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SURVEY AND ASSESSMENT OF POLLINATION SERVICE OF HONEY BEE FOR IMPROVEMENT OF MUSTARD PRODUCTION IN HAKALUKI HAOR: WETLAND ECOSYSTEM, AN ECOLOGICALLY CRITICAL AREA OF BANGLADESH

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ABSTRACT

Hakaluki haor is the largest haor (wetland ecosystem, north eastern part of Bangladesh) consisting of fresh water swamp forest which has been declared as Ecologically Critical Area (ECA) of Bangladesh. Mustard is one of the most promising short duration crops in this ecosystem to escape from the pre-monsoon flood. However, mustard yield was decreasing day by day due to the reduction of natural honey bee population. To develop a baseline information regarding the potentiality of apiculture practices, a survey of the local farmers and an experiment was conducted to assess the pollination services of honey bee in mustard field. It was found that about 62% of the farmers had positive perception about honey bee and 72% of the farmers were interested in apiculture. Around 73.3% of the farmers noticed the reduction of native honey bee population and 50% of the farmers considered reduction of natural honey bee being responsible for lower yield of mustard. About 77.3% of the farmers used different groups of pesticides viz. organophosphorous, pyrethroid, carbamate, triazoles, dicarboximide, and neonicotinoid in their mustard fields to manage different pests and diseases. In field experiment, open pollination with artificial beehive significantly increased the number of silique per plant, seed per silique, weight of 1000 seeds and yield per plant. This study highlighted the scope of increasing pollination services through adopting intensive apiculture practices in the surveyed area for the sustainable livelihood.

Keywords: Pollination service, Mustard, Farmers' Perception, Pesticides, Protected wetland, honey bee conservation

INTRODUCTION

Wetlands of Bangladesh encompass haors, baors (a dead section of a river created when the river changed course), beels (a lake-like wetland with static water), ponds, flooded rice lands and floodplains, natural lakes, man-made reservoirs, and coastal

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and marine areas. The total area of wetlands in Bangladesh is about 7–8 million ha, which constitutes about 50% of the land surface of the country (Islam *et al.* 2018, Haroon and Kibria 2017, Khan *et al.* 1994). Haor is a bowl-shaped large tectonic depression that is flooded every year during monsoon. Hakaluki haor is the largest natural inland freshwater wetland ecosystem located in Sylhet and Moulvibazar districts of Bangladesh as well as one of Asia's larger marsh wetland ecosystem (Ahmed *et al.* 2008). This haor also contains fresh water swamp forest. According to the Bangladesh Environment Conservation Act 1995 (BECA), it was announced as an "Ecologically Critical Area" (ECA) in 1999 by the Government of Bangladesh to conserve from extensive exploitation and deforestation (CNRS 2002). More than 190,000 people live around the haor and all of them are more or less dependent on the resources of the haor for their livelihoods (IUCN 2006, Islam *et al.* 2011). Most of the people depend on agricultural crop production for their livelihood. The farmers of Hakaluki haor area cultivate different crops only from November to April (Rabi season) (Kamruzzaman and Shaw 2018, Baishakhy *et al.* 2020, Mohsenipour *et al.* 2018). This haor is flooded with pre-monsoon rain till mid-May which causes serious damage to Rabi crops (Suman and Bhattacharaya 2015). To overcome this critical problem, mustard is cultivated at Hakaluki haor areas as a suitable short-duration crop during the Rabi season (Helal *et al*. 2016).

Mustard production is very crucial for the livelihood of the farmers of Hakaluki haor area. It is a cross pollinated crop. The contribution of pollinators during crop production is termed as pollination service. Pollination service is an unavoidable natural phenomenon in mustard crop. Several researchers have conducted researches on pollination service contributing to the yield of mustard in different countries of the world (Mandal *et al.* 2018, Atmowidi *et al.* 2007, Patidar *et al.* 2017, Devkota *et al.* 2021). Assessment of insect-mediated pollination service is essential to ensure sustainable use of biodiversity resources as they highlight the different aspects of land uses (Pascual *et al.* 2017). The annual worth of global pollination services was assessed as high as USD 600 billion (IPBES 2016). However, limited number of researches were conducted to evaluate the pollination service in local area and in locations with insufficient or low-quality data (Pandeya *et al.* 2016).

Approximately 78% of the flowering plants directly or indirectly depend on pollinators for their reproduction and survival (Klein *et al.* 2007, James *et al.*

2008, Ollerton *et al.* 2011) and it is directly related to the food security of human populations. Pollinators, mostly honey bees, contribute to 35% of the world's food production (FAO 2015). Due to their economic and ecological importance in agriculture sector, a variety of methods have been used to evaluate the pollination services of pollinators (Gallai and Vaissiere 2009, Breeze *et al.* 2016, Klein *et al.* 2007, 2018, Lautenbach *et al.* 2012, Losey and Vaughan 2006, Breeze *et al.* 2011, Calderone 2012, Giannini *et al.* 2015). Along with pollination service, honey bees provide different products like honey, royal jelly, beeswax, pollen and venom (Rabie *et al.* 2018, Kolayli and Keskin 2020). Apiculture practice can be a source of income for the economically vulnerable people of Hakaluki haor area (Ibrahim *et al.* 2021). In the fiscal year of 2018-19, Bangladesh produced around 1805.68 MT honey and earned foreign currency by exporting honey to different countries of the world (BSCIC 2019).

According to the farmers' of Hakaluki haor area, the yield of the mustard is reducing day by day due to a decline in honey bee population. Reduction in mustard yield often occurs due to inadequate pollination from lower abundance of pollinators, especially honey bees (Abrol 2007). To assess the congeniality of apiculture, local farmers' perception and scientific evidence are prerequisite. Therefore, it was aimed to evaluate the farmers' perception regarding the pollinators and pollination service and to assess pollination service at the mustard field in Hakaluki haor area.

MATERIALS AND METHODS

Two consecutive experiments were conducted in Hakaluki haor area of Bangladesh. In the first experiment a survey was conducted on farmers' perception about the pollinators and pollination services and in the second experiment, pollination service was assessed in the field of Hakaluki haor.

Experiment 1: Farmers' perception about pollinators and pollination services in the Hakaluki haor areas

Study Site: The study area lies between 24° 35′ N and 24° 44′ N latitude and between 92°00' E and 92°08′E longitude (Choudhury and Nishat 2005). It includes three upazilas (Sub district) (*viz.,* Baralekha, Juri, Kulaura) of Moulvibazar district and two upazilas (*viz.,* Golapganj and Fenchuganj) of Sylhet district in the North-Eastern part of Bangladesh (Fig. 1).

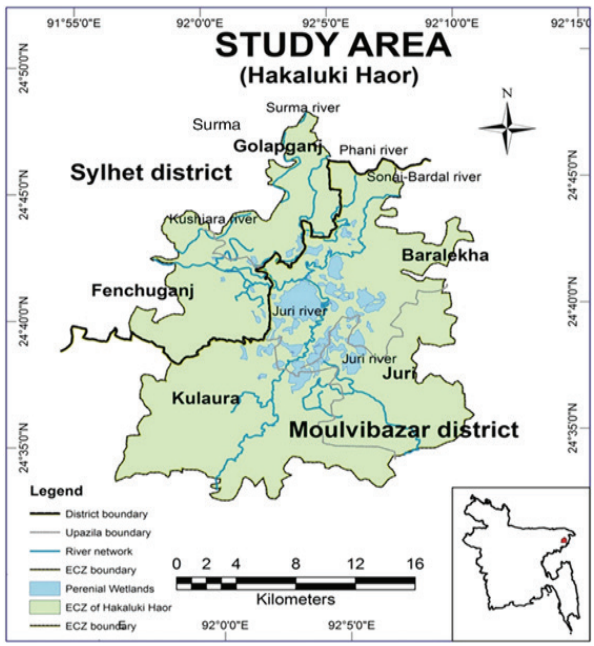


Fig. 1. The study area of Hakaluki haor in Bangladesh (Islam *et al.* 2018)

Questionnaire preparation and Survey: Conducted a comprehensive survey among the farmers of Hakaluki haor area of Bangladesh during November 2019 to February 2020 using a semi-structured and standardized questionnaire. The questionnaire was designed based on pre-survey and previous literature (Chanthayod *et al.* 2017, Bhattacharyya *et al.* 2017). The questionnaire consisted of 25 open and closed-ended questions. The questionnaire was divided into three parts. The first part of the questionnaire focused on collecting socio-economic characteristics about the farmers. This part aimed to collect information on various factors related to farmers' age, education, family size, land area, land ownership, participation in training programs etc. The second part included questions related to the farmers knowledge on apiculture, source of knowledge, interest of apiculture, ability to differentiate different honey bee species, their thinking about apiculture (i.e., beneficial, harmful, or neutral) and so on. The third part of the questionnaire was designed to collect information about management practiced by the mustard farmers.

To ensure the validity, clarity, relevance, and internal consistency of the questionnaire items, the questionnaire was thoroughly reviewed by experts in

the fields of agriculture and pest management. Based on the suggestions of the experts, the irrelevant questions of the questionnaire or the options in the closed-ended questions were removed from the final questionnaire format. Prior to data collection, each enumerator provided a brief overview of the questionnaire and the objectives of the study. They also received training on data collection methods prior to conducting the survey.

The representative respondents (farmers) were determined according to Tuan *et al.* (2014) and Singh and Masuku (2014) as:

$$n = \frac{z^2 * p * q}{e^2}$$

Where,

- n= the sample size,
- z = 1.96 for the desired confidence level of 95%,
- p = population proportion= 11% = 0.11,
- q= 1-p
- e = desired level of precision (0.05)

Conducted face-to-face interviews with randomly chosen 150 farmers of five upazilas (30 farmers from each upazila) from Moulvibazar and Sylhet districts (Table 1). These farmers were chosen through random sampling by consulting with the local officials of Department of Agriculture Extension, Ministry of Agriculture, Bangladesh to eliminate the negative effect of bias on the quality of the collected data (Jabed *et al.* 2020).

Table 1. Distribution of farmers in surveyed areas

Name of District	Name of Upazila	Number of blocks per upazila	Number of growers per block	Number of total growers per district
Moulvibazar	Baralekha	3	10	30
	Juri	3	10	30
	Kulaura	3	10	30
Sylhet	Fenchuganj	3	10	30
	Golapganj	3	10	30

Experiment 2: Assessment of honey bee pollination service in the Hakaluki haor areas

Study site: This field experiment was conducted at Barni village of Baralekha upazila during November 2020 to March 2021. We selected two fields to measure the pollination service with a minimum distance between these fields according to Garibaldi *et al.* (2011) and Hülsmann *et al.* (2015). The soil and weather parameter were more or less similar of these two fields as these fields belonged to the same Agro-Ecological Zone (Eastern Shurma Kushiyara Floodplain) and same haor area (BAMIS 2021).

Land preparation, Seed sowing and Intercultural operations: The experimental plot was prepared properly to obtain a good tilt. Mustard seeds (Tori-7) were sown in broadcasting method with a seed rate of 8 kg ha^{-1} (Biswas 2017). Intercultural operations *viz.* weeding, thinning, irrigation was done and nutrient elements through Urea, TSP, MoP, Gypsum, Magnesium sulphate, Zinc sulphate and borax were applied at the proper time as per recommended dose (Ahmmed *et al.* 2018, Chowdhury and Hassan 2013).

Experimental Design: This research was conducted by following Randomized Complete Block Design (RCBD). Study was set up in experimental plots in two different locations with two treatments, open pollination (OP) as control and open pollination with beehive (OPB) as the experimental treatment. In OPB, a wooden bee box with nine frames was set up to supply the additional honey bee to the mustard field. Honey bees of *Apis mellifera* species were used in the artificial wooden beehive. Each treatment was replicated five times in randomly selected plots with an area of 9m² (3m x 3m). In OP, only natural pollinators were allowed to pollinate the mustard flowers. On the other hand, both the natural pollinators and artificially provided honey bees were allowed to pollinate the mustard flowers in OPB as suggested by Hudewenz *et al.* (2014) and Hossain *et al.* (2018).

Harvesting: Mustard plants were harvested manually at maturity (after 90 days of seed sowing) from each plot. The harvested mustard plants were bundled and tagged properly. The tagged bundles of mustard plants were sun dried for proper drying. Threshing and cleaning were done separately with proper care. Then the mustard seeds were weighted and packed for storing.

Data collection: Yield contributing parameters of mustard such as number of siliques per plant, length of silique, number of seed per silique, weight of 1000 seeds and yield per plant were recorded. The number of siliques was counted at mature stage of the mustard crop before harvesting. All other parameters were recorded after harvesting the crop. Representative six plants from each replication were selected to record the silique length, seed number per silique, 1000 seed weight and yield per plant.

Data analysis: Survey data were analyzed by IBM® SPSS 26 software. Statistical differences in farmers' socio-economic characteristics (e.g., age, education, land ownership, total land area, participation in training programs, etc.) among surveyed areas were estimated using the Chi-square test. The Chi-square test was also used to assess the relationships of farmers' knowledge of apiculture with their socio-economic characteristics, such as their age, educational status, land area, and participation in training programs. Relationships of farmers' interest of apiculture with their knowledge of apiculture and participation in training programs was also analyzed using the chi-square test. On the other hand, field experiment data were used to perform independent t-test to analyze the significance of OP and OPB by using the same statistical software. Each time the level of significance was set at 0.05.

RESULTS

Farmers' perception on pollinators and pollination services at Hakaluki haor: The survey represented the socio-economic conditions of the farmers from Hakaluki haor areas of Bangladesh, which is situated in Baralekha, Juri, Kulaura, Golapganj and Fenchuganj upazila of Moulvibazar and Sylhet district, respectively. Farmers' ages and education level across the survey areas did not show any significant difference (Table 2). The result showed that the respondent's age ranged from 20 years to 75 years where 33.3% of the farmers were from 46 to 60 years. Among the respondents, 28.6% of farmers did not receive any formal education and 9.3% of farmers were unable to write their own names. Result showed that family size varied significantly across the survey areas. More than half (57.3%) of the farmers had medium family with 6-9 members followed by 26.7% and 16% of the farmers had small (up to five members) and large family (10 and above members), respectively.

It was revealed that the land ownership and land areas for mustard cultivation by the farmers of Hakaluki Haor has significant variation among the survey areas. Around 59.3% of the farmers had their own lands for crop cultivation. However, 44.8% were tenant farmers and 12.9% of the farmers took lease of land for crop cultivation. On an average 47% farmers cultivated mustard in less than 1 acre of land followed by 15.3% and 10.7% of the farmers cultivated mustard in 1.01 to 2 and more than 2 acres of land respectively. It was also found that only 10.7% of the farmers of Hakaluki haor area received training on apiculture (Table 2).

Table 2. Socio demography of the farmers of Hakaluki haor area of Bangladesh on 2019-20

Variables	Survey areas (% of farmers)						Chi-square test	
	Fenchuganj	Golapganj	Kulaura	Juri	Borolekha	Total	DF	X^2 value
Age								
Up to 35	23.3	23.3	43.3	23.3	30.0	28.7	12	8.9ns
36-45	30.0	23.3	26.7	33.3	20.0	26.7		
46-60	33.3	43.3	26.7	26.7	36.7	33.3		
Above 60	13.3	10.0	3.3	16.7	13.3	11.3		
Education								
Illiterate	6.7	10.0	6.7	10.0	13.3	9.3	16	18.7ns
Only Signature	23.3	20.0	13.3	20.0	20.0	19.3		
[1]PSC	23.3	46.7	30.0	26.7	53.3	36.0		
[2]JSC	20.0	16.7	26.7	26.7	10.0	20.0		
[3]SSC and above	26.7	6.7	23.3	16.7	3.3	15.4		
Family size								
Small (up to 5)	33.3	40.0	16.7	36.7	6.7	26.7	8	23.2*
Medium (6-9)	63.3	53.3	66.7	46.7	56.7	57.3		
Large (10 and above)	3.3	6.7	16.7	16.7	36.7	16.0		
Land ownership								
Own	56.7	53.3	76.7	80.0	30.0	59.3	12	50.7***
Lease	20.0	10.0	20.0	3.3	36.7	18.0		
Tenant (Borga)	63.3	73.3	40.0	50.0	86.7	62.7		

Land area								
Less than 0.5 acre	50.0	46.7	83.3	46.7	10.0	47.3	12	67.8***
0.51-1.00 acre	30.0	43.3	10.0	36.7	13.3	26.7		
1.01-2.00 acre	10.0	3.3	3.3	16.7	43.3	15.3		
More than 2.00 acre	10.0	6.7	3.3	0.0	33.3	10.7		
Participation in training								
Yes	20.0	16.7	0.0	6.7	10.0	10.7	4	7.9ns
No	80.0	83.3	100.0	93.3	90.0	89.3		

Note: 1= Primary School Certificate; 2 = Junior School Certificate; 3 = Secondary School Certificate; Statistically significant at *p < 0.05, **p < 0.01, ***p < 0.001, ns = not significant, DF = Degree of freedom, X2 = Chi-square co-efficient

Farmers usually cultivated oil seed crops *viz.,* mustard, sesame, sunflower, niger, flax, soybean, and groundnut; cereal crops *viz.,* rice, wheat, maize; vegetables *viz.,* pumpkin, cucumber, bottle gourd, bitter gourd, tomato, red amaranth, French bean, brinjal, potato, country bean, carrot, radish; and spices *viz.,* coriander, chili, onion; in their fields (Table 3).

Table 3. Crops cultivated by the farmers of Hakaluki haor area of Bangladesh on 2019-20

Name of the crops			
Oil crops	Cereal crops	Vegetables	Spices
Mustard (*Brassica* sp.) (Varieties: Tori-7, BARI Mustard-14, BARI Mustard-17)	Rice (*Oryza sativa*)	Pumpkin (*Cucurbita maxima*)	
Sesame (*Sesamum indicum*)	Wheat (*Triticum aestivum*)	Cucumber (*Cucumis sativus*)	
Sunflower (*Helianthus annuus*)	Maize (*Zea mays*)	Bottle gourd (*Lagenaria siceraria*)	
Niger (*Guizotia abyssinica*)		Bitter gourd (*Momordica charantia*)	
Flax (*Linum usitatissimum*)		Tomato (*Solanum lycopersicum*)	
Soybean (*Glycine max*)		Red amaranth (*Amaranthus cruentus*)	
Ground nut (*Arachis hypogaea*)		French bean (*Phaseolus vulgaris*)	
		Brinjal (*Solanum melongena*)	
		Potato (*Solanum tuberosum*)	
		Country bean (*Lablab purpureus*)	
		Carrot (*Daucus carota* subsp. *sativus*)	
		Radish (*Raphanus sativus*)	

About 77.3% of the farmers had knowledge about apiculture in mustard field and the main sources of this knowledge were local farmers (73.3%) and government organizations (22.4%) (Table 4). A large number of farmers (72%) were interested in apiculture. Most of the farmers (87.3%) were able to identify honey bee in their fields. Among the farmers, 62% considered honey bee as beneficial insect. However, 15.3% considered as harmful insect and rest of the farmers (22.7%) had no idea about the interaction of honey bee. Majority of the respondents (86.7%) agreed to allow bee hives in their mustard fields. Main causes were benevolence (41.5%) and from the belief that their crop production would be increased (38.5%) as well as 9.2% of the farmers believed that honey bee could reduce the abundance of harmful pests like aphid in the mustard field (Table 4).

Table 4. Farmers' perception on apiculture at mustard field in Hakaluki haor area of Bangladesh on 2019-20

Particulates	Responses	Frequency	Percentage (%)
Knowledge about apiculture	Yes	116	77.3
	No	34	22.7
Sources of knowledge on apiculture (N=116)	TV & Radio	3	2.6
	Local farmers	85	73.3
	Govt. organization	26	22.4
	Others	2	1.7
Interested in apiculture	Yes	108	72.0
	No	42	28.0
Identify honey bee	Yes	131	87.3
	No	19	12.7
Consider honey bee as	Beneficial insect	93	62.0
	Harmful insect	23	15.3
	No idea	34	22.7
Allowing apiculture near mustard field	Yes	130	86.7
	No	20	13.3
Causes of allowing apiculture (N=130)	Social welfare	54	41.5
	To increase crop production	50	38.5
	To get free honey	11	8.5
	To learn apiculture	3	2.3
	To reduce pest	12	9.2

Farmers' age and education level did not influence their knowledge of apiculture; however, their knowledge of apiculture was significantly influenced by the total land area they owned and their participation in training programs. On the other hand, both farmers' knowledge of apiculture and participation in training programs were significantly associated with their interest in apiculture (Table 5).

Table 5. Relationship between farmers' knowledge and interest of apiculture with their socio-economic characteristics

Characteristics	knowledge of apiculture	
	DF	X^2 value
Age	3	1.05ns
Education	4	2.1ns
Land area	3	11.4*
Participation in training	1	5.3*
	Interest of apiculture	
	DF	X^2 value
Knowledge of apiculture	1	29.4***
Participation in training	1	6.9**

Note: Statistically significant at *p < 0.05, **p < 0.01, ***p < 0.001, ns = not significant, DF = Degree of freedom, X2 = Chi-square co-efficient

About 77.3% of the farmers used pesticides in their mustard field (Fig. 2a). Moreover, around 38% of the farmers applied pesticides for two times in their mustard fields (Fig. 2b). The farmers of Hakaluki haor usually applied pesticides at noon to their crops (Fig. 2c). Farmers used pesticides from different groups like Organophosphorous, Synthetic Pyrethroid, Carbamate, Triazoles, Dicarboximide, Neonicotinoid and as a mixer of two groups like Organophosphorous + Synthetic Pyrethroid, Carbamate + Acylalanine, Neonicotinoid + Organochlorinated (Table 6).

It was found that 73.3% of the farmers noticed the decreasing population of honey bee in Hakaluki haor area while 20% of the farmers did not notice the population reduction of honey bee (Fig. 3a). Half of the farmers (50%) believed that crop yield was reducing due to less honey bee population and 23.3% of the farmers had no idea whether the honey bee population affects the crop yield or not (Fig. 3b).

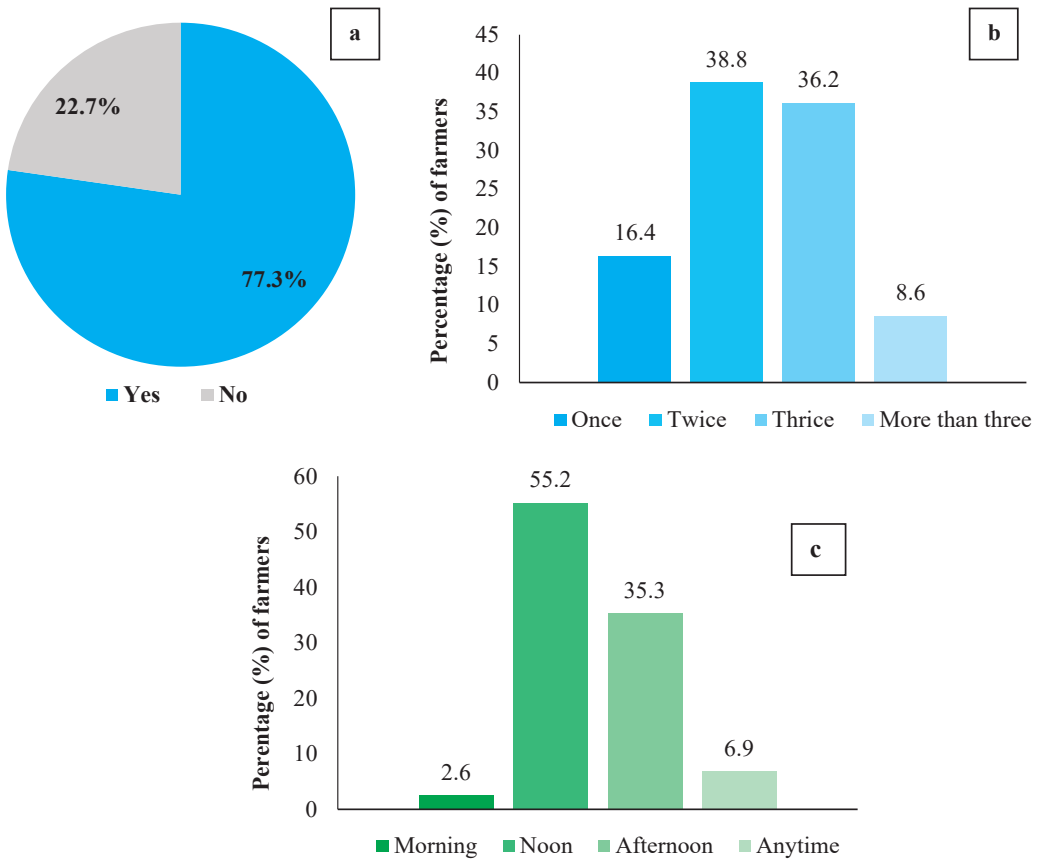


Fig. 2a. Percentage of farmers applying pesticides b) Frequency of pesticide application per season by the farmers (N=116) c) Time of applying pesticides by the farmers (N=116) on their mustard field in Hakaluki haor area of Bangladesh on 2019-20

Table 6. Pesticides applied by the mustard farmers of Hakaluki haor area of Bangladesh on 2019-20

Pesticide group	Common name of Pesticide	Pesticide types	WHO Class (GHS)
Carbamate	Carbosulfan	Insecticide	II (3)
	Cartap	Insecticide	II (4)
	Mancozeb	Fungicide	U (5)
Avermectin	Emamectin Benzoate	Insecticide	II (3)
Carbamate + Acylalanine	Mancozeb (64%) + Metalaxyl (8%)	Fungicide	U (5), II (4)
Dicarboximide	Iprodione (50%)	Fungicide	III (5)
Neonicotinoid	Imidacloprid	Insecticide	II (4)
	Thiamethoxam (25%)	Insecticide	II (4)
Neonicotinoid + Organochlorinated	Thiamethoxam(20%)+ Chlorantraniliprole (20%)	Insecticide	II (4), U (5)
Organophosphorous	Dimethoate	Insecticide	II (3)
	Fenitrothion	Insecticide	II (4)
	Malathion	Insecticide	III (5)
	Acephate	Insecticide	II (4)
Organophosphorous + Synthetic Pyrethroid	Chlorpyrifos (50%) + Cypermethrin (5%)	Insecticide	II (3), II (3)
	Profenofos (40%) + Cypermethrin (2.5%)	Insecticide	II (4), II (3)
	Chlorpyrifos (50%) + Cypermethrin (5%)	Insecticide	II (3), II (3)
	Profenofos (40%) + Cypermthrin (2.5%)	Insecticide	II (4), II (3)
Synthetic Pyrethroid	Cypermethrin	Insecticide	II (3)
	Lambda Cyhalothrin	Insecticide	II (3)
	Lambda Cyhalothrin	Insecticide	II (3)
	Cypermethrin	Insecticide	II (3)
	Cypermethrin	Insecticide	II (3)
Triazoles	Difenoconazole (25%)	Insecticide	II (4)

Note: WHO = World Health Organization, GHS = Globally Harmonized System of Classification and Labelling of Chemicals, II = Moderately Hazardous, III = Slightly Hazardous, U = Unlikely to present acute hazard

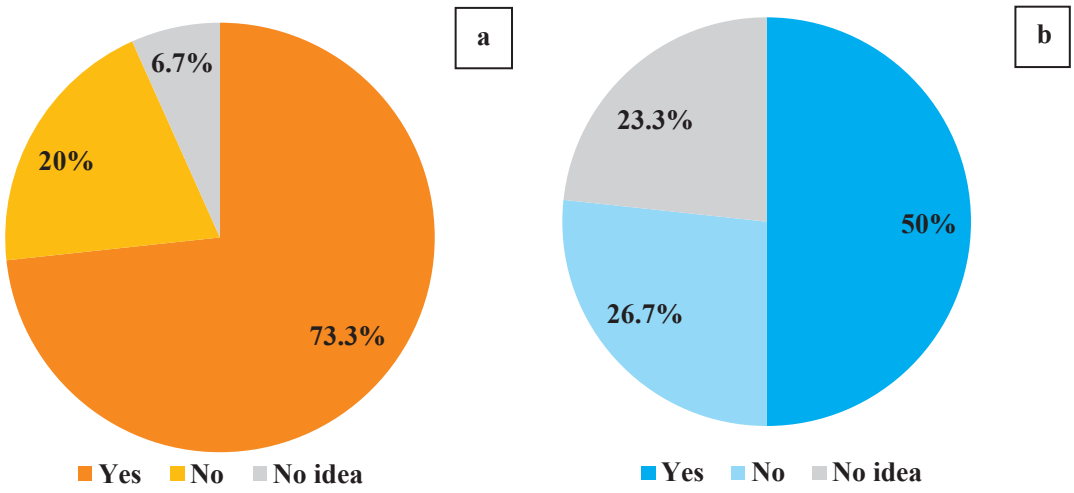


Fig. 3a. Percentage (%) of farmer noticed declining honey bee population b) Farmers' perception percentage (%) on reduced honey bee population responsible for low yield in Hakaluki haor area of Bangladesh on 2019-20

Evaluation of pollination service at Hakaluki hoar area of Bangladesh: The pollination treatments were found to be responsible for the variation in yield contributing parameters. Compared to the open pollination (OP), open pollination with beehive (OPB) had statistically significant contribution to the number of siliques per plant ($p<0.01$), number of seed per silique ($p<0.05$), however, the length of siliqua did not show any significant differences among the treatments (Fig. 4a, 4b, 4c). In open pollination, the number of siliques per plant, length of silique, number of seed per silique were 50.17±1.76, 3.87±0.2 cm, and 15.55±0.51 while in open pollination with beehive, those were 90.47±4.26, 3.83±0.23 cm, and 17.03±0.18, respectively. Eventually, weight of 1000 seeds ($p<0.01$) and yield per plant ($p<0.01$) also showed the significant difference among the treatments (Fig. 4d, 4e). In open pollination, the weight of 1000 seeds and yield per plant were 1.89±0.03 g and 1.47±0.07 g whereas in open pollination with beehive, it was 2.35±0.08 g and 3.6±0.12 g, respectively.

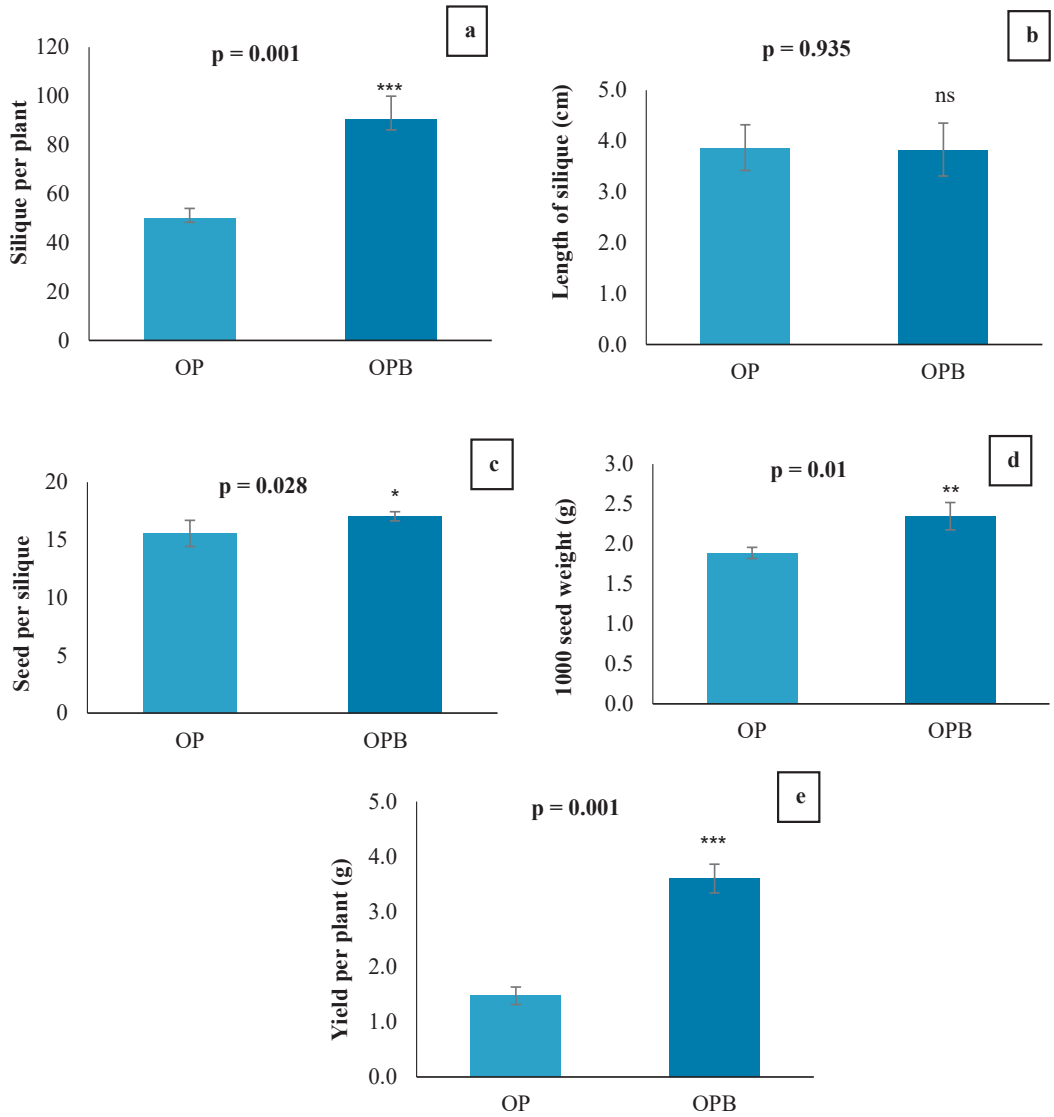


Fig. 4a. Mean number of silique per mustard plant b) Mean length (cm) of silique c) Mean number of seed per silique d) Mean of 1000 seed weight (g) of mustard e) Mean yield (g) of mustard per plant in different pollination treatments in Hakaluki haor area of Bangladesh on 2020-21.

OP= Open Pollination; OPB= Open Pollination with Beehive, ns = non-significant; * = significant at 5% level of significance; ** = significant at 1% level of significance; *** = significant at 0.1% level of significance.

DISCUSSION

Apiculture is a promising practice in mustard field. Day by day the farmers are being cognizant of apiculture in mustard field. Majority of the farmers of Hakaluki haor area were found to have knowledge about apiculture. In haor area, their main source of knowledge were local farmers and government organizations. Ayansola (2012) reported that, 65.3% of the respondents gained knowledge from their friends and acquaintances as well as some respondents gained knowledge on apiculture by attending seminars or workshops in southwestern Nigeria. Kasina *et al.* (2009) documented in Kenya that the regions where honey bees exist naturally in the surrounding areas, the farmers are well known to honey bees. As most of them have knowledge about apiculture, more than half of the farmers considered honey bee as beneficial insect. However, some considered honey bee as harmful insect. Moniruzzaman and Rahman (2009) also found similar kind of perception among the farmers in Bangladesh. From this belief, sometimes farmers did not allow the beekeepers to set up their hives in mustard field. As the farmers of this haor area had an overall positive perception about honey bee, they agreed to allow bee hive in their mustard field. In haor area, one third of the farmers were found to be conscious about pollination service in the mustard field. Ali *et al.* (2020) found that 64% the respondents were not sure about the pollination service in crop field of Punjab, Pakistan. Small portion of the farmers in haor area believed honey bee could reduce aphid. Morandin *et al.* (2016) reported that field edge habitat was able to increase the population of native honey bee along with natural enemies (beneficial insects) and this reduced the aphid population. Despite being very interested, only a limited number of farmers received training on apiculture due to the scarcity of training facilities. According to the annual report of Bangladesh Small and Cottage Industries Corporation (BSCIC 2019), only 270 members received training on apiculture during the fiscal year 2018-19. This number is too low to meet the national demand of Bangladesh. Moniruzzaman and Rahman (2009) reported that training facilities should be increased.

Insects and diseases cause damage to the mustard (Udin *et al.* 2019, Gupta *et al.* 2020). To manage these insects and diseases, the farmers injudiciously applied a large number of pesticides in their mustard fields. Biswas (2013) and Mandal (2020) reported that malathion, chlorpyriphos, cypermethrin were used to manage the pests

of mustard crop. When they face any problem in their fields, they prefer to go to the pesticide dealers and apply pesticides in their field without any consultation with experts or government officials. Sometimes they are deceived by the pesticides dealers and apply pesticides of one crop to another crop irrationally. Rashid *et al.* (2003) and Yadav (2020) found that many farmers of Bangladesh and India use pesticides irrationally in their crop fields. It was found that farmers usually apply pesticides to manage aphid in mustard field. When the infestation is low, they apply only once. In case of higher infestation, they increased the use of pesticides. They usually preferred noon for pesticide application as they used to do other works in the morning and spent leisure period in the evening as well as they could take a bath after the pesticide application.

According to the farmers' perception, honey bee population was declining day by day. Land cover change or deforestation in the haor area (Ferreira *et al.* 2020, Dar *et al.* 2021) and the increasing use of pesticides in mustard field (Stanley *et al.* 2015, Challa *et al.* 2019) could be responsible for negatively affecting the honey bee population. Half of the farmers believed that the lower abundance of honey bee was responsible for low yield of mustard in hoar area. Researchers also showed that honey bee plays an important role in yield enhancement of mustard (Devkota *et al.* 2021, Hossain *et al.* 2020).

In the field experiment, mustard yield was significantly higher in open pollination with beehive. This indicates that more pollination is positively related to mustard yield. Adequate pollination could be the cause of increased number of siliques per plant as well as it also increased the number of seed per silique (Shakeel and Inayatullah 2013, Tara and Sharma 2010). Sufficient pollination might be the reason of higher average weight of seed (Stanley *et al.* 2013, Bommarco *et al.* 2012, Hudewenz *et al.* 2014). Plants with incompletely pollinated flowers have fewer seeds and reduced fitness, and they produce inferior fruit (Kasina *et al.* 2009, Ricketts *et al.* 2004). But the average length of silique did not differ significantly. Hossain *et al.* (2020) reported that silique length was statistically same in open and netted with bee treatment. However, it was found that pollination treatments could influence the length of the silique (Ali *et al.* 2011, Sekhon *et al.* 2020). The results of this field experiment indicated the pollination crisis due to reduction of native honey bee in Hakaluki haor area which aligned with the local farmers' belief. Kremen *et*

al. (2002) described that natural honey bee reduction resulted in a decline of natural honey bee pollination service in California, USA.

CONCLUSIONS

Mustard yield is affected due to lack of pollinators in Hakaluki haor area of Bangladesh. Farmers of this area used pesticides in their mustard fields to manage harmful pests to recover their yield. The present research revealed that farmers of Hakaluki haor, carried a positive perception about the contribution of pollinators in the mustard field. Additionally, the field experiment at Hakaluki haor area highlighted the contribution of apiculture practices to maximize the yield of mustard crop. Henceforth, the information from this study shed light upon the importance of apiculture practice by the farmers in the mustard field of haor areas. The results of the study will use to aware the farmers on the value of pollination services of honey bees. These results also might be supportive to develop the farmers training manual on mustard production in Haor areas of Bangladesh by practicing apiculture. In addition, the findings of the study quantified the pollination services which might be emphasized further research for the improvement of mustard production.

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