BJNRD (2022), 9(2): 1-12
Bhutan Journal of Natural Resources & Development

Article

www.bjnrd.org

Open Access

ISSN 2409–2797 (Print)
ISSN 2409–5273 (Online)

DOI: https://doi.org/10.17102/cnr.2022.75

Farmers' Perception on Pollinators and Apple Pollination in Western Bhutan

Kinley Dorji[1], Leon Marshall[2,4], Sonam Tashi[1] and Koos Biesmeijer[3,4]

Abstract

Apples are one of the most important global fruit crops both in terms of yield and economic value, and rely on insect pollination. Pollination has been shown to increase apple production and economic value. The apple production in Bhutan has decreased from 7,051 MT in 2014 to 3,684 MT in 2018. Among the factors identified for the decline of apple quality and yield, pollinator deficits in orchards and inefficient pollination are hypothesised to be less recognised among Bhutanese farmers. Here we surveyed the knowledge and perception of farmers towards apple pollination and pollinators in the three dominant apple-producing districts of Bhutan: Thimphu, Paro, and Haa. One hundred and five farmers (35 from each district) were interviewed using a semi-structured questionnaire. When asked about the yield trend compared to previous years, 74.3% of the respondents noticed a decrease in yield compared to the year 2019, and 96.2% of the respondents said yield has decreased over the last five years. Sixty percent of the farmers were unaware of apple pollination and the importance of pollinators. The farmers could not differentiate between different pollinator species, with honeybees being the only pollinator known to the farmers. Education and years of working experience were found to influence farmers' knowledge about pollinators and apple pollination. This study establishes baseline information of farmers' knowledge in Bhutan, which will be useful to improve farm management practices that will benefit apple quality and productivity, as well as pollinator conservation.

Keywords: apple, bee, knowledge, pollination

Introduction

Pollination is an important natural process necessary for maintaining wild plant diversity globally and also in providing vital ecosystem services to agriculture (Giannini *et al*., 2012; Ollerton, 2017). Insects are by far the most dominant animal pollinators. IPBES (2016) states that an estimated US$ 235 to US$ 577 billion in annual global crop output is at risk as a result of insect pollinator loss. With an insect-dependency rate between 80-100% (Hein, 2009), one such fruit crop that requires insect pollination is apple, which is one of the most important global fruit crops both in terms of yield

[1]College of Natural Resources, Royal University of Bhutan, Punakha, Bhutan
[2]Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, The Netherlands
[3]Institute of Environmental Sciences, Leiden University, Leiden, The Netherlands
[4]Agroecology Lab, Université libre de Bruxelles (ULB), Bonlevard du Triomphe, CP 264/02, 13 B-1050, Brussels, Belgium
*Corresponding Author: dorjikinley43@gmail.com
Received: October 14, 2021
Accepted: December 22, 2022
Published online: December 30, 2022
Editor: Tulsi Gurung, College of Natural Resources, Lobesa

and economic value (FAO, 2020). However, several studies show that apple yield and quality have been declining in many parts of the world in recent years (Jasra *et al*., 2001; Partap and Partap, 2004).

Several factors have been identified for the decline of apple quality and yields, such as orchard shrinkage, tree nutrition level, and compatibility among cultivars (Sheffield, 2014). However, lack of enough pollinators in orchards (Rather *et al*., 2017) resulting in inefficient pollination is generally less recognized among the farmers in certain regions (Partap and Partap, 2004). Alemu (2014) reported that farm management activities for crops are well invested, but little is invested in pollination services. Moreover, farmers' knowledge of apple pollination and pollinators also plays a vital role in the conservation process of the pollinator species (Park *et al*., 2018). Understanding farmers' knowledge and perception of pollinators is vital for efficient farm management practices that will not only benefit pollinators' health but also bring about a sustainable agricultural ecosystem (Eardley *et al*., 2006; Park *et al*., 2018; Ali *et al.*, 2020).

Apples were introduced in Bhutan in the late 1960s and have been a leading cash crop in the country for over a decade (Choden and Shahnawaz, 2015). Apples in Bhutan are grown in the temperate zone (1,800–4,500 m above sea level) and are planted even on steep mountainous terrain by curving outward sloping terraces with a maximum of 30 degrees slope to prevent waterlogging (Choden and Shahnawaz, 2015), as Bhutan's agricultural policy encourages farmers to plant apples on marginal sloping lands that are unsuitable for cultivation of other crops (Partap *et al*., 2012). According to the RNR Census report (2019) of Bhutan, there are 5,533 apple growers in the country and a total of 263,702 apple trees.

Partap *et al.* (2012) evaluated the economic contribution of insect pollination for 32 different crops in Bhutan. The study reported that the economic value of insect pollination for these 32 crops was US$17.88 million with a vulnerability rate of 14.5%. Fruits benefited the most from insect pollinators in Bhutan with an economic value of US$ 10.92 and 20.7% is vulnerable to pollinator loss (Partap *et al*., 2012). However, apple production in the country has decreased from 7,051 metric tons (MT) in 2014 to 3,684 (MT) in 2018 (RNR Census report, 2019), and only little is known about farmers' perception and knowledge of pollinators and apple pollination in Bhutan. Pollination is potentially an unknown, undervalued, and understudied service in Bhutan.

In order to increase apple quality and yield sustainably and to benefit pollinators in apple orchards, it is important to study and understand farmers' perception and knowledge of pollinators and apple pollination. Here, surveys were used to examine the factors affecting this knowledge and establish a baseline of key information around apple pollination in Bhutan. This information will be useful to the local leaders and the government to develop context -specific conservation strategies of pollinators and come up with ways to improve apple farming in the country through basic knowledge on environmental education to the Bhutanese farmers.

Materials and Methods

Location of the study site

The study was conducted from February 2020 to October 2020, in Thimphu, Paro and Haa, which are three of the major apple-growing districts located in the western part of Bhutan (Figure 1). According to the RNR Census report (2019), Paro is the highest apple-producing district with 2,417.72 MT (65.62%), followed by Thimphu with 755.24 MT (20.50%), and Haa with 293.32 MT (7.96%). The mean annual temperature in the study sites varies from 4.6 ˚C in winter to 23 ˚C in summer (NCHM, 2017), which is considered very suitable for apple cultivation (Choden and Shahnawaz, 2015), and the mean annual rainfall varies between 386.3 mm and 858.4 mm (NCHM, 2017).

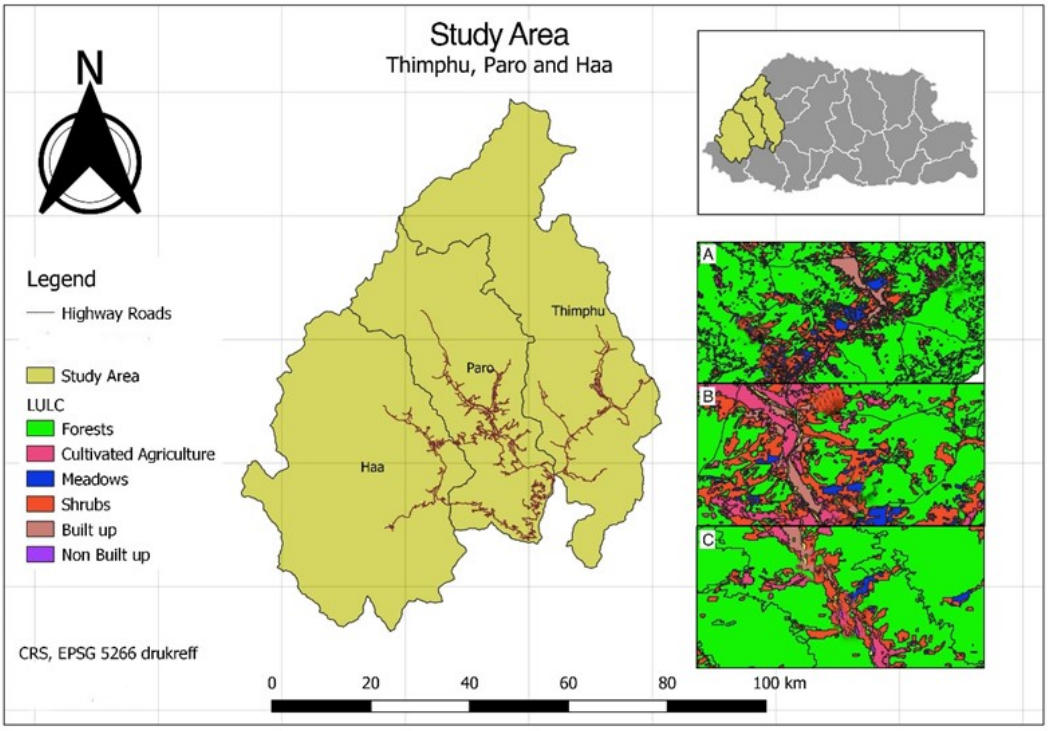

Figure 1: Location of the study site; (A) Thimphu, (B) Paro and (C) Haa, showing the land use land cover (LULC data of 2016)

Farmer survey: sampling techniques and data collection

Farmers' knowledge and perception of orchard management and pollination were obtained through a semi-structured survey questionnaire with closed and open-ended questions. A total of 105 apple farmers from Thimphu, Paro, and Haa districts (35 from each district) were surveyed using snowball sampling technique, where the surveyed farmers recommended and located their colleagues for the survey. The survey was conducted before flowering season (February-March, 2020). However, with the confirmation of the first Covid-19 case in the country in early March 2020, movements were restricted, and the survey had to be continued during the harvest period (September-October, 2020).

The survey questionnaire generated information on general characteristics of apple farmers and their orchards, including level of education and years of working experience of the farmers, orchard size and surrounding, annual production, and income. The survey questionnaire was pre-tested with 30 individuals comprising agricultural and forestry students of the College of Natural Resources, and vegetable farmers from nearby villages. Comments received from the pre-testing were used in improving the questionnaire. The final questionnaire had six focus areas: (1) demographics, (2) orchard details, (3) farm management, (4) production and income, (5) knowledge and perception of pollination, and (6) climate change perception.

Face-to-face survey interview was conducted in local language/dialect and in English where needed. While the farmers understood most of the questions and discussions, sometimes farmers required interpretation and proper explanation of some terms and processes to make them clearly understand the purpose of the questions. The survey interview lasted for about 30 minutes on an average.

Data processing and analysis

The education level of the farmers was categorized as none (no education at all), non-formal education (NFE, basic reading and writing in both English and Dzongkha), primary (a mini-

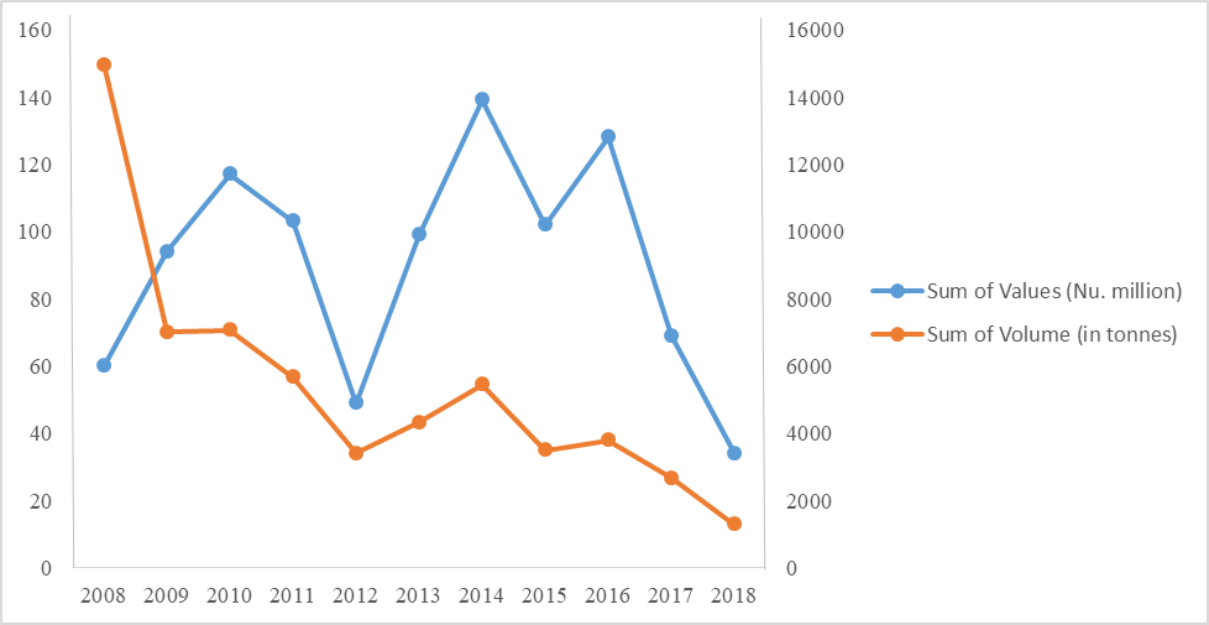

Figure 2: Apple export in production and value, based on the RNR Census report of Bhutan (2019)

mum of at least six years in school), and higher education (a minimum of nine years in school). Working experience of the farmers in the apple orchards was categorized as less than 10 years, between 10 to 20 years, between 20 to 30 years, and more than 30 years. The orchard surrounding was categorized based on the landscape that dominated the orchard (more than 50% of the land cover) as forest cover, agricultural land, agroforestry (both agricultural and forest land), orchard, and peri-urban with settlement.

Responses were recorded for all questions as a proportion of the 105 surveyed farmers. Frequency tables were used to compare the count of orchards in each of the landscapes surrounding the orchard within each of the districts, and to compare farmers' perception of the falling price of the Bhutanese apple in the export market. A Chi-square test was conducted to check association between annual apple production and annual income of households, annual apple production, and the number of fruit-bearing trees in the orchard. Logistic regression analysis was conducted to determine the factors influencing farmers' knowledge of apple pollination and pollinators. For this analysis, the set of independent variables were farmers' level of education and years of working experience in the orchard. All results were analysed using the statistical software R version 4.0.4.

Results and Discussion

Farmer and farm characteristics

Out of the 105 farmers surveyed, 57.1% (n = 60) were male. Thirty-nine percent (n = 41) of the respondent farmers had studied up to a higher secondary level, a minimum of nine years in school. Twenty-five percent (n = 26) of the farmers were educated up to primary level and 20% (n = 21) had no education at all. However, 16.2% (n = 17) of the farmers knew basic reading and writing through NFE. More than half of the farmers had orchards in their name and were the owner of the surveyed orchards, while 39% (n = 41) of the respondents were just responsible for the production of apples and did not own any orchard; the orchards were in their parents' name or spouse's name. Some were simply caretakers of the orchards (Table 1).

A total of 59% (n = 62) of the surveyed orchards had between 50 and 150 fruit-bearing trees, while 3.8% (n = 4) orchards had more than 300 trees. Twenty-one percent (n = 23) of the

orchards had less than 50 apple trees. A total of 93.3% (n = 98) of the farmers agreed on having pollinizer trees in the orchard, while 5.7% (n = 6) of the farmers did not have pollinizer trees in their orchards. Thirty-three percent (n = 35) of the orchards surveyed had agricultural land as the dominant landscape surrounding their orchards. This suggests that instead of depending on apple farming alone, farmers in Bhutan also cultivate vegetables that can be used either for self-consumption or commercial purposes. However, 24.8% (n = 26) of the orchards were in the peri-urban area with settlements near the orchards.

As shown in Table 2, from the 105 orchards surveyed, majority of orchards in Thimphu districts were situated in peri-urban areas, while agricultural land dominated in Haa and Paro districts. The population of Thimphu has been increasing every year due to the presence of government departments and better opportunities compared to other districts in the country (Rinzin, 2020). According to the records of the Economic Census of Bhutan 2018-2019, to accommodate this growing population, many lands have been converted into settlement areas with new constructions visible in every part of the district. A lot of the land that was previously used for agricultural purposes, including apple orchards, are now being converted to construction and development areas (Rinzin, 2020). Urbanization appears to be one of the main reasons for the shrinkage of agricultural and orchard land in Thimphu.

However, developmental activities in Haa and Paro are still minimal with a lower population compared to Thimphu. Most of the people in Haa and Paro still depend on farming as a source of income and livelihood for the family. Apart from the town centres, most of the area is still within semi-natural habitat. According to the records maintained by Ministry's horticulture division, the number of apple trees in these districts has decreased from 306,181 in 2012 to 277,670 trees in 2015. Land prices in Thimphu and Paro have increased to 133,298 US$ per 40.47 m^2 according to a report from BBS (2019), which encourages the farmers to convert their orchards into construction landforms to sell. This suggests that urbanization will continue to be one of the leading cause for the loss of apple orchards and apple farming, especially in Thimphu and Paro districts in the next few years.

Farmers' perception of apple yield decline

In terms of yield, 96.2% (n = 101) of the farmers saw a decrease in apple yield over the last five years. While 2.9% (n = 3) of the farmers reported that the yield has remained the same over the last five years, 1% (n = 1) saw an increase in the yield. However, 74.3% (n = 78) of the farmers saw a decrease in the yield last year in 2019. While 23.8% (n = 25) of the farmers said the yield has remained the same, 1.9% (n = 2) farmers saw an increase in their apple yield. The results suggest that according to the farmers, apple yield and production in the country are on a gradual decline. According to the records maintained by the RNR Census of Bhutan (2019), the decrease in apple has been eratic, but there has been a gradual decrease in the past three years (Figure 2).

There was a statistically significant association between annual apple production and annual household income from the apple market, ($X^2_{(9)}$ = 92.268, $p < 0.05$). The result suggests that the farmers are dependent on apple production for their annual income. There is also a statistically significant association between the number of fruit-bearing trees in the orchard and the income of farmers, ($X^2_{(9)}$ = 61.909, $p < 0.05$). Most of the surveyed farmers whose incomes were lower had older and diseased trees that would rarely bear fruit. When these farmers were asked about why no new apple trees are being planted, most of the farmers attributed it to lack of interest in apple farming as apples earn them less income compared to a few years ago. Lower income of the apple farmers suggests that the value and price of Bhutanese apples have been declining in the export market.

However, when farmers were asked about the major reason behind the declining price of

Table 1: Characteristics of the overall survey (overall is 105)

Characteristics	Count (%)
Gender = Male (%)	60 (57.1)
Level of Education (%)	
None	21 (20.0)
NFE	17 (16.2)
Primary	26 (24.8)
High school	41 (39.0)
Is the orchard in your name? = Yes (%)	64 (61.0)
Number of fruit-bearing trees (%)	
< 50 trees	23 (21.9)
50 - 150 trees	62 (59.0)
150 - 300 trees	16 (15.2)
> 300 trees	4 (3.8)
No. of non-fruit-bearing trees (%)	
0	27 (25.7)
< 50 trees	73 (69.5)
50 - 150 trees	5 (4.8)
Presence of polliniser tree (%)	
Yes	98 (93.3)
No	6 (5.7)
No idea	1 (1.0)
The primary habitat surrounding the orchard (%)	
Forest cover	16 (15.2)
Agricultural land	35 (33.3)
Agro-forestry	5 (4.8)
Orchard	23 (21.9)
Peri-urban	26 (24.8)
Number of fertilizer applications during flowering season (%)	
No	22 (21.0)
One time	35 (33.3)
Two times	41 (39.0)
Three times	7 (6.7)
Number of fertilizer applications after blossom (%)	
No	62 (59.0)
One time	39 (37.1)
Two times	4 (3.8)
Do you consider the impacts of pesticides on pollinators (%)	
Yes	33 (31.4)
No	28 (26.7)
Sometimes	44 (41.9)
When are most pollinators observed in the orchard (%)	
During the flowering season	69 (65.7)
All year round	14 (13.3)
I haven't observed	22 (21.0)

continued over next page ...

Bhutanese apples in the export market, 44.76% of the farmers reported that it was due to the lower quality of apples, while 13.33% of the farmers reported that it was due to the lower apple production in the country (Table 3). With better sales and higher price of other cash crops compared to apples, 14% of the farmers have already switched to producing other crops and vegetables. This suggests that the apples in Bhutan are not only declining in production but also in quality. The RNR Census report of Bhutan (2019) also reports that apple prices in the recent years have also been fluctuating in the export market with the decline in apple production (Figure 2). The results suggest that farmers' perception of the decline in apple production and the income they earn through apple farming is representative of the reality.

Farmers' knowledge on apple pollination and pollinators

Of the 105 farmers surveyed, 93.3% (n=98) of the farmers had pollinizer trees planted in their orchard. While 5.7% (n = 6) farmers denied having pollinizer trees in the orchard, 1% (n = 1) did not know. However, there was no significant association between the number of trees present in the orchard and the presence of a pollinizer tree ($X^2_{(6)} = 7.152$, p = .307). This suggests that having more trees did not mean the presence of pollinizer trees in the orchard. Moreover,

having more trees and the presence of a pollinizer tree in the orchard did not mean farmers knew more about apple pollination ($p > 0.05$ in both cases). The result suggests that even with the presence of pollinizer trees in the orchard, farmers were unlikely to know about the pollination and pollinators.

With regard to the presence of pollinators in the orchard, 65.7% ($n = 69$) of the respondents said that most pollinators were seen during the flowering period, while 13.3% ($n = 14$) said they saw pollinators all year round, and 21% ($n = 22$) did not observe pollinators in the orchard. In the case of wind pollination in apples, 40% ($n = 42$) of the respondents thought wind pollination was good enough for apple pollination, 14.3% ($n = 15$) thought it was not significant, while 45.7% ($n = 48$) had no idea about the pollination caused by wind. The results suggest that farmers in Bhutan are not well aware of apple pollination process and paid little attention to pollinators visiting their orchards. This could be because the primary goal of the agriculture system in Bhutan is to increase productivity and enhance self-sufficiency in staple crops through better farm management practices (FAO, 2012). No focus and effort has been placed on the importance of pollinators in the country so far. Hence, farmers are not well aware of pollinators in the orchards.

Thirty-eight percent ($n = 40$) of the respondents agreed that a

Table 1: Characteristics of the … *continued*

Do you use managed honeybees (%)	
Yes	1 (1.0)
No	99 (94.3)
Only for honey production	2 (1.9)
Beehives nearby	3 (2.9)
Is wind pollination significant? (%)	
Good enough	42 (40.0)
No idea	48 (45.7)
Not significant at all	15 (14.3)
Do you conduct hand pollination? = No (%)	105 (100.0)
When do you harvest? (%)	
Late summer	15 (14.3)
Early autumn	49 (46.7)
Mid-autumn	36 (34.3)
Late autumn	5 (4.8)
Annual production? (%)	
50 - 60 boxes	65 (61.9)
70 - 100 boxes	25 (23.8)
110 - 200 boxes	12 (11.4)
> 200 boxes	3 (2.9)
Annual income? (%)	
< 100,000	85 (81.0)
100,000 - 200,000	17 (16.2)
200,000 - 300,000	2 (1.9)
> 300,000	1 (1.0)
What you do with rejected apples (%)	
Personal consumption	53 (50.5)
Feed to cattle	27 (25.7)
Use as manure once dried	12 (11.4)
Contribute to agro-industry	8 (7.6)
Dispose of them	5 (4.8)
What do you do when a tree has a diseased part? (%)	
Cut off the diseased part	55 (52.4)
Spray some chemical fertilizers	9 (8.6)
Get help from the agricultural dept.	15 (14.3)
Simply leave it to fall from the tree	26 (24.8)
Do more pollinators mean better pollination? (%)	
No	52 (49.5)
Yes	40 (38.1)
Yes, but other factors contribute	13 (12.4)
What was the trend in yield last year? (%)	
Decreased	78 (74.3)
Increased	2 (1.9)
Remained the same	25 (23.8)

continued over next page ...

Table 1: Characteristics of the … *continued*

What was the trend in yield over the last 5 years (%)	
Decreased	101 (96.2)
Increased	1 (1.0)
Remained the same	3 (2.9)
Expected reason of apple price falling in the global market? (%)	
Better apples from other countries	29 (27.6)
Increase sale of other cash crops	15 (14.3)
Lower apple production	14 (13.3)
Lower apple quality	47 (44.8)
Change in tempt. in last 5 years = Increased (%)	105 (100.0)
Change in flowering period (%)	
Early flowering	35 (33.3)
Late flowering	33 (31.4)
Remained the same	37 (35.2)
Change in rainfall pattern (%)	
Early rainfall	51 (48.6)
Late rainfall	11 (10.5)
Too little rainfall	1 (1.0)
Heavy rainfall	42 (40.0)

higher pollinator count in the orchard (abundance) benefited production and apple quality, while 38.1% (n = 40) did not know. About 12.4% (n = 13) of the respondents thought other factors also contribute to better apple quality and yield, 11.4% (n = 12) disagreed and thought that insect pollinators were not beneficial. A farmer's knowledge of pollinators was affected by their education and the number of years they have been working in the orchard. Farmers' education level and the number of years they have been working in apple production were both significant ($p < .05$) suggesting that farmers with a higher level of education and more years of working experience were more likely to know and understand that the diversity of pollinating insects in the orchard would provide benefits to apple quality and production (Table 4).

A study conducted in Kakamega district in Kenya by Kasina *et al.* (2009) reported that farmers' knowledge on pollination was positively influenced by their education level. However, other factors also contributed to farmers' knowledge of pollination, such as training and extension services they received (Munyuli, 2011; Ali *et al.*, 2020). This suggests that there is a need to train and provide Bhutanese orchard owners with basic knowledge about pollination and the role of pollinators in apple production. A study conducted in Multan, Bahawalpur, and Khanewal districts of Pakistan by Ali *et al*. (2020) reported that training and demonstration plots are regarded as the best methods for enhancing farmers' knowledge on pollination. This kind of training, demonstrations, and awareness programmes can also be conducted in Bhutan to educate farmers and make them aware of the importance of pollinators.

A hands-on training was conducted in Bhutan by The Royal Society for Protection of Nature (RSPN) in collaboration with Renewable Natural Resources (RNR) and Panbang Organic

Table 2: Count of orchard with each of the surrounding landscape type in each District

Primary habitat surrounding the orchard	**Haa (*N*=35)**	**Paro (*N*=35)**	**Thimphu (*N*=35)**	**Overall (*N*=105)**
Agricultural land	11 (31.4%)	14 (40.0%)	10 (28.6%)	35 (33.3%)
Agro-forestry	3 (8.6%)	0 (0%)	2 (5.7%)	5 (4.8%)
Forest cover	3 (8.6%)	8 (22.9%)	5 (14.3%)	16 (15.2%)
Orchard	10 (28.6%)	7 (20.0%)	6 (17.1%)	23 (21.9%)
Peri-urban	8 (22.9%)	6 (17.1%)	12 (34.3%)	26 (24.8%)

Table 3: Farmers' perception of the falling price of Bhutanese apples

Reasons for falling price	Percentage
Better apples from other countries	27.62
Increase sale of other cash crops	14.29
Lower apple production	13.33
Lower apple quality	44.76

Vegetable group on organic components and pest management in 2014. Another training was conducted by the ARDC Wengkhar in the Mongar district on soil nutrient management and preparing bio-pesticides in 2017, both of which proved successful and beneficial to the farmers (Tshering and Jamtsho, 2017). Such training programmes can also be conducted on pollinators and their importance in crop production in Bhutan to improve apple production, and their contibution in pollinator conservation.

When the farmers were asked to identify the pollinators, honeybees were the most recognized pollinator with 94.29% (n = 99). While 63.81% (n = 67) of the respondents mentioned recognizing butterflies in the orchard, only 17.14% (n = 18) of the respondents knew about hoverflies as pollinators (Figure 3). Eighty seven percent of the farmers mistook hoverflies for honeybees and commented that it is difficult to differentiate between the two. Some farmers even believed that these insects are harmful to apple production. Ninety three percent of the farmers were unable to differentiate the beneficial pollinators from the harmful insects. Munyuli (2011) and Ali *et al.* (2020) also reported similar findings among farmers of Uganda and Pakistan respectively, where farmers confused hoverflies for fruit flies which are pests in some crops. Farmers should be trained on the identification of beneficial pollinators from the harmful pest insects so that this can not only benefit the pollination processes in the orchards but also help in the conservation of these pollinators.

Since the surveyed farmers did not know the scientific names of each insect species, the insect groups were not classified to the species level when asked to the farmers. Insects were described in local dialect only and individual species such as *Apis mellifera* or *Apis dorsata* do not have a specific name in the local dialect. All the species under particular family and order such as Hymenoptera or Diptera are known collectively with a single local name and this causes farmers to think that all the species are the same. Therefore, it is difficult to draw a conclusion on which species are exactly known to the farmers.

A capacity development workshop on pollination was organized for the apple growers in Himachal Pradesh in India (FAO, 2014). In the workshop, handouts were printed with photographs of the pollinators for the farmers so that farmers can recognize beneficial pollinating insects from harmful pests. The study reported that, those farmers who were able to recognize other insects as pollinators decreased their pesticide use and saw a better apple harvest compared to those who did not recognize other insects as pollinators (FAO, 2014). Such handouts, which differentiates pests from beneficial pollinators listed in the handouts, would be beneficial too for farmers in Bhutan.

According to the Bayer Bee Care Center (2018), CropLife India runs one such project that aims to raise farmers' awareness on the importance of pollinators, especially honeybees. The project provides the farmers with different trainings on beekeeping and how to

Table 4: Influence of level of education and years of working experience on pollination and pollinator knowledge

	Estimate	*SE*	*t value*	*p value*
	2.17	0.58	3.75	0.0002*
Level of education	-0.69	0.2	-3.45	0.0006*
Years of working	-0.68	0.26	-2.67	0.007*

*Significant at $p < 0.05$

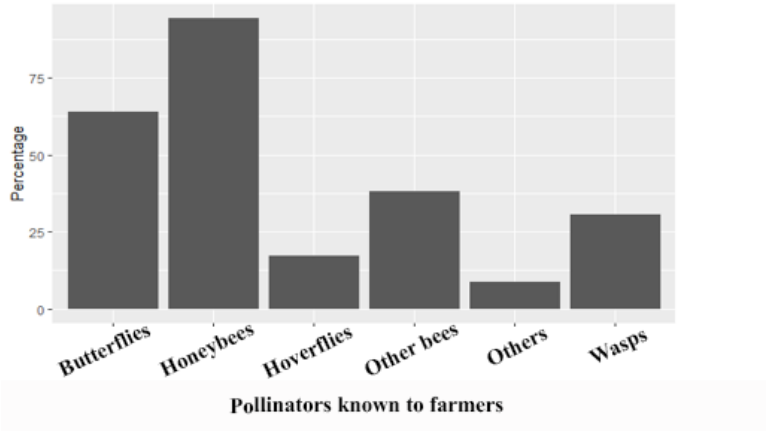

Figure 3: Pollinators recognized by the farmers

use these bees for managed pollination, and responsible use of pesticides. The project saw an increase in the yield of pomegranate by 35% and an increase in the income by 42% due to better yield as well as better quality of pomegranate (Bayer Bee Care Center, 2018).

Such projects can be replicated in Bhutan to educate and train farmers on differentiating pollinators from other harmful pests, responsible use of pesticides, and orchard management practices to support pollinator abundance and diversity. These projects can be funded and supported by the Ministry of Agriculture and Forest (MoAF) and other non-governmental organizations that work on nature conservation. Moreover, Bhutan can also participate in international workshops and symposiums and look into partnering with global projects such as the CliPS project and the Asian Pollinator Initiative. This will not only benefit farmers with better harvest but also help conserve pollinators at the National and International levels. Given that apple crops are dependent on insect pollination (Klein *et al.*, 2007) and that farmers in Bhutan are unaware of this, there is a great and good scope for increasing apple production with simple trainings and tools.

Conclusion

The majority of the farmers in the studied sites agreed that there has been a decline in apple production in their areas and lower apple price in the export markets in the recent years. Lower apple production and poor apple quality were pointed out as the main reasons for the lower price in the export markets. Inefficient pollination, among others, was one of the main reasons for poor fruit production and low quality in many parts of the world. In Bhutan, this study shows that most of the surveyed farmers are unaware of apple pollination process and the importance of pollinators in apple pollination. This suggest that farmers in Bhutan need to be trained and made aware of the importance of pollinators in apple pollination and provide a basic knowledge on how to identify beneficial pollinators and harmful pests. Farmers should also be provided workshops on how to use bee keeping practices for pollination purposes. Almost half of the population in Bhutan still depend on agriculture as their source of income and efficient pollination is of utmost importance. However, since the study only included farmers from three dzongkhags from Western Bhutan, more extensive research is required on a larger scale to obtain a comprehensive and adequate picture of the results obtained in this study, which can be used to underpin future orchard management practices that benefit not only production but also involve pollinator health and conservation strategy.

Acknowledgement

We are extremely grateful to the Naturalist Biodiversity Center, the Netherands for the course fund support and WWF Bhutan program for funding the expenses for the field study. We would like to thank Tenzin Rabgay (former Communication Manager, WWF Bhutan program) for making the research grant available. We also owe heartfelt thanks to enumerators, Kencho Tshering, Kuenzang Wangle, and Ugyen Wangchuk for their help, and all the farmers that participated in the survey interview.

References

Alemu, B. (2014). *Practices, Challenges and Prospects of Agricultural Land Management in Machakel Woreda, East Gojjam Zone, Ethiopia*. Addis Ababa, Ethiopia: Addis Ababa University.

Ali, M., Sajjad, A., Farooqi, M., Bashir, M. A., Aslam, M. N., Nafees, M., Khan, K. (2020). Assessing indigenous and local knowledge of farmers about pollination services in cucurbit agro-ecosystem of Punjab, Pakistan. *Saudi Journal of Biological Sciences,* 27, 189-104. doi:10.1016/j.sjbs.2019.07.001

Bayer Bee Care Center. (2018). *Tackling the risks and opportunities for Pollinators through Science*.

Bhutan Broadcasting Service (BBS). (2019). *Land price at the highest in Thimphu*. Retrived from https://www.bbs.bt/news/?p=116452. Retrived September 7, 2020.

Choden, J., & Shahnawaz, S. (2015). Apple Cultivation in Bhutan - Past Trends and Future Potential. (Shahnawaz, & U. Thinley, Eds.) *Proceedings of the Conference on 'Climate Change, Environment and Development in Bhutan'*(1), 65-72.

Eardley, C., Roth, D., Clarke, J., Buchmann, S., & Gemmill, B. (2006). *Pollinators and pollination: a resource book for policy and practice*. African Pollinator Initiative (API).

Food and agriculture Organizaton of the United Nations (FAO). (2012). *Bhutan Agricultual sector review: Issues, institutions and policies (Vol. 1)*. Thimpu, Bhutan: FAO and World Bank.

Food and Agriculture Organization of the United Nations (FAO). (2014). *Pollinator Safety in Agriculture*. (D. Roubik, Ed.) Rome: FAO and UNEP.

Giannini, T., Acosta, A., Garófalo, C., Saraiva, A., Alves-dos-Santos, I., & Imperatriz-Fonseca, V. (2012). Pollination services at risk: Bee habitats will decrease owing to climate change in Brazil. *Ecological Modelling*, 224, 127-131. doi:10.1016/j.ecolmodel.2012.06.035

Hein, L. (2009). The Economic Value of the Pollination Service, a Review Across Scales. *The Open Ecology Journal*, 2, 74-82. doi:10.2174/1874213000902010074

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2016). Summary for policymakers of the assessment report of the intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. In S. Potts, V. Imperatriz-Fonseca, H. Ngo, J. Biesmeijer, T. Breeze, L. Dicks, B. Viana, Eds. *Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, 36.

Jasra, A. W., Ashfaq, S., & Kasi, M. A. (2001). Apple pollination problems in Balochistan, Pakistan. *International Journal of Agriculture and Biology*, 3(2), 210-213.

Kasina, M., Kraemer, M., Martius, C., & Wittmann, D. (2009). Farmers' knowledge of bees and their natural history in Kakamega district, Kenya. *Journal of apicultural Research*, 48(2), 126-133. doi:10.3896/IBRA.1.48.2.07

Klein, A.-M., Vaissie`re, B., Cane, J., Steffan-Dewenter, I., Cunningham, S., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proccedings of the Royal Society B*, 274, 303-313. doi:10.1098/rspb.2006.3721

Munyuli, T. (2011). Farmers' perception of pollinators' importance in coffee production in Uganda. *Agricultural Sciences*, 2, 318-333.

National Statistics Bureau and World Bank Groups. (2019). *Economic Census of Bhutan 2018-2019*. Thimphu, Bhutan: National Statistics Bureau.

Ollerton, J. (2017, August 28). Pollinator Diversity: Distribution, Ecological Function, and Conservation. *Annual Review of Ecology, Evolution, and Systematics*, 353-376. doi:10.1145/annurev-ecolsys-110316-022919

Park, M., Joshi, N., Rajotte, E., Biddinger, D., Losey, J., & Danforth, B. (2018). Apple grower pollination practices and perceptions of alternative pollinators in New York and Pennsylvania. *Renewable Agriculture and Food Systems*, 35(1), 1-14. doi:10.1017/S1742170518000145

Partap, U., & Partap, T. (2004). Apple pollination issues in the Hindu Kush-Himalayan region. *International Society for Horticultural Science*, 662, 443-450. doi:10.17660/ActaHortica.2004.662.67

Partap, U., Partap, T., Sharma, H., Phartiyal, P., Marma, A., Tamang, N., . . . Munawar, M. (2012). *Value of Insect Pollinators to Himalayan Agricultural Economies*.

Rather, G., Paray, M., Javid, R., Khursheed, R., Yaqoob, M., Rehman, M., & Majid, F. (2017). Pollination

problems in apple of Kashmir Himalaya. *International Journal of Pure and Applied Bioscience*, 5(6), 817-823. doi:10.18782/2320-7051.6071

Rinzin, Y. (2020, March 2). *Three towns have 56 percent of urban population*. Thimphu: Kuensel Corporation Ltd. Retrieved from https://kuenselonline.com/three-towns-have-56-percent-of-urban-population/

Renewable Natural Resources (RNR) Statistics Divison. (2019). *RNR Census of Bhutan*. Thimphu, Bhutan: Royal Government of Bhutan (RGoB), Ministry of Agriculture and Forests (MoAF).

Sheffield, C.S. (2014). pollination, seed set and fruit quality in apples: studies with Osmia lignaria (Hymenptera: Megachilidae) in the Annapolis Valley, Nova Scotia, Canada. *Journal of Pollination Ecology*, 12, 120-128. doi:10.26786/1920-7603(2014)11

The National Center for Hydrology and Meteorology (NCHM). (2017). *Bhutan State of the Climate 2017*. Thimphu, Bhutan: Weather and Climate Services Division (WCSD), National Center for Hydrology and Meteorology(NCHM), Royal Government of Bhutan.

Tshering, K., & Jamtsho, S. (2017). *Lead farmer training (coure III)*. ARDC Wengkhar, Mongar.