The role of wild pollinators enhancing the sustainable productivity and quality of arabica coffee in agroforestry

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Abstract

Crop, coffee, productivity and quality, in this study, was conducted at Ban Khun Lao, Chiang Rai Province and investigated the impact of pollination services. The different pollinations were compared between autogamy, wind pollination, and open pollination on various parameters following: fertilisation ratio, fruit set, cherry weight, ripening uniformity. Among these, open pollination was recorded at the significantly highest results. Data on weight of green beans and total yield exhibited clearly that open pollination were heavier than on wind pollination and autogamy. In addition, the taste and aroma of given coffee from open pollination were honey, caramelised and jasmine which navigated mostly to the sweet and floral. These results indicated that the community and diversity of insect pollinators had the dramatic effectiveness toward the productivity and quality of arabica coffee in organic-agroforestry.

Keywords: Wild pollinators, Arabica coffee, Agroforestry, Productivity, Cup quality

Introduction

Agroforestry is the land-use system which applied together with technology and land management in perennials area aimed for agricultural production. In agroforestry system, particularly, can be defined as a dynamic, ecologically based, natural resource management system that benefit to human, notably pollination services (Priess et al., 2007). Pollination service is the most important for both natural and agricultural system due to most of flowering plants depend on insect pollinators for crop production. (Bentrup et al., 2019). In our previous investigation, we studied on insect diversity and density of insect fauna in agroforestry area, coffee farming among natural plants, at Ban Khun Lao, Wieng Pa Pao district, Chiang Rai Province, northern Thailand, which leads to present study "The role of wild pollinators enhancing the sustainable productivity and quality of arabica coffee in agroforestry". Coffea arabica, is dominant variety of coffee in northern Thailand. The previous study indicated that coffee flower pollination was performed by a number of native insect species. (Wissarut et al., 2017). These species contained various of insect orders which were confederate in action. Even though, wind pollination and autogamy were usually occurred; there were various evidence that quality and quantity of arabica coffee bean were enhanced by insect pollinators (Ngo et al., 2011; Smith, 2010). The number of cherries was increased significantly in the area where has higher density and diversity of insect fauna. High diversity and density pollinator. High diversity and density of pollinator service increased effectiveness of pollination by enormous number of pollens deposited on

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stigmas and the chance of cross pollination. In addition, ripening was more uniformity when flowers were pollinated from insect pollinators for example bees, and stingless bees (Corbet et al., 2015; Karanja et al., 2013; Klein et al., 2003; Vergara & Badano, 2009)

Not only in productivity, coffee cup quality was also influenced by the many inputs especially the pollination services from insect. Previous reports revealed that taste and aroma of processed coffee were enhanced by the pollination distinctively. (Karanja et al., 2013; Ricketts et al., 2004; Roubik, 2002) Mostly, the higher quality of C. arabica commonly grown in north of Thailand were located where national park nearby. Therefore, organic plantation method is probably introduced and recognised for growers allowing not any effects to the natural fauna and flora.

Materials and methods

The experiment was carried out in flowering season of April, 2016 in arabica coffee plantation where organic practices held at 1,200 to 1,300 metres above sea level at Ban Khun Lao village Wieng Pa Pao district, Chiang Rai province, north of Thailand. The temperature ranged between 13.23±2.01 to 27.45±1.75 oC and relative humidity was between 78.41±3.12 and 86.73±2.21%. The 5 to 6 years old coffee plants without any applied chemicals, were selected from 3 different sites for replication. Branches on selected plants with six clusters of flower pods were marked for experiment. There were 3 treatments: self pollination or autogamy (control treatment), wind pollination (none of insect pollinating service), and open pollination (insect pollinating services).

Number of flower pods on selected branches were counted prior applied experimental treatments, including (1) self pollination or autogamy (2) wind pollination and (3) open pollination or insects' pollinator service, which were considered as control treatment, insects' pollination services and insects' pollination services. Firstly, self pollination or autogamy, the pods were covered with gauze to protect them from other factors, while the second treatment-wind pollination, the selected branches with six clusters of flowers were enclosed in nylon mesh bag until the pollination completed. The latter treatment, the selected branches were leaved openly to attract the pollinators.

After 3 days, the distinctly enlarged receptacles were counted and the fertilisation ratio were calculated using the following equation : (Number of enlarged receptacles/ total number of flower pods) x100. The treatments then were left for harvesting.

At harvesting season, the total number of cherries and ripe fruits were counted, then ripening uniformity was calculated using (Number of ripe cherries/ total number of cherries) x100. Fully ripe cherries were picked from each treatment were weighed and measured for quantifying. Cherries, then, were taken into dried processing within 10 hours to prevent the deterioration that might affect to quality cup. The 100 green beans and total yield per shrub were weighted.

The none defected coffee green beans from each 3 different pollination methods were taken into light roasting process, hot-air roaster with internal temperature of 180°c – 205°c until the beans popped or cracked and expanded in size to serve cupping process. The light roasting was held for the cupping study to retain more the origin flavours and unique elements, reflecting the natural qualities of the coffee and also offered the multilayered complexity, revealing traces of sweetness, fruit tanginess, or even subtle floral aroma. The coffee cupping was conducted at the laboratory of the coffee factory of Green Net Co., Ltd using the method by SCAA to clarify the he characteristics of the given coffee from the experiment. The quality scale ranged following the table below. Moreover, the specific descriptors of coffee experiences were navigated using the Coffee Flavour Wheel of SCAA.

Results and Discussion

The 3 different pollination methods from the previous flowering season in 2016 were significantly different from all aspects. The open pollination with the services of various insect pollinators of organic coffee agroforestry showed the dramatic highest of the successful fertilisation with 98.75 % followed by wind pollination showing at 64.23%. In contrast, the lowest

Table 1 Standard quality scale from SCAA Cupping Form.

Scale	Description
6.00 - 6.75	Good
7.00 - 7.75	Very good
8.00 - 8.75	Excellent
9.00 - 9.75	Outstanding

Table 2 Pre-harvest productivity of arabica coffee given from 3 different pollination method.

Pollination methods	Fertilisation ratio (%)	Fruit set (%)	Berry weight (g)	Ripening uniformity (%)
Autogamy	23.71±1.23	4.2±0.52	1.61±0.04	8.38±0.12
Wind pollination	64.23±2.01	11.3±0.42	2.13±0.05	34.84±0.24
Open pollination	98.75±1.34	75.43±0.65	2.14±0.07	88.26±0.51
MEAN	81.79	30.31	1.96	43.83
F-test	**	**	**	**

Table 3 Yield and quantity of coffee green bean given from 3 different pollination method

Pollination methods	Weight of 100 green beans (g)	Total yield (green bean) per shrub (kg)
Autogamy	14.95±2.2	0.05±0.3
Wind pollination	17.77±2.3	0.11±0.02
Open pollination	18.25±1.8	0.25±0.02
MEAN	16.65	0.13
Prop entry	**	**

successful fertilisation was observed from the autogamy showing at 23.71%. Similarly, the highest percentage of fruit set was observed from the open pollination followed by wind pollination and autogamy showing at 75.43%, 11.30%, and 4.20%, respectively. Noticeably, cherry weights per fruit from the open pollination and wind pollination were not significantly different at 2.14 g and 2.13g. While the autogamy gave the lowest cherry weight at 1.61 g. Moreover, the ripening uniformity from these pollination methods was significantly different. The open pollination remained the good productivity of ripening uniformity at 88.26% followed by wind pollination and autogamy showing at 34.84g, and 8.38g. (Table 2)

Weight of 100 green beans from 3 different pollination methods was clarified that open pollination gave the highest quantity than the 2 others. Consequently, the total yield of green bean observed from the open pollination was better than wind pollination and autogamy, distinctively. (Table 3)

The fertilisation ratio held from the enlarged receptacles due to the fact that after the incident of fertilisation, the ovary within the flower suddenly developed. This current results have shown that fertilisation ratio of coffee flower given from open pollination is approximately four times greater than on autogamy which are similar to the other studies. (Karanja et al., 2013) Moreover, the consequence of open pollination had distinctively shown the difference to other pollination methods. The amount of fruit-set from open-pollinated flower was the greatest among three pollination method. Correspondingly, the higher coffee yields given from open pollination have been reported in previous studies. The berry weight from open pollination was heavier than on autogamy and wind pollination which were bagged with fine-mesh .These translated to higher yielding coffee (Karanja et al., 2013)

With the SCAA coffee cupping form, there were similar results from the different pollination methods. The total scores were slightly different ranging from 66.75, 65.75, and 64.75 from the open pollination, wind pollination and autogamy, respectively. The 2 variables were discarded out from the consideration for instance uniformity and clean cup, because only non-defected green beans had been selected prior to the roasting process. The sweetness and body of coffee were similar among the 3 pollination methods. The acidity from autogamy was merely higher than the others which represented a bit sourer. The autogamy also lost some balance compared to the others. Importantly, the highest scores of the fragrance or aroma of coffee were obtained from the open pollination followed by wind pollination and autogamy. (Figure 1)

According to the Coffee Flavour Wheel from SCAA, the taste and aroma of given coffee from open pollination were honey, caramelised and jasmine which navigated mostly to the sweet and floral. The wind pollination in contrast gave the green/ vegetative

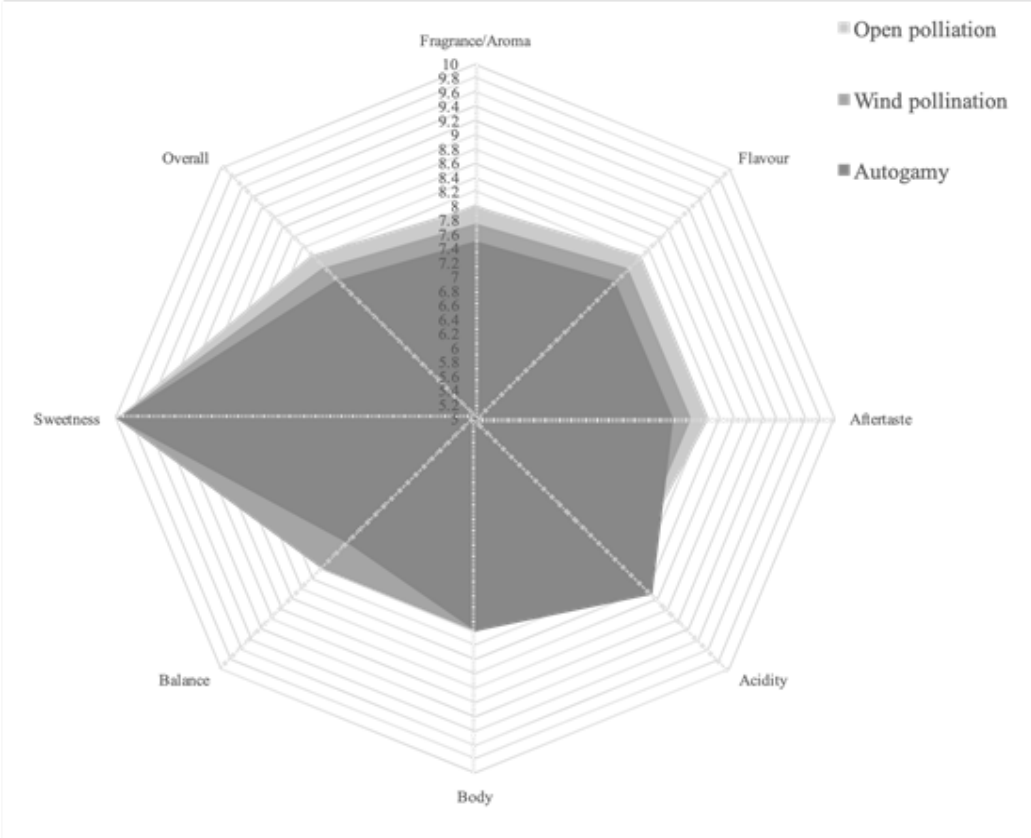

Figure 1. The quality cup of coffee from 3 different pollination methods. The variables compared were following: sweetness, overall, fragrance/aroma, flavour, aftertaste, acidity, body, and balance and were considered with the method by SCAA.

sense from fresh and herb-like aroma. Interestingly, the aromas navigated on flavour wheel were varied for instance brown sugar, nutty, and cereal.

This recent study has shown that the wild pollinators caused the cross pollination of coffee flowers were not influenced only on the enhancement of fertilisation, fruit set, and berry weight, but also played a significant role to cup quality. This phenomenon was described as the presence of pollinators affected to the quality of flower fertilisation, avoiding the misshapen fruits, and defected green bean. Without pollinators, the coffee flowers were leaded to self pollination or autogamy which inferior biological qualities associated with the pleasant aroma of cup quality. (Karanja et al., 2011; Karanja et al., 2014; Krishnan et al., 2012; Roubik, 2002)

Conclusion

Ecological service available from pollinating insect community as can be seen from open pollination was significant influenced to the productivity of arabica coffee especially in pre-harvest stage. The quality of fertilisation, fruit set, cherry weight, and ripening uniformity given from open pollination were superior than on wind pollination and self pollination or autogamy. These beneficial productivities initiate to the lower cost in hand-picking harvest, less time consuming of green bean grading. Importantly, the presence of wild pollinators built up the uniqueness of cup quality. As can be seen from the Coffee Flavour Wheel, the light roasted coffee given from open pollination indicated to wild flowers scent. Therefore, keeping abundance of wild pollinators where the organic agriculture is held for coffee plantation could lead the potential of arabica coffee production.

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