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Assessing indigenous and local knowledge of farmers about pollination services in cucurbit agro-ecosystem of Punjab, Pakistan

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ABSTRACT

Being the ultimate beneficiary of ecosystem services provided by on-farm agricultural biodiversity, the participation of farmers in its sustainable utilization and conservation is crucial. How much aware they are with the significance and conservation of agricultural biodiversity in order to improve their crop yield remains unclear, especially from the developing courtiers. Pollination is one of such ecosystem services, enormously contributed by the wild bees. In the present study, we have investigated the knowledge of farmers about bees and pollination in general in three districts i.e. Multan, Bahawalpur and Khanewal of southern Punjab, Pakistan. Some 300 farmers (100 cucurbit growers in each district using convenient sampling method) were interviewed using a semi-structured questionnaire. Respondents were first presented with a box of insect specimens and then were asked to identify bees among those. Those who identified correctly were asked to state about their nesting sites. Only 11% of the respondents could correctly identify the bees and half of them could report something about nesting sites. A majority (63%) of the farmers was unable to tell fertilization requirements in cucurbits, 59% could not distinguish female flower from the male flower and 64% could not state any benefit of bees. However, upon briefing about the significance of bee pollinators, 58% of the farmers showed eagerness to conserve bees at their farms. Keeping in view the inadequacies of farmers' knowledge about wild bees and pollination in general, the present study also gives some policy recommendations.

1. Introduction

According to Convention on Biological Diversity, agricultural biodiversity –the variety and variability in on-farm biological diversity at genetic, species and ecosystem levels- is responsible for maintenance of structure and processes of key ecosystem functions (Dias et al., 1999). However, it is also an established fact that urbanization and intensification in agriculture are the two main drivers of loss in agricultural biodiversity (Hennig and Ghazoul, 2012).

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Agricultural biodiversity ensures sustainability by delivering ecosystem services of provisioning, supporting and regulating in shape of crop pollination, nutrient cycling, biological control and reducing greenhouse gases, etc. The ecosystem service of crop pollination contributes 35 percent of the global food supply of worth $190.5 billion per year (Gallai et al., 2009; Ollerton et al., 2011).

Being the custodian and ultimate beneficiary of agricultural biodiversity, farmers can contribute decisively in its conservation and sustainability. However, it is hard to make them invest in conservation and sustainability without improving their understanding of agricultural biodiversity and convincing them for its importance. Conservation of pollinators for improved livelihood is one of such dimensions which needs farmers' attention (Krishna, 2007).

Kasina et al. (2009) have previously reported a strong positive relationship between updating farmers' knowledge of pollination and the degree of willingness they show towards conservation. Therefore, effective extension services and strong collaboration with research scientists can achieve the sustainability goals (Gurung, 2003; Muchagata and Brown, 2000).

Bees (Apoidea: Hymenoptera) are well known for their effectiveness towards pollination (Garibaldi et al., 2013; Latif et al., 2019; Saeed et al., 2019; Saeed et al., 2012; Shakeel et al., 2019). Kevan et al. (1990) overviewed that poor perception of pollinating bees is as an equal threat to sustainable agriculture as that of habitat loss, pesticides pollution and invasive species. Since intensification of agriculture is an important reason for loss in bee populations (Kennedy et al., 2013; Senapathi et al., 2015), there is a need to fully understand that how different farming practices affect their populations and then device conservation strategies for their sustainable use (Kremen et al., 2007).

In developing countries like Pakistan, there is little known about perception and awareness of farmers about bees in specific and crop pollination in general. Therefore, the present account is the first effort aiming to establish a baseline of this key information. We assessed six basic requisites of management of crop pollination: (i) ability of farmers to recognize bees and their nesting sites, (ii) their knowledge of host plants, (iii) their perception on 'whether or not bee visitation is useful for crops, (iv) their knowledge of process of fertilization in crop plants, (v) their opinions on bee poisoning by pesticides and (vi) their willingness to become a part of any future conservation programs after briefing thoroughly about the benefits of pollinators. In light of local knowledge gaps and requirements, this study may help support the establishment of context-specific conservation strategies with a special focus on environmental education for farmers.

2. Materials and methods

A survey-based study was conducted in three districts (i.e. Multan, Bahawalpur, and Khanewal) of Southern Punjab, Pakistan from March to September 2017. Farmers were formally interviewed using a semi-structured questionnaire; developed after having a thorough review of literature and consultation with the field experts. Twenty-five villages (2–20 km apart) with cucurbit growers were chosen in each district and selected at least 4 cucurbit growers from each village using purposive sampling method (Creswell and Clark, 2017).

One hundred male farmers were interviewed in each district (total of 300 farmers) to assess their knowledge on ecosystem service of pollination in cucurbits. Women were not included in the survey as they are not decision-makers in crop management while they mostly serve as a labor force in Pakistan (Sarwar and Abbasi, 2013).

In southern Punjab, farmers do not practice managed beekeeping yet the two native honey bee species are well recognized for their honey i.e. *Apis dorsata* and *A. florea*. Vegetables belonging to family Cucurbitaceae were selected as they are monoecious (i.e. having separate male and female flowers) in nature and require insects (especially the bees) for cross-pollination and fruit setting (Schaefer and Renner, 2011). In the absence of pollinators, fruits and flowers are aborted by 60–100 percent while good pollination can increase the yield from 100 to 1,550150 percent in cucurbit crops (Melnichenko and Khalifman, 1960). In Pakistan, cucurbits rank 3rd among summer and winter vegetables in terms of area under cultivation and their production (FBS, 2008; MINFAL, 2008).

There were four main sections of the semi-structured questionnaire. The first section referred to the socio-economic features of the farmers i.e. age, marital status, education level, farming experience and the source of advisory services regarding their farming practices. In the second section, respondents were evaluated for their ability to distinguish bees from other insects, presented to them as dead collection from the study areas i.e. moths, wasps, butterflies, and beetles. Besides this, they were also asked for the occurrence of nesting sites of the bees in nature from the best of their perception. The third section sought farmers' cognizance towards the harmful impacts of pesticide on the bees. Finally, as a last segment of the survey, farmers were first delivered a lecture on the significance and usefulness of pollinators and then they were investigated about their inclination towards conservation of pollinator biodiversity.

2.1. Data analysis

To summarize data, descriptive statistics were applied by using means and percentages in pivot tables-in Microsoft Excel 2007. Chi-square analyses were applied in order to see among districts differences in socio-demographic features and farmers' knowledge (i.e. their response towards various questions).

The relationship between 'yes' or 'no' response (binary values) of dependent variable (i.e. farmers' knowledge of nectar and pollen forage by the bees) and discrete set of independent variables was evaluated with the help of Logistic Regression Model (LRM) whilst the independent variables included age, education, farming experience, knowledge of monoecious nature flowers, knowledge of fertilization, contact with the extension staff and bee identification.

In order to know the factors which could potentially affect the knowledge of farmers about pollination, three hypotheses were made prior to applying LRM. The first hypothesis was made as 'the farmers' knowledge of the importance of pollination may be positively influenced by their age and farming experience as both may increase the number of encounters with the bees (Munyuli, 2011). The second hypothesis was 'farmers with higher education are supposed to have a better knowledge of the importance of pollination'. Likewise, the third hypothesis was 'frequent contact with the agriculture extension agents can increase farmers' knowledge (Kasina et al., 2009).

The estimated logistic regression model is given as follows:

$$\mathrm{Ln}(P1/1-Pi) = \beta_0 - \beta_1\mathrm{Age} + \beta_2\mathrm{EDU} - \beta_3\mathrm{FE} + \beta_4\mathrm{SOI} + \beta_5\mathrm{BEE\ \ ID} + \beta_6\mathrm{FER} - \beta_7\mathrm{DIO} + \beta_8\mathrm{BV} + \varepsilon$$

where β_0 was intercept and β_i (I = 1, 2, ..., 6) were slope coefficients and ε was random error term.

Stepwise multiple regression models were used to identify the most important factors contributing to the knowledge of bee forage. Moreover, the Multicollinearity Test i.e. Variance Inflation Factor (VIF) was conducted to identify the relationship among the regressors. Computer software Minitab (Minitab 16; Minitab Inc., State College, PA) was used to perform the statistical analyses.

3. Results

3.1. Socio-economic features of respondents

The demographic features were important to understand as they can directly influence the responses of farmer communities. Although respondents varied in their age from 25 to 65 years' majority (34%) of them ranged from 35 to 44 years with the farming experience of 10–30 years. Overall, 11% of the farmers got a middle school education, 24% got primary school education while the majority (45%) were illiterate. The literate respondents (i.e. having secondary and higher school educations) were less numerous in Bahawalpur (BWP, 13%) than Khanewal (KWL, 20%) and Multan (MUL, 26%). The majority (73%) of respondent farmers were relying on their own farming experience, 18% were following nearby progressive farmers while only 8% were taking services of Department of Agriculture Extension for obtaining information on farming practices, (Table 1).

3.2. Knowledge of bees and their natural history

The entire respondents showed some familiarity towards common native honey bees with their local names (*Apis dorsata* and *A. florea*) (Fabricius) but 36% regarded them are destructive for their crops. Only a few (11%) respondents were able to sort out some non-*Apis* native bees mainly *Lasioglossum* sp. (Curtis) and *Ceratina smaragdula* (Fabricius). Out of them, 47% pointed out three types of nesting sites i.e. mud wall (25%), tree trunks (37%) and soil (19%). Farmers in MUL were more familiar with non-*Apis* native bees than KWL and BWP (Table 2).

Most of the farmers misidentified fruit flies as syrphid flies and carpenter bees *Xylocopa* sp. as destructive wasps. Thirty percent of the respondents deemed that bees are harmful just like fruit flies. The majority (85%) of respondents stated flowers as the visitation site for bees while remaining stated leaves in addition to flowers.

Sixty-five percent of the respondents regarded bees as the main foragers of nectar; 12.7% of which reported pollen in addition to nectar. Thirty-four percent of the respondents were not sure about the fee forage. Bees were found higher in abundant during morning hours (i.e. 92% to the total abundance of a day) (Table 2).

Sixty-four percent of the respondents were not sure about the consequences of good pollination on cucurbit yield while just 9% recognized the good impact of bee visits on fruit set and yield. Fifty fine percent of the respondents were unaware of the monoecious nature of flowers. Moreover, the majority (63%) of the respondents were unaware of the fertilization requirements of cucurbit crops (Table 2).

3.3. Bee conservation in farmland

Fifty percent of the respondent farmers stated an increase in yield than the previous years while 30% stated a decrease in yield. They also reported some reasons like insect attack (28%), diseases (30%) and weather (42%). However, nobody regarded poor pollination as one of the factors in this regard.

All of the interviewees acknowledged the significance of pesticide usage towards pest management whilst 85% were applying pesticides before and after the initiation of flowering in cucurbits. Notably, early hour insecticide application was the most common (67% of the respondents) practice whilst 71% could not realize their negative impacts on the bees, while only 17% regarded them as harmful for the bees.

Upon briefing the important role of pollinators in cucurbit production, 58% of the respondents got convinced with on-farm conservation of bees and other pollinators. Regarding how to promote bee pollination, 68% of respondents were not sure while 25% deemed it conceivable through an increased number of hives (Table 2).

3.4. Factors affecting farmers' knowledge

Numerous important factors were selected for applying logistic regression that could affect the knowledge of pollination of cucurbit growers (Table 3). The results revealed that four of the factors significantly predicted the farmer's knowledge of bee forage i.e. those who were successful in identifying bee species, having knowledge of fertilization in cucurbits, knowledge of the importance of bee visitation and had contact with the extension staff. The Multicollinearity Test (VIF test) did not find any relationship between the selected variables (Table 4). Moreover, the stepwise multiple regression models also validated the importance of four of the factors identified by logistic regression model contributing significantly towards farmer knowledge of pollination (bee forage) (Table 5).

Table 1
Descriptive statistics of selected farm and farm characteristics of cucurbit growers in southern Punjab.

	Multan n (%)	Bahawalpur n (%)	Khanewal n (%)	Total n (%)	P
Age					
25–34 years	32 (32)	29 (29)	25 (25)	86 (28.7)	
35–44 years	23 (23)	4 (44)	35 (35)	102 (34)	
45–54 years	35 (35)	21 (21)	23 (23)	79 (26.3)	
55–65 years	10 (10)	6 (6)	17 (17)	33 (11)	<0.001
Experience of farming					
10 years	33 (33)	53 (53)	34 (34)	120 (40)	
20 years	50 (50)	38 (38)	54 (54)	142 (47.3)	
30 years	15 (15)	9 (9)	10 (10)	34 (11.3)	
>30 years	2 (3)	0 (0)	2 (2)	4 (1.3)	0.009
Education					
Uneducated	38 (38)	52 (52)	45 (45)	135 (45)	
Primary	27 (27)	25 (25)	22 (22)	72 (24)	
Middle	10 (10)	9 (9)	15 (15)	34 (11.3)	
≥Matric	25 (25)	14 (14)	20 (20)	59 (19.7)	0.196
Source of information					
Self-experience	70 (70)	68 (68)	79 (79)	217 (72.3)	
Other farmers	19 (19)	24 (24)	10 (10)	53 (17.7)	
Agriculture extension staff	8 (8)	9 (9)	8 (8)	25 (8.3)	
Radio	3 (3)	0 (0)	2 (2)	5 (1.7)	0.113

*P values are based on chi-square analysis of data in each category.

Table 2
Knowledge of growers on bee and cucurbit attributes in southern Punjab.

	Multan % (n)	Bahawalpur % (n)	Khanewal % (n)	Total % (n)	P
Knowledge of identified bee species					
Yes	18 (18)	5 (5)	11 (11)	11.3 (34)	
No	82 (82)	95 (95)	89 (89)	88.7 (266)	0.015
Bee species identified					
Lasioglossum sp. 2	5 (5)	1 (1)	1 (1)	20.6 (07)	0.102
Ceratina smaragdula	4 (4)	2 (2)	3 (3)	26.5 (09)	0.717
Deunomia sp.	2 (2)	0 (0)	0 (0)	5.9 (02)	
Amegilla cingulata	3 (3)	1 (1)	1 (1)	14.7 (05)	0.449
Nomia sp.	0 (0)	0 (0)	1 (1)	2.9 (01)	
Megachile sp.	1 (1)	0 (0)	0 (0)	2.9 (01)	
Lasioglossum sp. 1	1 (1)	0 (0)	0 (0)	2.9 (01)	
Tetralonia sp.	0 (0)	1 (1)	1 (1)	5.9 (02)	
Halictus sp.	0 (0)	0 (0)	1 (1)	2.9 (01)	
Halictidae sp.	2 (2)	0 (0)	3 (3)	14.7 (05)	0.247
Xylocopa sp.	0 (0)	0 (0)	0 (0)	0 (0)	
Knowledge of bee nesting sites					
Yes	8 (8)	2 (2)	6 (6)	47.1 (16*)	0.174
Nesting places of bees					
Ground	2 (2)	0 (0)	1 (1)	18.7 (03)	0.102
Tree trunk	3 (3)	0 (0)	3 (3)	37.5 (06)	0.717
Roofs made of sarkanda	1 (1)	0 (0)	0 (0)	6.2 (01)	
Holes in mud wall	2 (2)	0 (0)	2 (2)	25 (04)	0.449
Bamboo poles	0 (0)	1 (1)	0 (0)	6.2 (01)	
Dry wood	0 (0)	1 (1)	0 (0)	6.2 (01)	
Knowledge of bee forage					
Nectar	58 (58)	49 (49)	65 (65)	57.3 (172)	
Pollen and nectar	13 (13)	3 (3)	9 (9)	8.3 (25)	
Not sure	29 (29)	48 (48)	26 (26)	34.3 (103)	0.002
Bees beneficial to cucurbits					
Beneficial	13 (13)	4 (4)	9 (9)	8.7 (26)	
Not beneficial	57 (57)	72 (72)	63 (63)	64 (192)	
Not sure	30 (30)	24 (24)	28 (28)	27.3 (82)	0.128
Male and female flowers in cucurbits					
Present	26 (26)	19 (19)	29 (29)	24.7 (74)	
Absent	61 (61)	64 (64)	52 (52)	59 (177)	
Not sure	13 (13)	17 (17)	19 (19)	16.3 (49)	0.331
Knowledge of fertilization					
Had some knowledge	21 (21)	9 (9)	14 (14)	14.7 (44)	
No knowledge	59 (59)	69 (69)	61 (61)	63 (189)	
Not sure	20 (20)	22 (22)	25 (25)	22.3 (67)	0.171
Pesticide killing bees					
They kill bee	22 (22)	10 (10)	19 (19)	17 (51)	
They don't kill bees	69 (69)	78 (78)	65 (65)	70.7 (212)	
Not sure	9 (9)	12 (12)	16 (16)	12.3 (37)	0.098
Intent to increase bees					
Yes	60 (60)	51 (51)	62 (62)	57.7 (173)	
No	40 (40)	49 (49)	38 (38)	42.3 (127)	0.245

*P values are based on chi-square analysis of data in each category (Only given for most identified bee species and nesting places).
*Percentage of nesting sites knowledge mentioned of only those who identified non-*Apis* bees.

Table 3
Selected variables of binary logistic regression model.

Variable selected	Description of Variable
Age	Age of the cucurbit farmers in years
EDU	Attained school education in years
FE	Farming experience of the respondents in years
SOI	Source of information about farming practices, 1 extension staff, 0 other sources
Bee ID	Identification of bees, 1 yes, 0 no
FER	Fertilization (crossing of male and female flowers) necessary for cucurbits to set seed, 1 yes, 0 no
DIO	Two type of flowers in cucurbits, 1 yes, 0 no
BV	Bees beneficial to cucurbits, 1 yes, 0 no

4. Discussion

The two honey bee species (*A. dorsata* and *A. florea*) were well known among the farming communities in all the districts. This was due to the cultural and historical connotations of obtaining honey from these bees (Bentley and Rodrguez, 2001). Such associations have been well documented from the regions where honey bees exist in their natural range i.e. *A. mellifera* and *Meliponula* sp. are well known among farmers of Kakmega (Kasina et al., 2009). Nearly 35% of the respondent farmers confounded honey bees with some harmful sucking pests thereby reducing the yield.

Only a few respondents in the present study correctly identified native non-*Apis* bees especially the green colored, *C. smaragdula*. Color of a bee is one of the most important predictors in traditional

Table 4
Logistic regression values of relationship between the farmer knowledge of pollination (bee forage) and key factors listed in table (S = 0.112, r^2 = 90.48).

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.0746	0.0724	1.03	0.305	2.87
Age	−0.00221	0.00158	−1.40	0.163	4.6
EDU	0.0168	0.0700	0.24	0.811	1.14
FE	−0.0088	0.0723	−0.12	0.903	2.79
SOI	0.4119	0.0425	9.69	0.000	2.93
BEE ID	0.4112	0.0460	8.94	0.000	4.55
FER	0.0736	0.0244	3.02	0.003	1.65
DIO	−0.0103	0.0287	−0.36	0.719	2.85
BV	0.1172	0.0433	2.71	0.007	3.38

Table 5
Features of the best fit multiple regression model of farmer knowledge of pollination (bee forage).

Vars	R-Sq	R-Sq (adj)	R-Sq (pred)	Mallows Cp	S	Age	EDU	FE	SOI	BEE ID	FER	DIO	BV
1	78.7	78.6	77.3	162.0	0.15023				✓	✓			
1	70.8	70.6	69.8	302.5	0.17609				✓				
2	86.1	85.9	83.5	34.0	0.12179				✓	✓			
2	81.2	81.0	78.3	120.2	0.14154					✓			✓
3	87.2	87.0	83.9	16.5	0.11715				✓	✓			✓
3	87.2	87.0	84.6	16.6	0.11718				✓	✓	✓		
4	**88.0**	**87.7**	**84.7**	**4.7**	**0.11379**				✓	✓	✓		✓
4	87.2	87.0	84.5	17.6	0.11721				✓	✓	✓	✓	
5	88.0	87.7	84.6	5.5	0.11375				✓	✓	✓	✓	✓
5	88.0	87.7	84.6	6.1	0.11391		✓		✓	✓	✓		✓
6	88.1	87.7	84.7	6.8	0.11381	✓		✓	✓	✓	✓		✓
6	88.0	87.7	84.6	7.2	0.11394	✓			✓	✓	✓	✓	✓
7	88.2	87.8	84.6	7.2	0.11365	✓		✓	✓	✓	✓	✓	✓
7	88.1	87.7	84.7	7.9	0.11383	✓	✓	✓	✓	✓	✓		✓
8	88.2	87.7	84.6	9.0	0.11387	✓	✓	✓	✓	✓	✓	✓	✓

Note: Values in bold text indicate the significant model.

knowledge besides its occurrence and body size (Atran, 1987; Bentley, 1994). In a similar study, farmers of Kakamega (Kenya) identified a large carpenter bee (*Xylocopa* sp.) like a bee due to its large size (Kasina et al., 2009). On the other hand, none of the farmers in the study could recognize large carpenter bee yet owing to a black color and large body size, they confused it with some wasp. Therefore, farmers' perception towards the same bee may vary with cultures and norms.

As a common trend in developing countries, due to poor knowledge, farmers cannot differentiate beneficial insects from the harmful ones (Munyuli, 2011). We observed similar results in the present study; flower-visiting bees and flies were mistaken as some harmful insects. Contrarily, the farmers of Kakamega (Kenya) were quite correct in distinguishing bees from other insect pests mainly due to familiarity with the process of pollination in general (Kasina et al., 2009). However, distinguishing bees is sometimes difficult for farmers among the array of other bees like an insect. Reason being most of the farmers in the present study mistook hoverflies as fruit flies. In a previous study performed by Benjamin et al. (2012), farmers even confused honey bees and houseflies with the fruit flies. The correct identification of insects is so crucial that syrphid flies are important pollinators whereas fruit flies are notorious pests of cucurbit crops (Abdullah and Latif, 2001; Saeed et al., 2012). Therefore, there is need to train farmers for proper identification of pollinators versus insect pests.

The 11% of respondents who recognize the solitary bees also reported the nesting sites i.e. holes in the ground, mud walls and dry tree trunks. Kasina et al. (2009) reported similar feedback of farmers from Kakamega, Kenya. The coffee growers of Uganda have also reported termite mounds and abandoned snail shells as bee nesting sites (Munyuli, 2011).

The majority of farmers in this study did not know the role of bees in cross-pollinators of cucurbits. Instead, they regarded their foraging activity as the main reason of flower abortion. This was so because they did not know about the monoecious nature of flowers in cucurbit crops where female flowers transform into the fruit while the male flower finally drops down (NeSmith et al., 1994). The farmers' knowledge of pollination varies with crops, level of education and training and extension services they receive. Another important predictor is their ability to recognize bees and other pollinators (Kasina et al., 2009; Munyuli, 2011).

The majority of respondent farmers were of the view that pollination could be improved by promoting honey bee hives alone while they ignored the non-*Apis* bees. Some earlier studies, however, have shown native non-*Apis* bees as a better performer than honey bees for a few crops in the region (Ali et al., 2011; Bashir et al., 2018; Sajjad et al., 2009). Therefore, there was a need to train farmers on proper identification and conservation of both *Apis* and non-*Apis* native bee species.

Farmers' knowledge of pollination (bee forage) did not find to be influenced by age, farming experience, and education. The non-significant relationship of farmers' knowledge with education in this study might arise due to the absence of science subjects in their higher qualification. The education of respondents positively influenced the knowledge of pollination in Kenya (Kasina et al., 2009) while it did not influence in Uganda (Munyuli, 2011). On the other hand, farmers' knowledge of pollination was influenced by the source of information about farming practices and three other closely associated factors i.e. identification of bee species, knowledge of fertilization, benefits of bees. In Pakistan, farmers mainly get new information from the agents of agriculture extension department and partially from neighboring farmers and print and electronic media (Mallah, 1997). Agricultural ecosystems can become more sustainable by increasing the awareness and understanding of the value of pollination services delivered by pollinators (Eardley et al., 2006). In developing countries, the production and use of insects for pollination services would require major research and extension efforts as compared to the developed countries (Uma et al., 2012). In general, training, meetings, and demonstration plots have been regarded as the best extension methods not only in Pakistan but also in other developing countries (Sattaka et al., 2017).

5. Conclusions and recommendations

The on-farm pollination management should be based on enhanced farmers' knowledge on pollination in general and biology and ecology of native bees in specific. Following recommendations are suggested in this regard:

1. The present study confers a baseline on farmers' knowledge and perception about pollinators and pollination; this can help establish the conservation strategies not only for cucurbits but also other important crops in the region.
2. The regular contacts with agriculture extension staff can increase the knowledge of farmers about bees. Therefore, the capacity of agriculture extension staff should be built in this regard.
3. The literature on native pollinator fauna published in the local language can further help the farmers in this regard.
4. Effective channels for enhancing and improving farmer knowledge should be considered, for instance, farmer field school.
5. Farmers can be convinced to adopt different on-farm conservation practices in order to improve bee diversity e.g. raising multipurpose agroforestry, reducing the number of insecticidal applications and maintaining some uncultivated patches as nesting sites of bees.

Declaration of interest

The authors declared that there is no conflict of interest.

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