORDS:
Exotic plants,
pollination,
stingless bees

ABSTRACT

Mauritius raspberry (*Rubus rosifolius*) is an exotic plant cultivated in Indonesia. Studies showed that the productivity of exotic plants is reducing due to a lack of pollination agent for their origin region. Several methods could be applied to overcome this problem. The study aimed to find the most effective method for pollinating this plant among four pollination regimes: Self-pollination, wild insects, stingless bees (*Tetragonula laeviceps*), and hand-pollination. The observation was conducted on the insect pollinators' activities (visitation rate, flower constancy, and flower handling time), pollination efficiency, and quality of the fruits produced (fruit volume). The results showed a higher visitation rate (10 to 70 per hour), higher flower constancy (visited from 07.00 to 16.00), and longer flower handling time (13.6 s) of *T. laeviceps* on raspberry flowers than other insects. High activities related to better raspberry pollination success (96%) and bigger fruits produced. Based on this study, applying stingless bees as pollination agents for exotic plants was the best and potentially applicable to other exotic crops.

1. Introduction

One of the emerging farming activities in many tropical countries is the cultivation of exotic fruits (Tiwari *et al.* 2021), which could alter the distribution and abundance of species (Taylor and Irwin 2004; Seebens *et al.* 2015). The most cultivated exotic fruits are berries, which are the most widely cultivated, such as strawberry, mulberry, and raspberry (*Rubus rosifolius*) (Valkenburg and Bunyapraphatsara 2001). Even though the economic value of raspberry is higher than that of other berries, this species is the least likely to be cultivated and, to some extent, has become an invasive species in highland Java (Kalkman 1993). The most common reason for the lack of intensive raspberry is low productivity level, which is suspected to be related to genetics, soil conditions, environmental factors, and biotic interactions. In this study, the biotic interaction effect on the productivity of raspberries becomes the main subject.

Pollination is one of the important biotic interactions for fruit production (Ollerton *et al.* 2011; Burkle *et al.* 2013; Gonzalez-Varo *et al.* 2013; Reilly *et al.* 2020). Raspberry has a perfect flower with 60–120 stamens located around a central receptacle and pistils arising spirally from the receptacle and predominantly able to do self-pollination (Żurawicz 2016). This arrangement usually only allows the outer stigmas to contact the anthers (Free 1993), and insect pollination, especially that mediated by bumble bees and honey bees, could improve the yield and quality of the fruit that comply with commercial standards (Andrikopoulos and Cane 2018; Saez *et al.* 2018; Chen *et al.* 2021).

* Corresponding Author
E-mail Address: ramadhani@sith.itb.ac.id

In nature, flowering plants have developed strong relations with particular animals for pollination services. Exotic crops usually suffer from a lack of pollination due to the unavailability of their natural pollinators, and they must rely on wild native pollinators (Garibaldi *et al.* 2013, 2014; Rader *et al.* 2016; Page *et al.* 2021; Miñarro *et al.* 2023; Eeraerts *et al.* 2023; Saez *et al.* 2023). The benefits of the pollination service by wild pollinators depend on the diversity and abundance of the visiting wild pollinators and the location (Garibaldi *et al.* 2013; Kleijn *et al.* 2015; Winfree *et al.* 2015; Pérez-Méndez *et al.* 2020; Earaerts *et al.* 2023). Diverse wild pollinators will provide better services as different insect species could complement each other and produce an additive pollination effect (Miñarro and García 2018; Winfree 2013). Even though this model is promising, accumulating evidence suggests that wild pollinator populations are declining worldwide, primarily due to farming practices (Shuler *et al.* 2005; Potts *et al.* 2010; Hallmann *et al.* 2017; Evans *et al.* 2018; Dicks *et al.* 2021). On the other hand, there needs to be more clarity about the quantity and quality of the pollen transferred by wild pollinators (Garibaldi *et al.* 2016), which makes this service relatively unstable and unreliable. Furthermore, the information on the impact of wild pollinators on the productivity of exotic crops is relatively scarce, which could lead to inappropriate conservation programs for wild pollinators as some efficient pollinators are non bees (Rader *et al.* 2016) that could be mistaken as destructive insects.

Hand pollination, an assisted supplementary or exclusive pollination in which pollen is manually or mechanically applied onto flower pistils, is also applicable to ensure the pollination of exotic crops (Pinillos and Cuevas 2008; Wurz *et al.* 2021). In supplementary terms, during hand pollination, pollen is applied to augment natural pollination (Silveira *et al.* 2012), while as exclusive pollination, hand pollination is the only pollination regime since natural pollination is absent (Westerkamp and Gottsberger 2000). This method is commonly applied in plant breeding (Frankel and Galun 2012). Still, it is now seen as a solid alternative to reduce the effect of pollination limitation due to the lack of natural pollinators (Baldock 2020). The successful hand pollination technique, however, depends on the skill of the workers and the timing of pollination, as the stigma has a short and dynamic receptive time. Further, there needs to be more information on the effectiveness of hand pollination on raspberry production.

Another possible method to ensure the pollination of exotic crops is by applying local domesticated bees. In the tropics, stingless bees play an essential role in the pollination of tropic flower-pollinator networks (Heard 1999; Santos and Absy 2010; May-Itza *et al.* 2021; Bueno *et al.* 2023; Woitowicz *et al.* 2023). This insect has been domesticated (practices called Melliponiculture) and showed high efficiency when applied as a pollination agent in the agricultural system of various local crops (Suhri *et al.* 2022; Waithaka *et al.* 2023; Wongsa *et al.* 2023). Among the available stingless bees, *T. laeviceps* is considered the best pollinator based on the results of various studies on local crops (Putra *et al.* 2014; A'yunin *et al.* 2019; Alpionita *et al.* 2021) and berries in Indonesia (Alpionita *et al.* 2021; Atmowidi *et al.* 2022).

This study tested the effectiveness of local wild pollinators, hand pollination, and domesticated stingless bees (*T. laeviceps*) in pollinating the exotic Mauritius raspberry. The information gathered could be applied to develop possible pollination strategies for other exotic crops.

2. Materials and Methods

2.1. Study Area

The study was conducted on a small-scale raspberry plantation located at Parongpong, West Bandung, from November to December 2019 (Figure 1A), dominated by vegetable farms. The study area was divided into four designated areas based on the type of pollination application consisting of (i) open pollination, (ii) Stingless bee pollination (using *T. laeviceps*), (iii) hand pollination, (iv) self-pollination (Figure 1B). Two colonies of *T. laeviceps* were installed for *T. laeviceps* pollination group.

The area is located at 1,147 meters above sea level, and precipitation is between 39 and 442 mm^3. Average humidity was 55 to 100%, temperature 16 to 30°C, and maximum light intensity 120,000 lux. Raspberries were planted on the soil with an average soil temperature of 25°C, humidity between 10 to 12.5%, and pH of 6.53.

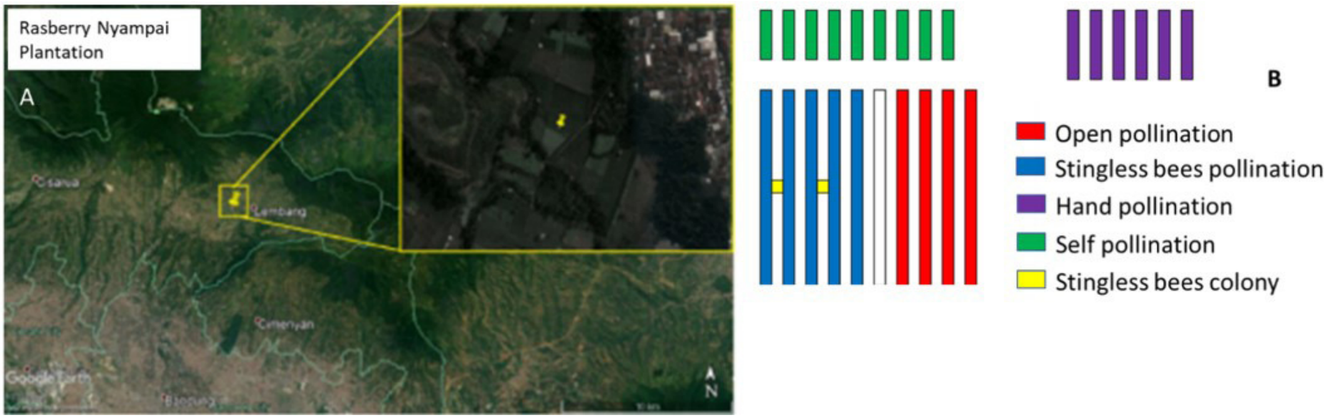

Figure 1. (A) Study area location at small-scale raspberry plantation, (B) arrangement of the study area

2.2. Pollination Study

For this purpose, 200 unbloomed flowers were randomly selected and bagged with a pollination bag (14 × 17 cm) made of nylon mesh (diameter 1 mm). The flowers are divided evenly into four pollination regimes, totaling 50 flowers per pollination regime. All bags were removed when the flowers started blooming, except for the self- pollination group. The bags were opened for *T. laeviceps* and human pollination until the flower was pollinated by *T. laeviceps* and human (using a fine brush), respectively. After pollination, the flower is then bagged (until fruit is produced), and the flower stem is covered with glue to prevent further pollination by wild insects. On the other hand, the pollination bags were entirely removed for the open pollination group.

2.3. Flower Visiting Insect Observation

Observations were conducted on the blooming flowers during the periods (1) morning (07.30-09.30), (2) noon (12.30–14.30), and afternoon (15.30-17.30). Observations were conducted by focal sampling the species and the total number of visiting insects. Insects were sampled and identified based (1) Borror *et al.* (2005) (for the general insect to family level), (2) Lien and Carpenter (2002), Lien *et al.* (2006), Michener (2007), Engel (2012), and Smith (2012) (for Hymenoptera to genus level), (3) Scudder and Cannings (2006), Carvalho and Patiu (2008), Speight (2014), Sengupta *et al.* (2016) (for Diptera to genus level), (4) Dombroskie (2011) and Baskoro *et al.* (2018) (for Lepidoptera to genus level).

Information on activity time (the time when a particular insect could be found visiting flowers), visitation rate (number of individuals visiting flowers), and handling time (time spent in the flowers) were recorded.

The level of pollination efficiency (PE) was calculated based on Keys *et al.* (1995):

$$PE = \frac{\text{Total number of flower produced fruits}}{\text{Total number of observed flowers}}$$

2.4. Fruit Quality

Raspberry quality was determined by fruit volume as the fruit consisted of a collection of smaller fruits and the irregular shape of the fruit, which usually caused inconsistency in weight measurement by digital scale. Further, volume is generally applied based on the fruit's quality after post-harvest treatment (usually by drying and freezing treatment) (Stamenkovic *et al.* 2019). The volume of the raspberry was determined by the water displacement method.

2.5. Data Analysis

The data on the fruit quality showed a non-normal distribution. Thus, the differences in the effect of pollination regimes on the fruit quality were determined by the Kruskal-Wallis test, followed by the Least Significant Difference as a post hoc test. The significance level was at P<0,05. A simple X-Y graph was produced by Microsoft Excel to show the effect of pollination efficiency and visitation rate. All statistical processes were done using the IBM Statistical Package for Social Science (IBM SPSS) ver. 22.

3. Results

3.1. Wild Flower-Visiting Insects

During this study, 16 wild insects visited raspberry flowers dominated by Hymenoptera. Interestingly, all visiting Hymenoptera belong to solitary insects. All of the wild insects did not visit the flower after 13.00, and only 5 species had a flower handling time of more than 1 second (Table 1).

3.2. Visitation Rate and Handling Time of Stingless Bees at Raspberry Flowers

Unlike wild insects, stingless bees constantly visited, especially from 10.00 to 14.00. The peak visitation rate of stingless bees to raspberry flowers was recorded at 13.00 (Figure 2A. Stingless bees also showed significantly longer flower handling time than wild insects (See Table 1). The longest handling time was recorded at 13.00 (Figure 2B).

3.3. Pollination Efficiency

The pollination efficiency of stingless bees was the highest among other pollination regimes. This study also showed that raspberries can produce fruits by self-pollination at a relatively good level. Application of stingless bees improved the fruit production level by 12%, 20%, and 50% compared to wild insect, human-assisted pollination, and self-pollination, respectively (Figure 3A). Each pollination regime had a different effect on the fruit volume produced as stingless bees pollination produced significant bigger fruits (Figure 3B). On the other hand, pollination success positively correlated to fruit volume (Figure 3C).

In this study, we found some failed to produce and abort fruit from human and self-pollination groups. Both failed and aborted fruit characterized by a lack of fruit formation and irregular shape (Figure 4). Among the pollination regime, the stingless bees regime had the lowest number of failed and aborted fruit (2, 4% of total sampled flowers) followed by open pollinators (8, 16% of total sampled flowers), hand pollination (12, 24% of total sampled flowers) and self-pollination (27, 54% of total sampled flowers).

Table 1. List of wild insects (without stingless bees) that visited raspberry flowers during the study

Species	Ordo	Active time	Average flower handling time (second)
Vespa velutina			2
Lasius niger			6
Xylocopa aestuans			5
Myzinium quinquecincta			< 1
Monobia quandridens	Hymenoptera	07.00–13.00	< 1
Ropalidia marginata			< 1
Tachypompilus analis			< 1
Vesa affinis			< 1
Lucilia sericata			< 1
Sarcophaga haemorrhoidalis			< 1
Simosyrphus grandicornis	Diptera	09.00–13.00	5
Eristalinus quinquelineatus			< 1
Ypthima nigricans			< 1
Junonia almana			7
Hypolimnas misippus	Hymenoptera	07.00–12.00	< 1
Mycalesis horsfeldii			< 1

3.4. Fruit Quality

The fruit volume of the self-pollination group was significantly lower than that of other groups. Application of stingless bees as pollination agent produced the most significant fruit (ANOVA, P<0.05, Tukey's pairwise P<0.05) (Figure 5A). Application of

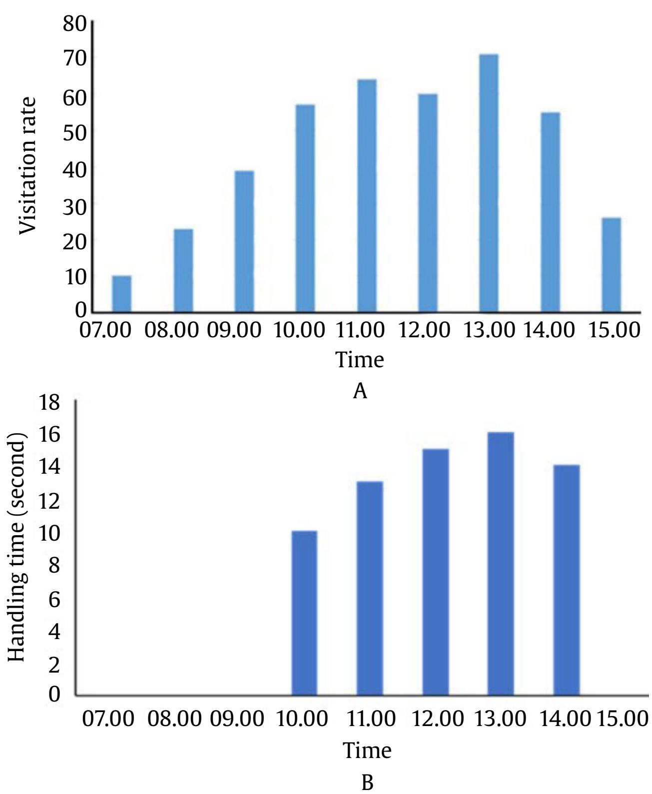

Figure 2. (A) Visitation rate of stingless bees on raspberry, (B) handling time of stingless bees on raspberry. Handling time less than 1 second was not shown

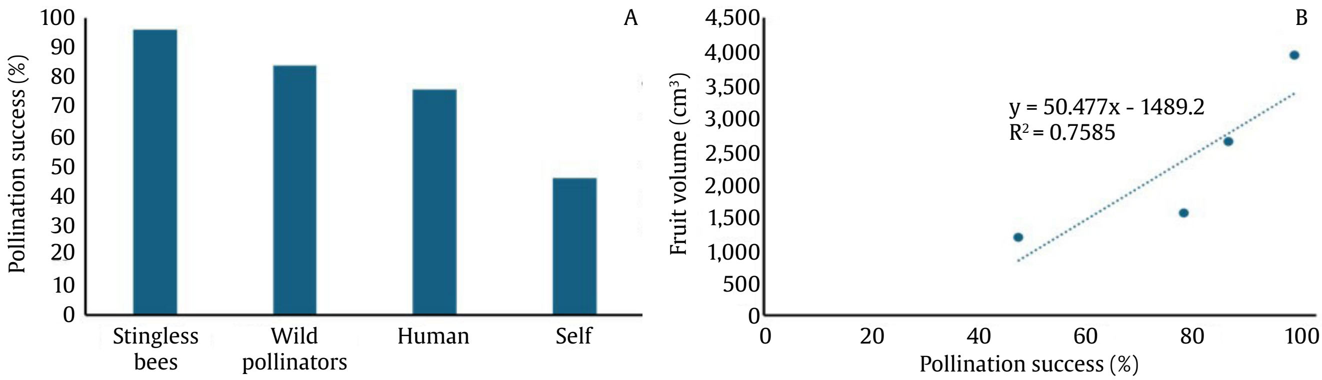

Figure 3. (A) Comparison of the pollination efficiency of four types of pollination regimes and (B) Effect of pollination efficiency on fruit volume

Figure 4. Failed and aborted raspberry fruits

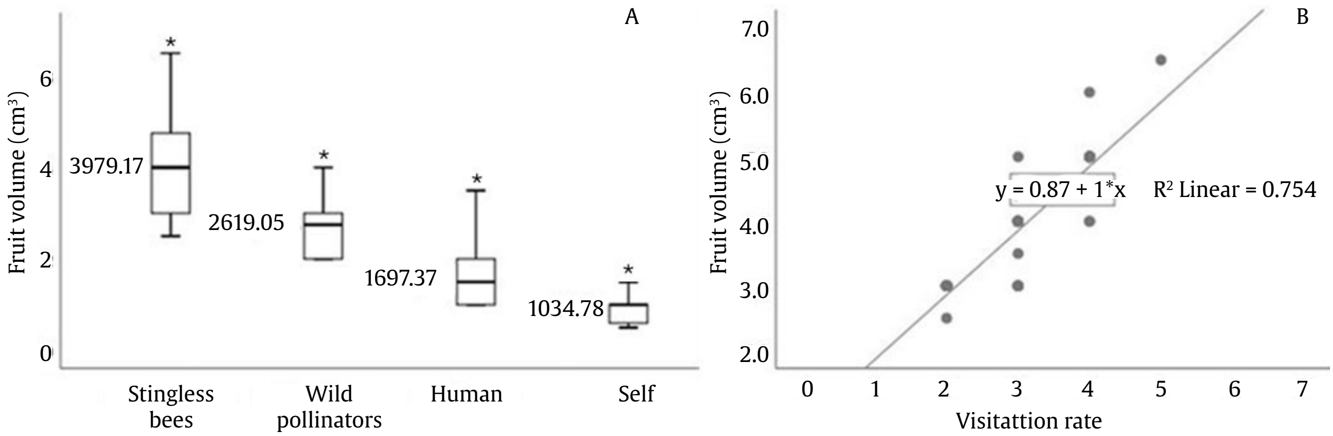

Figure 5. (A) Comparison of the raspberry volume produced by four types of pollination. (*) indicated significant value with P<0.05. Box indicated the average and standard deviation of the result while the line indicated the range of the data, (B) effect of visitation rate on fruit volume

stingless bees significantly as pollinator improved the volume level of fruit by % compared to fruit produced by wild insects pollination, 134% compared to human pollination, and 285% compared to self-pollination. Further analysis of the data of the fruit volume produced by stingless bee pollination showed a strong positive correlation between visitation rate and fruit volume (Figure 5B).

4. Discussion

4.1. Development of Local Pollination Interaction by Raspberry

In their native land, raspberry flowers are pollinated mainly by bumble bees and honey bees (Willmer *et al.* 2008; Cane 2005; Lye *et al.* 2011; Sáez *et al.* 2014; Neilsen *et al.* 2017). During our study, however, only one wild bee species, *Xylocopa aestuans*, visited raspberry flowers. Further, no social bees visited the flower, which may indicate the low environmental condition of the plantation, as the social bees required a constant supply of energy from both wild and cultivated flowers.

However, this study found a high pollination efficiency provided by local insect communities and local domesticated stingless bees, albeit a lack of honeybees as significant pollinators of this fruit. The result confirmed the importance of wild insects and non-bees as pollinators of crops (Garibaldi *et al.* 2013; Rader *et al.* 2016). It seems that non-bee insects provided pollination services to raspberries from resource-gathering activities as raspberry acts as potential food resources (Drossart *et al.* 2017). Collection of food resources, especially nectar, which is abundant in the raspberry flower (Kostryco and Chwil 2022), by insects from exotic species may relate to changes in insect community and the availability of traditional food sources due to climate change and land use alteration (Villa *et al.* 2009; Potts *et al.* 2010; Williams *et al.* 2011).

Although specific studies on the importance of pollination for each wild insect species were not done, it could be assumed that insects that spent more time act as possible pollinators of raspberry. Among wild species collected in this study, it is more likely that ants and flies acted as primary pollinators for raspberry in our study area, and both of these guilds were also reported as primary non-bee pollinators (Schiestl and Glaser 2012; Cook *et al.* 2020). Further studies are required to test this hypothesis.

4.2. Stingless Bees as Pollinator of Raspberry

Our study showed constant visits of stingless bees to raspberry flowers, which are attractive to bees (Goodwin 2012; Howard *et al.* 2021). Raspberry is a generalist floral morphology (i.e., open flower, short corollas, numerous stamens) that provides easy access to stingless bees to collect nectar and pollen resources (Olesen *et al.* 2007). Raspberry provides abundant nectar sources compared to surrounding vegetation, dominated by leafy vegetables, corn, and trees that produce flowers seasonally. This condition strongly attracts wild pollinators (Krishna and Keasar 2018; Dellinger 2020; Staab *et al.* 2020; Schmack and Egerer 2023). On the other hand, nectar production of raspberry followed a clear pattern that depended on the cultivar, which may explain the longer flower handling time at 10.00 (Schmidt *et al.* 2015). Further study is needed to confirm if this pattern matches pollen quality and stigma receptivity, two major components that ensure successful pollination. This constant visit to flowers was translated into extremely high pollination efficiency at 96%, which was higher than the level of pollination efficiency by their native pollinator like bumble bees and honey bees (at 75 to 85%) (Andrikopoulos and Cane 2018).

Our study showed constant visit of stingless bees to raspberrys, which is in accordance with Goodwin (2012) and Howard et al. (2021). Raspberry is an aggregate fruit consisting of multiple smaller fruits called drupe (Jenning 1988). The shape and cohesion of the fruit highly depend on the number of drupelets in which each of them developed from the fertilized ovary. Lack of successful pollination will significantly reduce the number of drupelets that produce smaller, lighter, and misshapen fruit (Chagnon *et al.* 1989), as shown on fruits produced by human and self-pollination groups. The structure of the reproductive part of the raspberry is not allowing wind pollination to be successful (Normasiwi *et al.* 2021), which explains the low number of drupelets for the self-pollination group. As for hand pollination, which is considered as the best pollination regime, lack of successful pollination could be caused by (1) low quality and quantity of pollen used, which could related to the pollen viability (Gonzalez *et al.* 2006), (2) source of the pollen to ensure cross-pollination between different cultivar which could be lacking at sampled raspberry plantation (Pritchard and Edwards 2006; Zurawicz 2016). The level of self-incompatibility is varies among raspberry cultivars (Pawar *et al.* 2017; Pinczinger *et al.* 2021), (3) timing of the pollination, which related to the stigma receptivity (Pawar *et al.* 2017), and damage to the pollen and stigma during the pollination process.

Although Goldwin (2012) reported that raspberry plants produce more extensive and more fruit when visited by various insects, our study showed that single species may be able to pollinate raspberries efficiently. It seems that unconstrained visits by stingless bees are more likely to produce successful fertilization, and this study further confirms the lesser importance of the number of pollen grains deposited for raspberry pollination (Saez *et al.* 2014). The result also supports the benefit of introducing domesticated bees to the productivity of various crops, including raspberry (Chen *et al.* 2021). However, some studies showed that this activity could enhance the visitation rate of pollinators insect to flower, which, in the end, reduces the productivity of plants, especially for honey bees (Garibaldi *et al.* 2013; Saez *et al.* 2014). The decreasing productivity is most likely caused by floral damage due to insect activities on the flower. However, our study showed that heavy flower visits by stingless bees improve pollination and fruit quality without causing damage to flowers. The lack of damage to flowers could be related to the body size of stingless bees. Smaller body size prevents possible damage to flowers. It may explain better pollination efficiency by stingless bees than natural pollinators of raspberry (Saez *et al.* 2014), and smaller body size probably matches the characteristics of the raspberry flower (Naghiloo *et al.* 2021). Further studies are required to confirm this hypothesis.

4.3. Implication of Study

This study proves the importance of local ecosystem service (e.g., pollination) systems for small-scale farmers' resilience and sustainability (Stratton *et al.* 2020). Further, the result showed the possibility of the positive contribution of insect pollinators to self-fertile crops (Costa and Machado 2012; Saez 2018). In the case of pollination services, alternative or supplemental pollinators could be applied when they are proven to be a practical, economical alternative and could compensate for the level of pollination provided by wild pollinators (Hallet *et al.* 2017).

Our study showed that local domesticated stingless bees could applied as alternative pollinators for raspberry instead of importing native pollinators, which potentially significantly altered the local community and plant-insect interaction (Paini and Roberts 2005; Morales *et al.* 2013). As for small-scale farmers, the application of domesticated stingless bees could be developed into an integrative farming system in which farmers could get additional benefits from stingless bee products (e.g., honey, propolis, pollen) while practicing environmentally friendly cultivation methods due to the sensitivity of these bees to the pesticide. Further, this study could act as a base for developing a sustainable model for using pollination services by local wild and domesticated bees (Garibaldi *et al.* 2013) as a precision pollination system that ensures the cross-pollination and application of suitable pollinator agents.

Acknowledgements

This study was partly funded by Riset Kolaborasi Indonesia 2022, which was granted to the corresponding author.

References

Andrikopolous. C.J., Cane, J.H., 2018. Comparative pollination efficacies of five bee species on raspberry. *J Econ Entomol.* 111, 2513-2519. https://doi.org/10.1093/jee/toy226.

Alpionita, R., Atmowidi, T., Kahono, S., 2021. Pollination services of *Apis cerana* and *Tetragonula laeviceps* (Hymenoptera: Apidae) on strawberry (*Fragaria x ananassa*). *Asian J. Agric. Biol.* 2021, 202101057. https://doi.org/10.35495/ajab.2021.01.057

A'yunin, Q., Rauf, A., Harahap , I.S., 2019. Foraging behaviour and pollination efficiency of *Heterotrigona itama* (Cockerell) and *Tetragonula laeviceps* (Smith) (Hymenoptera: Apidae) on chayote. *JIPI*. 24, 247-257. https://doi.org/10.18343/jipi.24.3.247

Atmowidi, T., Prawasti, T.S., Rianti, P., Prasojo, F.A., Pradipta, N.B., 2022. Stingless bees pollination increases fruit formation of strawberry (*Fragaria x annanassa* Duch) and melon (*Cucumis melo* L.). *Trop. Life Sci. Res.* 33, 43-54. https://doi.org/10.21315/tlsr2022.33.1.3

Baldock, K.C.R., 2020. Opportunities and threats for pollinator conservation in global towns and cities. *Curr. Opin. Insect. Sci.* 38, 63-71. https://doi.org/10.1016/j.cois.2020.01.006

Baskoro, K., Kamaludin, N., Irawan, F., 2018. *Lepidoptera Semarang Raya: Atlas Biodiversitas Kupu-Kupu di Kawasan Semarang. Departemen Biologi*. Universitas Diponegoro Press, Semarang.

Borror, D., Triplehorn, C., Johnson, N., 2005. *Borror'and DeLong's Introduction to the Study of Insect*. Thompson Brooks/Cole, Belmont.

Bueno, F.G.B., Kendall, L., Alves, D.A., Tamara, M.L., Heard, T., Latty, T., Gloag, R., 2023. Stingless bee floral visitation in the global tropics and subtropics. *Glob. Ecol. Conserv.* 43, e02454. https://doi.org/10.1016/j.gecco.2023.e02454
Burkle, L., Marlin, J., Knight, T., 2013. Plant-pollinator interactions over 120 years: loss of species, co-occurrence, and function. *Science*, 80, 1611–1615. https://doi.org/10.1126/science.1232728
Cane, J.H., 2005. Pollination potential of the bee *Osmia aglaia* for cultivated red raspberries and blackberries (Rubus: Rosaceae). *HortScience*. 40, 1705–1708. https://doi.org/10.21273/HORTSCI.40.6.1705
Carvalho, C., Patiu, C. 2008. Key to the adults of the most common forensic species of diptera in South America. *Rev. Bras. Entomol.* 52, 390-406. https://doi.org/10.1590/S0085-56262008000300012
Chagnon, M., Gingras, J., De Oliveira, D., 1989. Effect of honey bee (Hymenoptera: Apidae) visits on the pollination rate of strawberries. *J. Econ. Entomol.* 82, 1350–1353. https://doi.org/10.1093/jee/82.5.1350
Chen, K., Fijen, T.P.M., Kleijn, D., Scheper, J. 2021. Insect pollination and soil organic matter improve raspberry production independently of the effects of fertilizers. *Agric. Ecosyst. Environ.* 309, 107270. https://doi.org/10.1016/j.agee.2020.107270
Cook, D.F., Voss, S.C., Finch, J.T.D., Rader, R.C., Cook, J.M., Spurr, C.J., 2020. The role of flies as pollinators of horticultural crops: an Australian case study with worldwide relevance. *Insects.* 11, 341. https://doi.org/10.3390/insects11060341
Costa, A.C., Machado, I.C., 2012. Flowering dynamics and pollination system of the sedge Rhynchospora ciliata (Vahl) Kükenth (Cyperaceae): does ambophily enhance its reproductive success? *Plant Biol.* 14, 881-887. https://doi.org/10.1111/j.1438-8677.2012.00574.x
Dellinger, A.S., 2020. Pollination syndromes in the 21st century: where do we stand and where may we go? *New Phyto.* 228, 1193-1213. https://doi.org/10.1111/nph.16793
Dicks, L.V., Breeze, T.D., Ngo, H.T., Senapathi, D., An, J., Aizen, M.A., Basu, P., Buchori, D., Galetto, L., Garibaldi, L.A., Gemmill-Herren, B., Howlett, B.G., Imperatriz-Fonseca, V.L., Johnson, S.D., Kovács-Hostyánszki, A., Kwon, Y.J., Lattorff, H.M.G., Lungharwo, T., Seymour, C.L., Vanbergen, A.J., Potts, S.G., 2021. A global-scale expert assessment of drivers and risks associated with pollinator decline. *Nat. Ecol. Evol.* 5, 1453-1461. https://doi.org/10.1038/s41559-021-01534-9
Dombroskie, J., 2011. A matrix key to families, subfamilies, and tribes of Lepidoptera of Canada. *Can. J. Arthropod Identif.* 17, 1-129. https://doi.org/10.3752/cjai.2011.17
Drossart, M., Michez, D., Vanderplanck, M., 2017. Invasive plants as potential food resource for native pollinators: a case study with two invasive species and a generalist bumble bee. *Sci. Rep.* 7, 16242. https://doi.org/10.1038/s41598-017-16054-5
Eeraerts, M., DeVetter, L.W., Batary, P., Ternest, J.J., Mallinger, R., Arrington, M., Benjamin, Blaauw, B.R., Campbell, J.W., Cavigliasso, P., Daniels, J.C., de Groot, G.A., Ellis, J.D., Gibbs, J., Goldstein, L., Hoffman, G.D., Kleijn, D., Melathopoulos, A., Miller, S.Z., Montero-Castaño, A., Naranjo, S.M., Nicholson, C.C., Perkins, J.A., Rao, S., Raine, N.E., Reilly, J.R., Ricketts, T.H., Rogers, E., Isaacs, R., 2023. Synthesis of highbush blueberry pollination research reveals region-specific differences in the contributions of honeybees and wild bees. *J. Appl. Ecol.* 60, 2528-2539. https://doi.org/10.1111/1365-2664.14516
Engel, M., 2012. The honey bees of Indonesia (Hymenoptera: Apidae). *Treubia.* 39, 1-85. https://doi.org/10.14203/treubia.v39i0.22
Evans, E., Smart, M., Cariveau, D., Spivak, M., 2018. Wild, native bees and managed honey bees benefit from similar agricultural land uses. *Agric. Ecosyst. Environ.* 268, 162–170. https://doi.org/10.1016/j.agee.2018.09.014
Frankel, R., Galun, E., 2012. *Pollination Mechanisms, Reproduction and Plant Breeding,* Vol. 2. Springer Science & Business Media, New York.
Free, J.B., 1993. *Insect Pollination of Crops*, second ed. Academic Press, London, UK.
Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., Aizen, M.A., Bommarco, R., Cunningham, S.A., Kremen, C., Carvalheiro, L.G., Harder, L.D., Afik, O., Bartomeus, I., Benjamin, F., Boreux, V., Cariveau, D., Chacoff, N.P., Dudenhöffer, J. H.B., Freitas, M., Ghazoul, J., Greenleaf, S., Hipólito, J., Holzschuh, A., Howlett, B., Isaacs, R., Javorek, S.K., Kennedy, C.M., Krewenka, K.M., Krishnan, S., Mandelik, Y., Mayfield, M.M., Motzke, I., Munyuli, T., Nault, B.A., Otieno, M., Petersen, J., Pisanty, G., Potts, S.G., Rader, R., Ricketts, T.H., Rundlöf, M., Seymour, C.L., Schüepp, C., Szentgyörgyi, H., Taki, H., Tscharntke, T., Vergara, C.H., Viana, B.F., Wanger, T.C., Westphal, C., Williams, N., Klein, A.M., 2013. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science.* 339, 1608–1611. https://doi.org/10.1126/science.1230200
Garibaldi, L.A., Carvalheiro, L.G., Leonhardt, S.D., Aizen, M.A., Blaauw, B.R., Isaacs, R., Kuhlmann, M., Kleijn, D., Klein, A.M., Kremen, C., Morandin, L., Scheper, J., Winfree, R., 2014. From research to action: enhancing crop yield through wild pollinators. *Front. Ecol. Environ.* 12, 439–447. https://doi.org./10.1890/130330
Garibaldi, L.A., Carvalheiro, L.G., Vaissiere, B.E., Herren, B.G., Hipolito, J., Freitas, B.M., Ngo, H.T., Azzu, N., Sáez, A., Åström, J., An, J., Blochtein, B., Buchori, D., García, F.J.C., da Silva, F.O., Devkota, K., de Fátima Ribeiro, M, Freitas, L., Gaglianone, M.C., Goss, M., Irshad, M., Kasina, M., Filho, A.J.S.P., Kiill, L.H.P., Kwapong, P., Parra, G.N., Pires, C., Pires, V., Rawal, R.S., Rizali, A., Saraiva, A.M., Veldtman, R., Viana, B.F., Witter, S., Zhang, H., 2016. Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science*. 351, 388-391. https://doi.org/10.1126/science.aac7287
Gonzalez, M., Baeza, E., Lao, J.L., Cuevas, J., 2006. Pollen load affects fruit set, size, and shape in cherimoya. *Sci. Hort.* 110, 51-56. https://doi.org/10.1016/j.scienta.2006.06.015
Gonzalez-Varo, J.P., Biesmeijer, J.C., Bommarco, R., Potts, S.G., Schweiger, O., Smith, H.G., Steffan-Dewenter, I., Szentgyorgyi, H., Woyciechowski, M., Vila, M., 2013. Combined effects of global change pressures on animal-mediated pollination. *Trend. Ecol. Evol.* 28, 524–530. https://doi.org/10.1016/j.tree.2013.05.008
Goodwin, M., 2012. *Pollination of Crops in Australia and New Zealand*. Rural Industries Research and Development Corporation, New Zealand.
Hallett, A.C., Mitchell, R.J., Chamberlain, E.R., Karron, J.D., 2017. Pollination success following loss of a frequent pollinator: the role of compensatory visitation by other effective pollinators. *AoB PLANTS.* 9, plx020. https://doi.org/10.1093/aobpla/plx020
Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Muller, A., Sumser, H., Horren, T., Goulson, D., de Kroon, H., 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLOS One.* 12, e0185809. https://doi.org/10.1371/journal.pone.0185809
Heard, T.A., 1999. The role of stingless bees in crop pollination. *Annu. Rev. Entomol.* 44,183-206. https://doi.org/10.1146/annurev.ento.44.1.183

Howard, S.R., Ratnayake M.N., Dyer, A.G., Garcia, J.E., Dorin, A., 2021. Towards precision apiculture: traditional and technological insect monitoring methods in strawberry and raspberry crop polytunnels tell different pollination stories. *PLoS ONE.* 16, e0251572. https://doi.org/10.1371/journal.pone.0251572

Jennings, D.L., 1988. *Raspberries and Blackberries: their Breeding, Diseases and Growth*. Academic Press, London.

Kalkman, C., 1993. Flora malesiana ser. *I. Letters.* 11, 227-351.

Keys, R.N., Buchmann, S.L., Smith, S.E., 1995. Pollination effectiveness and pollination efficiency of insects foraging *Prosopis velutina* in South-Eastern Arizona. *J Appl Ecol.* 32, 519-27. https://doi.org/10.2307/2404649

Kleijn, D., Winfree, R., Bartomeus, I., Carvalheiro, L.G., Henry, M., Isaacs, R., Klein, A.M., Kremen, C., M'Gonigle, L.K., Rader, R., Ricketts, TR.H., Williams, N.M., Adamson, N.L., Ascher, J.S., Báldi, A., Batáry, P., Benjamin, F., Biesmeijer, J.C., Blitzer, E.J., Bommarco, R., Brand, M.R., Bretagnolle, V., Button, L., Cariveau, D.P., Chifflet, R., Colville, J.F., Danforth, B.N., Elle, E., Garratt, M.P.D., Herzog, F., Holzschuh, A., Howlett, B.G., Jauker, F., Jha, S., Knop, E., Krewenka, K.M., Le Féon, V., Mandelik, Y., May, E.A., Park, M.G., Pisanty, G., Reemer, M., Riedinger, V., Rollin, O., Rundlöf, M., Sardiñas, H.S., Scheper, J., Sciligo, A.R., Smith, H.G., Steffan-Dewenter, I., Thorp, R., Tscharntke, T., Verhulst, J., Viana, B.F., Vaissière, B.E., Veldtman, R., Ward, K.L., Westphal, C., Potts, S.G., 2015. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. *Nat. Comm.* 6, 7414. https://doi.org/10.1038/ncomms8414

Krishna, S., Keasar, T., 2018. Morphological complexity as a floral signal: from perception by insect pollinators to co-evolutionary implications. *Int. J. Mol. Sci.* 19, 1681. https://doi.org/10.3390/ijms19061681

Kostryco, M., Chwil, M., 2022. Nectar abundance and nectar composition in selected Rubus idaeus *L. varieties. Agriculture*. 12, 1132. https://doi.org/10.3390/agriculture12081132

Lien, N., Carpenter, J., 2002. Vespidae of Vietnam (Insect: Hymenoptera) 1. Vespinae. *J. New York Entomol. Soc.* 110, 199-211.

Lien, N., Saito, F., Kojima, J., Carpenter, J., 2006. Vespidae of Vietnam (Insecta: Hymenoptera) 1. Taxonomic notes on Vespinae. *Zool. Scie.* 23, 95-104.

Lye, G.C., Jennings, S.N., Osborne, J.L., Goulson, D., 2011. Impacts of the use of non-native commercial bumble bees for pollinator supplementation in raspberry. *J. Econ. Entomol.* 104, 107-114. https://doi.org/10.1603/ec10092.

May-Itza, W.J., Martinez-Fortun, S., Zaragoza-Trello, C., Ruiz, C., 2021. Stingless bees in tropical dry forests: global context and challenges of an integrated conservation management. *J. Apic. Res.* 61, 642-653, https://doi.org/10.1080/00218839.2022.2095709

Michener, C. 2007. *The Bees of the World*. The Johns Hopkins University Press, Maryland.

Minnaro, M., Garcia, D., Rosa-Garcia, R., 2023. Pollination of exotic fruit crops depends more on extant pollinators and landscape structure than on local management of domestic bees. *Agric. Ecosyst. Environ.* 347, 108387. https://doi.org/10.1016/j.agee.2023.108387

Minnaro, M., Garcia, D., 2018. Complementarity and redundancy in the functional niche of cider apple pollinators. *Apidologie.* 49, 789-802. https://doi.org/10.1007/s13592-018-0600-4

Morales, C.L., Arbetman, M.P., Cameron, S.A., Aizen, M.A., 2013. Rapid ecological replacement of a native bumble bee by invasive species. *Front. Ecol. Environ.* 11, 529–534. https://doi.org/10.1890/120321

Naghiloo, S., Nikzat-Siahkolaee, S., Esmaillou, Z., 2021. Size-matching as an important driver of plant–pollinator interactions. *Plant Biol.* 23, 583-591.https://doi.org/10.1111/plb.13248

Nielsen, A., Reitan, T., Rinvoll, A.W., Brysting, A.K. 2017. Effects of competition and climate on a crop pollinator community. *Agric. Ecosyst. Environ.* 246, 253-260.

Normasiwi, S., Salamah, A., Surya, M.I. 2021. Morphological characteristics of Indonesian Rubus flowers. *Biodiversitas.* 22, 1441-1447. https://doi.org/10.13057/biodiv/d220347

Olesen, J.M., Dupont, Y.L., Ehlers, B.K., Hansen, D.M., 2007. The openness of a flower and its number of flower-visitor species. *Taxon.* 56, 729-736. https://doi.org/10.2307/25065857

Ollerton, J., Winfree, R., Tarrant, S., 2011. How many flowering plants are pollinated by animals? *Oikos.* 120, 321-326. https://doi.org/ 10.1111/j.1600-0706.2010.18644.x

Page, M.L., Nicholson, C.C., Brennan, R.M., Britzman, A.T., Greer, J., Hemberger, J., Kahl, H., Müller, U., Peng, Y., Rosenberger, N.M., Stuligross, C., Wang, L., Yang, L.H., Williams, N.M., 2021. A meta-analysis of single visit pollination effectiveness comparing honeybees and other floral visitors. *Am. J. Bot.* 108, 2196–2207. https://doi.org/10.1002/ajb2.1764

Paini, D.R., Roberts, J.D., 2005. Commercial honey bees (*Apis mellifera*) reduce the fecundity of an Australian native bee (*Hylaeus alcyoneus*). *Biol. Conserv.* 123, 103-112. https://doi.org/10.1016/j.biocon.2004.11.001

Pawar, N. Thakur, N., Negi, M., Paliwal, A., 2017. Studies on pollen germination, pollination and fruit set in raspberry (*Rubus ellipticus*) under hilly conditions of Uttarakhand. *Int. J. Curr. Microbiol. App. Sci.* 6, 3698-3703. https://doi.org/10.20546/ijcmas.2017.609.456

Perez-Mendez, N., Andersson, G.K.S., Requier, F., Hipolito, J., Aizen, M.A., Morales, C.L., Garcia, N., Gennari, G.P., Garibaldi, L.A., 2020. The economic cost of losing native pollinator species for orchard production. *J. Appl. Ecol.* 57, 599-608. https://doi.org/10.1111/1365-2664.13561

Pinczinger, D., von Reth, M., Hanke, M.V., Flachowsky, H., 2021. Self-incompatibility of raspberry cultivars assessed by SSR markers. *Sci. Hort.* 288, 110384. https://doi.org/10.1016/j.scienta.2021.110384

Pinillos, V., Cuevas, J., 2008. Artificial pollination in tree crop production. *Hortic. Rev.* 34, 239–276. https://doi.org/10.1002/9780470380147.ch4

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., Kunin, W.E., 2010. Global pollinator declines: trends, impacts and drivers. *Trend. Ecol. Evol.* 25, 345–353. https://doi.org/10.1016/j.tree.2010.01.007

Pritchard, K.D., Edwards, W., 2006. Supplementary pollination in the production of custard apple (*Annona* sp.) – the effect of pollen source. *J. Hortic. Sci. Biotechnol.* 81, 78-83. https://doi.org/10.1080/14620316.2006.11512032

Putra, R.E., Permana, A.D., Kinasih I., 2014. Application of asiatic honey bees (*Apis cerana*) and stingless bees (*Trigona laeviceps*) as polinator agents of hot pepper (*Capsicum annuum* L.) at local Indonesia farm system. *Psyche: A Journal of Entomology*. 2024, 1-11. https://doi.org/10.1155/2014/687979

Rader, R., Bartomeus, I., Garibaldi, L.A., Garratt, M.P., Howlett, B.G., Winfree, R., Cunningham, S.A., Mayfield, M.M., Arthur, A.D., Andersson, G.K.S., Bommarco, Brittain, C., Carvalheiro, L.G., Chacoff, N.P., Entling, M.H., Foully, B., Freitas, B.M., Gemmill-Herren, B., Ghazoul, J., Griffin, S.R., Gross, C.L., Herbertsson, L., Herzog, F., Hipólito, J., Jaggar, S., Jauker, F., Klein, A.M., Kleijn, D., Krishnan, S., Lemos, C.Q., Lindström, S.A.M., Mandelik, Y., Monteiro, V.M., Nelson, W., Nilsson, L., Pattemore, D.E., Pereira, N.O., Pisanty, G., Potts, S.G., Reemer, M., Rundlöf, M., Sheffield, C.S., Scheper, J., Schüepp, C., Smith, H.G., Stanley, D.A., Stout, J.C., Szentgyörgyi, H., Taki, H., Vergara, C.H., Viana, B.F., Woyciechowski, M., 2016. Non-bee insects are important contributors to global crop pollination. *PNAS*. 113, 146-151. https://doi.org/10.1073/pnas.1517092112

Reilly, J.R., Artz, D.R., Biddinger, D., Bobiwash, K., Boyle, N.K., Brittain, C., Brokaw, J., Campbell, J.W., Daniels, J., Elle, E., Ellis, J.D., Fleischer, S.J., Gibbs, J., Gillespie, R.L., Gundersen, K.B., Gut, L., Hoffman, G., Joshi, N., Lundin, O., Mason, K., McGrady, C.M., Peterson, S.S., Pitts-Singer, T.L., Rao, S., Rothwell, N., Rowe, L., Ward, K.L., Williams, N.M., Wilson, J.K., Isaacs, R., Winfree, R., 2020. Crop production in the USA is frequently limited by a lack of pollinators. *Proc. R. Soc. B.* 287, 20200922. https://doi.org/10.1098/rspb.2020.0922

Saez, A., Morales, C.L., Ramos, L.Y., Aizen, M.A., 2014. Extremely frequent bee visits increase pollen deposition but reduce drupelet set in raspberry. *J. App. Ecol.* 51, 1603-1612. https://doi.org/10.1111/1365-2664.14519

Saez, A. Morales, J.M., Morales, C.L., Harder, L.D., Aizen, M.A., 2018. The costs and benefits of pollinator dependence: empirically based simulations predict raspberry fruit quality. *Ecol. Appl.* 28, 1215-1222. https://doi.org/10.1002/eap.1720

Saez, A., Garibaldi, L.A., Aizen, M.A., Morales, C.L., Traveset, A., de Groot, G.S., Schmucki, R., 2023. Phenological overlap between crop and pollinators: contrasting influence of native and non-native bees on raspberry fruits over the flowering season. *J. App. Ecol.* 60, 2540-2549.

Santos, C.F., Absy, M.L., 2010. Pollinators of *Bertholletia excelsa* (Lecythidales: Lecythidaceae): interactions with stingless bees (Apidae: Meliponini) and trophic niche. *Neotrop. Entomol.* 39, 854-861. https://doi.org/10.1590/s1519-566x2010000600002

Schiestl, F.P., Glaser, F., 2012. Specific ant-pollination in an alpine orchid and the role of floral scent in attracting pollinating ants. *Alp. Bot.* 122, 1–9. https://doi.org/10.1007/s00035-011-0098-0

Schmack, J.M., Egerer, M., 2023. Floral richness and seasonality influences bee and non-bee flower interactions in urban community gardens. *Urban Ecosyst.* 26, 1099-1112. https://doi.org/10.1007/s11252-023-01353-9

Schmidt, K., Filep, R., Orosz-Kovács, Z., Farkas, A., 2015 Patterns of nectar and pollen presentation influence the attractiveness of four raspberry and blackberry cultivars to pollinators. *J. Hort. Sci. Biotechnol.* 90, 47-56. https://doi.org./10.1080/14620316.2015.11513152

Scudder, G., Cannings, R., 2006. *The Diptera Families of British Columbia*. University of British Columbia Press, Vancouver.

Seebens, H., Essl, F., Dawson, W., Fuentes, N., Moser, D., Pergl, J., Pyšek, P., van Kleunen, M., Weber, E., Winter, M., Blasius, B., 2015. Global trade will accelerate plant invasions in emerging economies under climate change. *Glob. Change Biol.* 21, 4128-4140. https://doi.org/10.1111/gcb.13021

Sengupta, J., Naskar, A., Maity, A., Hazra, S., Banerjee, D., 2016. New distributional records and annotated keys of hover flies (Insecta: Diptera: Syrphidae) from Himachal Pradesh. *India. J. Adv. Zool.* 37, 29-52.

Shuler, R.E., Roulston, T.H., Farris, G.E., 2005. Farming practices influence wild pollinator populations on squash and pumpkin. *J. Econ. Entomol.* 98, 790–795. https://doi.org/10.1603/0022-0493-98.3.790

Silveira, M.V., Abot, A.R., Nascimento, J.N., Rodrigues, E.T., Rodrigues, S.R., Puker, A., 2012. Is manual pollination of yellow passion fruit completely dispensable? *Sci. Hortic.* 146, 99-103. https://doi.org/10.1016/j.scienta.2012.08.023

Smith, D., 2012. Key to Workers of Indo-Malayan stingless bees. *In: Proceedings of the 11th International Conference of the Asian Apicultural Association, Kuala Terengganu, Malaysia, Vol 1*. Terengganu: Kansas Univ Pr. pp. 1-42.

Speight, M., 2014. *Key for the Identification of the Genera of European Syrphidae*. Trinity College Press, Dublin.

Staab, M., Pereira-Peixoto, M.H., Klein, A.M., 2020. Exotic garden plants partly substitute for native plants as resources for pollinators when native plants become seasonally scarce. *Oecologia.* 194, 465-480. https://doi.org/10.1007/s00442-020-04785-8

Stamenkovic, Z., Pavkov, I., Radojcin, M., Horecki, A.T., Kešelj, K., Kovacevic, D.B., Putnik, P., 2019. Convective drying of fresh and frozen raspberries and change of their physical and nutritive properties. *Foods*. 8, 251. https://doi.org/10.3390/foods8070251

Stratton, A.E., Kuhl, L., Blesh, J., 2020. Ecological and nutritional functions of agroecosystems as indicators of smallholder resilience. *Front. Sustain. Food Syst.* 4, 543914. https://doi.org/10.3389/fsufs.2020.543914

Suhri, A.G.M.I., Soesilohadi, R.C.H., Putra, R.E., Raffiudin, R., Purnobasuki, H., Agus, A., Kahono, S., 2022. The effectiveness of stingless bees on pollination of bitter melon plants *Momordica charantia* L. (Cucurbitaceae). *J. Trop. Biodiv. Biotech.* 7, 69124. https://doi.org/10.22146/jtbb.69124

Taylor, B.W., Irwin, R.E., 2004. Linking economic activities to the distribution of exotic plants. *PNAS.* 101, 17725-17730. https://doi.org/10.1073/pnas.0405176101

Tiwari, A., Singh, S.K., Bora, A., Gogoi, B.J., Dwidevi, S.K., 2021. Introduction and evaluation of new exotic vegetable crops under protected conditions in high altitude of Tawang, Arunachal Pradesh. *Progress. Hortic.* 53, 83-89. https://doi.org/10.5958/2249-5258.2021.00015.4

van Valkenburg, J.L.C.H, Bunyapraphatsara, N., 2001. *Plant Resources of South-East Asia no. 12 (2). Medicinal and Poisonous Plants 2.* Backhuys Publishers: Leiden, Netherlands.

Vila, M., Bartomeus, I., Dietzsch, A.C., Petanidou, T., Steffan-Dewenter, I., Stout, J.C., Tscheulin, T., 2009. Invasive plant integration into native plant pollinator networks across Europe. *Proc. R. Soc. B.* 276, 3887–3893. https://doi.org/10.1098%2Frspb.2009.1076

Waithaka, N.A., Kasina, M., Samita, N.E., Guantai, M.M., Omuse, E.R., Toukem, N.K., Lattorff, H.M.G., Abdel-Rahman, E.M., Adan, M., Mohamed, S.A., Dubois, T., 2023. Interactions between integrated pest management, pollinator supplementation, and normalized difference vegetation index in pumpkin, *Cucurbita maxima* (Cucurbitales: Cucurbitaceae), production. *Environ. Entomol.* 16, 416-425. https://doi.org/10.1093/ee/nvad035

Westerkamp, C., Gottsberger, G., 2000. Diversity pays in crop pollination. *Crop. Sci.* 40, 1209-1222. https://doi.org/10.2135/cropsci2000.4051209x

Williams, N.M., Cariveau, D., Winfree, R., Kremen, C., 2011. Bees in disturbed habitats use, but do not prefer, alien plants. *Basic App. Ecol.* 12, 332–341. https://doi.org/10.1016/j.baae.2010.11.008

Willmer, P.G., Bataw, A.A.M., Hughes, J.P., 2008. The superiority of bumble bees to honey bees as pollinators: insect visits to raspberry flowers. *Ecol. Entomol.* 19, 271–284. https://doi.org/10.1111/j.1365-2311.1994.tb00419.x

Winfree, R., 2013. Global change, biodiversity, and ecosystem services: what can we learn from studies of pollination? *Bas. Appl. Ecol.* 14, 453-460. https://doi.org/10.1016/j.baae.2013.07.004

Winfree, R., Fox, J.W., Williams, N.M., Reilly, J.R., Cariveau, D.P., 2015. Abundance of common species, not species richness, drives delivery of a real-world ecosystem service. *Ecol. Lett.* 18, 626-635. https://doi.org/10.1111/ele.12424

Woitowicz, F.C.G., da Silva, C.I., Ramalho, M., 2023. Influence of generalist stingless bees on the structure of mutualistic flower–pollinator networks in the tropics: Temporal variation. *Ecol. Entomol*. 49, 338-356. https://doi.org/10.1111/een.13308

Wongsa, K., Duangphakdee, O., Rattanawannee, A., 2023. Pollination efficacy of stingless bees, *Tetragonula pagdeni* Schwarz (Apidae: Meliponini), on greenhouse tomatoes (*Solanum lycopersicum* Linnaeus). *PeerJ.* 11, e153657. https://doi.org/10.7717/peerj.15367

Wurz, A. Grass, I., Tscharntke, T. 2021. Hand pollination of global crops – a systematic review. *Bas. Appl. Biol.* 56, 299-321. https://doi.org/10.1016/j.baae.2021.08.008

Żurawicz, E., 2016. Cross-pollination increases the number of drupelets in the fruits of red raspberry (*Rubus idaeus* L.). *Acta Hortic.* 1133. 145–152. https://doi.org/10.1016/j.scienta.2018.02.064