 DOI: 10.13102/sociobiology.v73i3.12876

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - BEES

Assessing Farmers' Knowledge and Perceptions About Pollinators in Mango Agro-ecosystems of Southern Punjab, Pakistan

Ammad Ahmad[1], Asif Sajjad[2], Haris Khurram[3], Waseem Akram[4]

1 - Beekeeping and Hill Fruit Pests Research Sub-station, Murree, Punjab, Pakistan
2 - Department of Entomology, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur, Punjab, Pakistan
3 - FAST School of Management, National University of Computer and Emerging Sciences, Chiniot-Faisalabad Campus, Faisalabad, Pakistan
4 - Honeybee Research Institute (HBRI), National Agricultural Research Centre (NARC), Islamabad, Pakistan

Article History

Edited by
Evandro Nascimento Silva, UEFS, Brazil
Received 04 May 2026
Initial acceptance 22 July 2026
Final acceptance 07 September 2026
Publication date 22 September 2026

Keywords
Farmer knowledge, Pollinators, Pollination, Conservation, Bees, Syrphid.

Corresponding author
Ammad Ahmad
Beekeeping and Hill Fruit Pests Research Sub-station, Murree
Punjab, Pakistan.
E-Mail: ammadahmad445@gmail.com

Abstract

Farmers are the ultimate beneficiaries of the ecosystem service of crop pollination, and their indigenous knowledge can be used to address the current challenges of pollinator decline. However, their perception and knowledge about pollinators is rarely investigated, particularly for orchard-based agroecosystems. This study aimed to assess the farmers' knowledge and perception about pollinators and pollination in the mango agroecosystem. Also, statistical modelling identified the factors that affect the farmers' knowledge. We interviewed 280 mango farmers from four districts (70 from each district) of South Punjab, Pakistan, to assess their knowledge about pollinators and pollination. Overall, 80% of respondents had no knowledge about pollination. Two native honeybee species, *Apis dorsata* and *Apis florea,* were well known among farmers, but only 13.57% of respondents showed some knowledge about non-bee pollinators. The results of the logistic regression model showed that farmers' age (B = -0.051, SE = 0.017, p = .003), farming experience (B = 0.071, SE = 0.018, p = .000), primary education (B = 0.671, SE = 0.333, p = .044) and matric education (B = 0.830, SE = 0.398, p = .037) significantly impacted their knowledge about pollinators and pollination. The knowledge gap recognized in this study warrants the capacity building of farmers about the pollinators and their pollination services. By using indigenous and local knowledge, the conservation strategies for pollinators can be established in the region.

Introduction

The decline in on-farm invertebrate biodiversity is driven by intensive and mechanized farming practices (Hall & Steiner, 2019; Hall & Martins, 2020). Healthy agricultural biodiversity contributes to sustainability by providing ecosystem services such as biological control, crop pollination, and nutrient cycling. Crop pollination is an important ecosystem service provided by animals (particularly insects), contributing 35% to the world's food supply and valued at $190.5 billion annually (Gallai et al., 2009; Ollerton et al., 2011). Animal-mediated pollination is essential for about 75% of globally important crops (Klein et al., 2007), particularly those vital for human nutrition (Eilers et al., 2011).

Farmers are the primary beneficiaries of ecosystem services provided by insects; their involvement in sustaining and conserving insect biodiversity is necessary (Ali et al., 2020). Farmers' decisions about adopting farm management practices are crucial for conserving on-farm biodiversity. However, it is difficult to convince farmers to invest in the sustainability and conservation of agricultural biodiversity without enhancing their knowledge. Therefore, pollinator conservation is one aspect that needs farmers' attention to improve their livelihoods. (Krishna, 2007).

Mango flowers exhibit complex reproductive biology containing both male (staminate) and hermaphroditic flowers on a panicle (Ramirez & Davenport, 2016). Pollination in mango flowers can occur by wind, but insect pollinators are

Open access journal: http://periodicos.uefs.br/index.php/sociobiology
ISSN: 0361-6525

essential for adequate fruit set. Multiple studies across diverse regions documented effective pollinators such as honeybees (*Apis mellifera*, *A. cerana*), large flies (*Chrysomya* and *Eristalis* spp.), and native bees (*Trigona* sp.) (Anderson et al., 1982; Dag & Gazit, 2000; Sung et al., 2006; Fajardo et al., 2008). Pollinator contribution accounts for approximately 53% of total fruit set (Huda et al., 2015). Fajardo et al. (2008) reported that without pollinators, fruit set drops dramatically, i.e., from 41% to 0.7% in caged inflorescences.

Several studies have reported a sharp decline in the population of pollinators, resulting in a pollination crisis, which has economic implications and reduced crop yield (Kevan & Phillips, 2001; Kevan & Viana, 2003; Klein et al., 2007; Bauer & Wing, 2010; Brittain et al., 2010; Carvalheiro et al., 2010; Potts et al., 2010; Menz et al., 2011). Scientists have paid close attention to reduced pollination services in agricultural ecosystems. Pollinator population decline is primarily caused by ecological changes, i.e., habitat loss (Ricketts et al., 2008; Carvalheiro et al., 2010), climate change (Hegland et al., 2009), and agricultural intensification (Kennedy et al., 2013; Senapathi et al., 2015). To protect pollinators and pollination services, farmers must be involved in mitigating pollinator declines in monocropping-dominated landscapes and should be willing to implement pollinator-friendly management practices (Osterman et al., 2021).

Farmers' knowledge of pollination and pollinators positively impacts crop management plans and conservation efforts, such as reducing insecticide use and diversifying crops (Hevia et al., 2020). Indigenous knowledge of farmers can be used to solve the current challenges of pollinator decline, because it can broaden our knowledge regarding the spatial and temporal dynamics of biodiversity, provide critical information on the use of locally adapted crop varieties, and support practices that are suited to local needs and visions (Sutherland et al., 2013).

According to some studies focused on farmer knowledge, there are substantial disparities in local and indigenous understanding about pollination and pollinators among farmers between countries, regions, and crops (Kasina et al., 2009; Hanes et al., 2015; Smith et al., 2017; Elisante et al., 2019; Breeze et al., 2019; Ali et al., 2020; Hevia et al., 2020). Farmers in developed countries are more dynamic, as they have used their local knowledge base to change their on-farm pollination practices over the last ten years (Osterman et al., 2021). However, farmers in developing countries still do not fully understand the importance of crop pollination as an ecosystem service (IPBES, 2016). Generally, studies on farmers' perceptions and knowledge of pollinators, particularly non-bees, are limited in developing countries like Pakistan (Garbach & Morgan, 2017; Breeze et al., 2019; Rawluk & Saunders, 2019; Hevia et al., 2020).

This study aimed to assess farmers' knowledge and perceptions of pollinators and pollination in the mango agroecosystem. It also aimed to identify the factors that affect farmers' knowledge using statistical modeling. For this purpose, we interviewed 280 mango farmers from four main mango-growing districts in South Punjab (i.e., Bahawalpur, Multan, Khanewal, and Rahim Yar Khan). We assessed the five fundamentals of crop pollination and pollinators: (1) ability of farmers to identify the pollinators (2) their ability to differentiate between beneficial and harmful insects (3) their perception of whether pollinator visitation is beneficial for fruit set or not (4) their knowledge about harmful impacts of pesticides on pollinators and (5) their intent to increase the pollinators.

Materials and Methods

Study sites and area

A survey-based study was carried out in the four districts i.e., Bahawalpur (29°19'32" N 71°56'09" E), Rahim Yar Khan (28°24'50"N 70°18'14"E), Multan (30°10'52"N 71°28'28"E) and Khanewal (30°17'41"N 71°56'09"E) of Southern Punjab, Pakistan (Fig 1). Southern Punjab is featured by cold winters and hot summers. The climate is arid, with average daily maximum and minimum temperatures of 15 °C to 20 °C and 30 °C to 35 °C, respectively. The average annual rainfall is 300-500 mm (Akram et al., 2019; Ahmad et al., 2025). In South Punjab, wheat, cotton, rice, and sugarcane are major crops cultivated over large areas (Ahmad et al., 2023). In mango orchards, major mango cultivars such as Dusehri, Anwar Ratol, Langra, Chaunsa, Desi, Sindhri, and Fijri are grown. Bahawalpur, Muzaffargarh, Multan, and Rahim Yar Khan are the primary regions for mango production (Bakhsh et al., 2006).

Sampling technique and Questionnaire survey

Before conducting the survey, the questionnaire was discussed with extension workers and pollination-relevant experts. Mango farmer data were obtained from the Agriculture Extension Department in each district, and a pilot survey was conducted before the main survey to test the questionnaire. The pilot survey results were used to improve the questionnaire. Surveys were carried out from March to June 2023, during the mango flowering and fruit setting period. In total, 280 mango farmers (70 farmers of different ages ranging from 21 to above 60 years from each district) were selected based on their orchard area (minimum 01 acre) and informally interviewed to assess their knowledge. All participants were male because no female farmers were found to be involved in mango farming. A semi-structured questionnaire (Supplementary material) was used to gather information about farmers' knowledge, which consisted of four main sections. The first section involved questions about socioeconomic features of farmers, i.e., orchard area, age, education, farming experience, and the source of information for farming practices. The second section included questions to assess respondents' knowledge of pollinators and pollination, as well as their ability to identify honeybees and non-bee pollinators. Farmers were shown

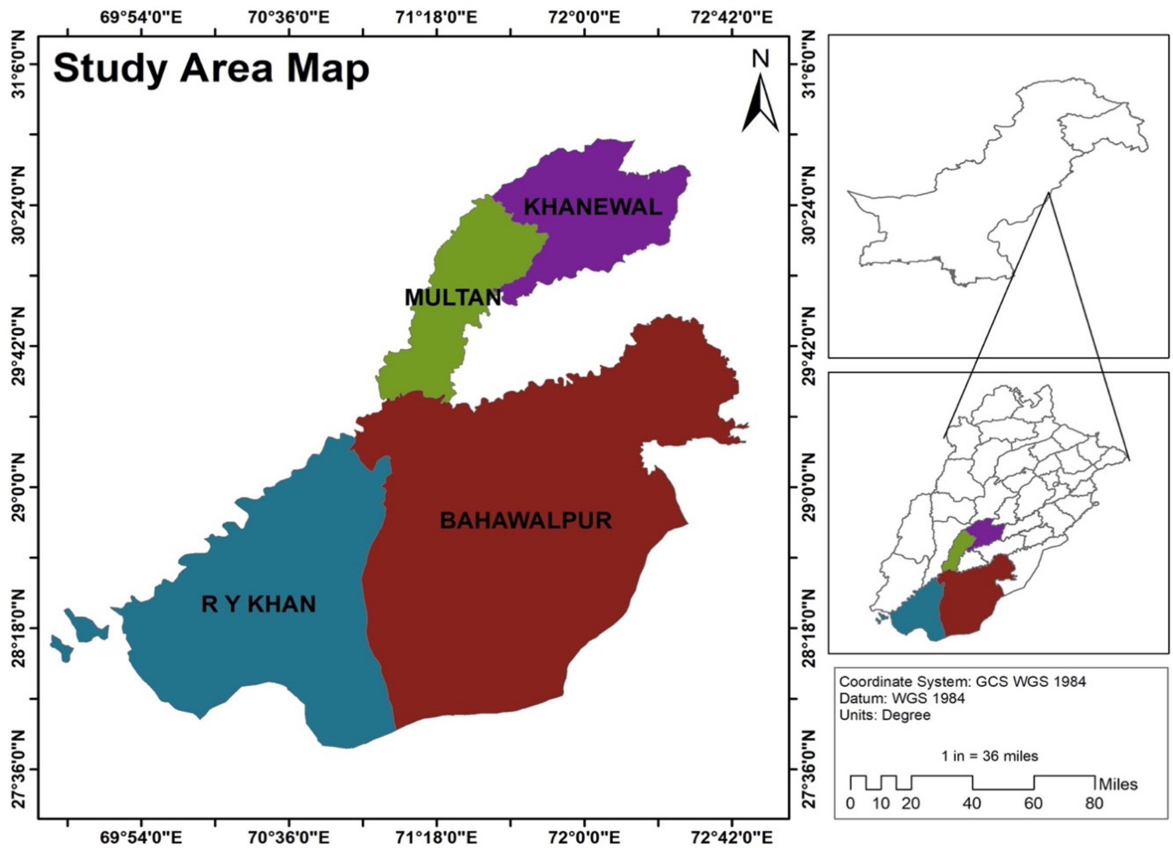

Fig 1. Map of the study area showing the four districts of South Punjab, Pakistan.

pinned specimens of different insect pests and pollinators and asked to distinguish between beneficial and harmful insects. Because dipterans are common mango pollinators, farmers were asked only about dipteran habitat. Their perceptions of mango yield trends were also recorded, and they were asked to identify one major factor involved in yield reduction. The third section aimed to assess farmers' perceptions of the harmful impact of pesticides on pollinators. In the last section, a lecture was delivered to farmers on the importance of pollinators and their inclination to participate in any program aimed at conserving pollinators.

Data description

Sixteen questions representing farmers' knowledge (dependent variable) were selected, and farmers' responses were coded in binary values, i.e., "Yes = 1" and "No = 0" (Ali et al., 2020; Hevia et al., 2020). The knowledge index was scored between 0 and 16 for each respondent to indicate their knowledge level and was used for regression analysis. For classification analysis, we categorized scores below 10 as inadequate knowledge and above 10 as adequate knowledge.

Data analysis

We used frequencies and percentages to analyze bivariate characteristics across geographic areas. We used the chi-square test to assess the association between residential district and knowledge. This helped us understand the distribution of knowledge and characteristics across different geographical locations. We used a logistic regression model to evaluate the factors affecting adequate knowledge among farmers. We considered four socio-demographic features: age, orchard area, education, and farming experience as predictors. We used a box plot to visualize the distribution of knowledge across different education levels and sources of information. Finally, we used the locally weighted scatterplot smoothing (LOWESS) model to examine the relationship between different factors and farmers' knowledge. We considered all p-values < 0.05 statistically significant. All the results were evaluated using XLSTAT software and the R language.

Results

Demographic features of farmers

We identified demographic features of farmers that are important to understand farmers' decision-making. In this study, farmers' ages ranged from 21 to 60 years, with a majority (28.57%) in the 50 to 60 age group. Most farmers (37.14%) had 10 years of farming experience, and most belonged to the districts of Khanewal and Multan. Generally, most farmers (45.36%) stated that they get information about farming practices from pesticide dealers, followed by extension workers (23.93%), whereas 22.86% of farmers stated that they use their own experience for decision-making. The majority of respondents (44.64%) who participated in this study were illiterate or uneducated. The highest percentage of uneducated farmers was in Rahim Yar Khan (50%), followed by Multan (45.7%), Bahawalpur (42.9%), and Khanewal (40%) (Table 1).

Knowledge of pollinators and pollination

First, farmers were asked about their knowledge of pollination, and only 20% gave the correct answer. The majority of respondents (80%) had no knowledge of pollination. Farmers from Multan (25.71%) had more knowledge about pollination, followed by Khanewal (21.43%) and Rahim Yar Khan (18.57%). A few respondents from Bahawalpur (14.29%) were familiar with pollination. Overall, 92.14% of respondents ranked pollinators as beneficial, with Multan being the only district where 100% of respondents favored pollinators as beneficial creatures (Table 2).

Respondents from all four districts knew about native honeybees (*Apis dorsata* and *Apis florea*) and their benefits for crops, but only 62.86% and 64.64% could identify *A. florea* and *A. dorsata*, respectively, when shown the specimens. Only a few (13.57%) of the respondents knew pollinators other than honeybees. In the identification of non-*Apis* pollinators, 21.07% were able to identify *Episyrphus balteatus,* and 19.29% identified *Eristalinus aeneus*. Only a few farmers (1-4%) were able to identify the other pollinator species, i.e., *Chrysomya megacephala*, *Xylocopa fenestrata*, *Polistes watti,* and *Eupeodes corollae*. Farmers from Multan (24.29%) and Rahim Yar Khan (20%) were more familiar with non-*Apis* pollinators (Table 2).

As Dipteran pollinators were the most abundant, the farmers were asked about their habitats. Only 6.79% of respondents knew the habitat of Dipteran pollinators, while the rest were unaware. In the Multan district, none of the respondent farmers knew the habitat sites of Dipteran pollinators. The majority of the farmers (77.14%) were unable to differentiate between beneficial and harmful insects. The farmers in Rahim Yar Khan (37.14%) and Bahawalpur (30%) districts had comparatively greater knowledge of how to differentiate between beneficial and harmful insects. Farmers were unable to differentiate between the syrphid fly (*E. balteatus*) and the fruit fly, as most farmers (78.93%) misidentified *E. balteatus* as the fruit fly. Only 2.14% of respondents knew that mango has male and hermaphrodite flowers (Table 2).

Table 1. Bivariate Analysis and the association between different demographic characteristics and geographic areas.

Characteristics	Bahawalpur n (%)	Rahim Yar Khan n (%)	Multan n (%)	Khanewal n (%)	Total n (%)	p-value*
Age of farmer						
21-30 years	10 (14.3)	7 (10)	5 (7.1)	15 (21.4)	37 (13.21)	
31-40 years	14 (20)	14 (20)	19 (27.1)	16 (22.9)	63 (22.50)	
41-50 years	20 (28.6)	19 (27.1)	18 (25.7)	8 (11.4)	65 (23.21)	<0.0001
51-60 years	20 (28.6)	23 (32.9)	8 (11.4)	29 (41.4)	80 (28.57)	
Above 60 years	6 (8.6)	(7 (10)	20 (28.6)	2 (2.9)	35 (12.50)	
Education						
Uneducated	30 (42.9)	35 (50)	32 (45.7)	28 (40)	125 (44.64)	
Primary	15 (21.4)	13 (18.6)	18 (25.7)	26 (37.1)	72 (25.71)	
Middle	5 (7.1)	5 (7.1)	1 (1.4)	0 (0)	11 (3.93)	0.100
Matric	14 (20)	11 (15.7)	12 (17.1)	6 (8.6)	43 (15.36)	
Above Matric	6 (8.6)	6 (8.6)	7 (10)	10 (14.3)	29 (10.36)	
Farming Experience						
10 years	24 (34.3)	20 (28.6)	29 (41.4)	31 (44.3)	104 (37.14)	
20 years	25 (35.7)	24 (34.3)	21 (30)	16 (22.9)	86 (30.71)	
30 years	15 (21.4)	17 (24.3)	10 (14.3)	15 (21.4)	57 (20.36)	0.189
40 years	4 (5.7)	8 (11.4)	5 (7.1)	8 (11.4)	25 (8.93)	
> 40 years	2 (2.9)	1 (1.4)	5 (7.1)	0 (0)	8 (2.86)	
Source of Information						
Self-experience	23 (32.9)	17 (24.3)	20 (28.6)	4 (5.7)	64 (22.86)	
Pesticide dealer	25 (35.7)	30 (42.90	30 (42.9)	42 (60)	127 (45.36)	
Extension worker	13 (18.6)	18 (25.7)	15 (21.4)	21 (30)	67 (23.93)	0.019
Neighbor farmer	5 (7.1)	3 (4.3)	2 (2.9)	2 (2.9)	12 (4.29)	
Other	4 (5.7)	2 (2.9)	3 (4.3)	1 (1.4)	10 (3.57)	

*p-values are based on the chi-square test.

Table 2. Measuring the association between knowledge of mango farmers in different geographical areas.

Knowledge	Bahawalpur n (%)	Rahim Yar Khan n (%)	Multan n (%)	Khanewal n (%)	Total n (%)	p-value*
Knowledge about pollination						
Correct	10 (14.29)	13 (18.57)	18 (25.71)	15 (21.43)	56 (20)	0.386
Wrong	60 (85.71)	57 (81.43)	52 (74.29)	55 (78.57)	224 (80)	
Knowledge of honeybees						
Yes	70 (100)	70 (100)	70 (100)	70 (100)	280 (100)	
No	0 (0)	0 (0)	0 (0)	0 (0)	0(0)	
Knowledge of other pollinators						
Yes	6 (8.57)	14 (20)	17 (24.29)	11 (15.71)	38 (13.57)	0.386
No	64 (91.43)	56 (80)	53 (75.71)	59 (84.29)	232 (82.86)	
Where you rank pollinators						
Beneficial	62 (88.57)	65 (92.86)	70 (100)	61 (87.14)	258 (92.14)	0.022
Harmful	8 (11.43)	5 (7.14)	0 (0)	9 (12.86)	22 (7.86)	
Knowledge about habitat of Dipteran pollinators						
Know	6 (8.57)	5 (7.14)	0 (0)	8 (11.43)	19 (6.79)	0.049
Don’t know	64 (91.43)	65 (92.86)	70 (100)	62 (88.57)	261 (93.21)	
Differentiate between beneficial and harmful insect						
Yes	21 (30)	26 (37.14)	10 (14.29)	7 (10)	64 (22.86)	0.000
No	49 (70)	44 (62.86)	60 (85.71)	63 (90)	216 (77.14)	
Identified Pollinator species						
Apis florea	42 (60)	41 (58.57)	48 (68.57)	45 (64.29)	176 (62.86)	<0.0001
Apis dorsata	46 (65.71)	45 (64.29)	43 (61.42)	47 (67.14)	181 (64.64)	
Episyrphus balteatus	9 (12.86)	24 (34.29)	14 (20)	12 (17.14)	59 (21.07)	
Eristalinus aeneus	6 (8.57)	27 (38.57)	16 (22.86)	5 (7.14)	54 (19.29)	
Chrysomya megacephala	7 (10)	2 (2.86)	0 (0)	0 (0)	9 (3.21)	
Xylocopa fenestrata	0 (0)	1 (1.43)	0 (0)	0 (0)	1 (0.36)	
Polistes wattii	0 (0)	0 (0)	3 (4.29)	0 (0)	3 (1.07)	
Eupeodes corollae	5 (7.14)	0 (0)	0 (0)	7 (10)	12 (4.29)	
Difference between *Episyrphus balteatus* and Fruit fly						
Know	9 (12.86)	24 (34.29)	14 (20)	12 (17.14)	59 (21.07)	0.012
Don’t know	61 (87.14)	46 (65.71)	56 (80)	58 (82.86)	221 (78.93)	
Male and Hermaphrodite flowers in mango						
Know	0 (0)	2 (2.86)	4 (5.71)	0 (0)	6 (2.14)	0.058
Don’t know	70 (100)	68 (97.14)	66 (94.29)	70 (100)	274 (97.86)	
Mango yield trend						
Increasing	23 (32.86)	29 (41.43)	30 (42.86)	37 (52.86)	119 (42.50)	0.123
Decreasing	47 (67.14)	41 (58.57)	40 (57.14)	33 (47.14)	161 (57.50)	
Yield declining factors						
Insect pests	12 (17.14)	13 (18.57)	10 (14.29)	10 (14.29)	45 (16.07)	<0.0001
Weather conditions	20 (28.57)	22 (31.43)	9 (12.86)	0 (0)	51 (18.21)	
Diseases	15 (21.43)	6 (8.57)	21 (30)	23 (32.86)	65 (23.21)	
Crop stage at which pesticides applied						
Before and after flowering	35 (50)	29 (41.43)	24 (34.29)	57 (81.43)	145 (51.79)	<0.0001
Only before flowering	6 (8.57)	5 (7.14)	0 (0)	0 (0)	11 (3.93)	
During flowering	29 (41.43)	36 (51.43)	46 (65.71)	13 (18.57)	124 (44.29)	
Pesticides kill pollinators						
Yes	45 (64.29)	48 (68.57)	47 (67.14)	57 (81.43)	197 (70.36)	0.012
No	18 (25.71)	14 (20)	22 (31.43)	6 (8.57)	60 (21.43)	
Not Sure	7 (10)	8 (11.43)	1 (1.43)	7 (10)	23 (8.21)	
Intent to increase pollinators						
Yes	54 (77.14)	65 (92.86)	63 (90)	56 (80)	238 (85)	0.023
No	16 (22.86)	5 (7.14)	7 (10)	14 (20)	42 (15)	

*p-values are based on the chi-square test.

Yield trend and conservation of pollinators in orchards

Farmers gave mixed responses regarding the mango yield trend over the last three years. More than half (57.50%) of the farmers stated that mango yield is decreasing. Among them, 23.80% reported diseases, 18.21% reported weather, and 16.07% reported insect pests as major factors in yield decline. Seventy percent (70.36%) of the farmers stated that pesticides are eliminating pollinators, while 21.43% stated that they are not harmful to pollinators. Only a few respondents (8.21%) were not sure about the harmful impacts of pesticides on pollinators. In Khanewal district, most farmers (81.43%) were well aware of the harmful impacts of pesticides. Overall, 44.29% of respondents reported applying pesticides during the flowering period of mango, and among them, most farmers were from Multan (65.71%) and Rahim Yar Khan (51.43%). After the lecture on the importance of pollinators and their conservation, 85% of respondents showed willingness to increase pollinators in their orchards. But when asked how to promote pollinators, no one had any clue due to a lack of knowledge (Table 2).

Factors affecting farmer knowledge

Among uneducated and primary-educated farmers, the information source from neighboring farmers is the main factor that lowers their knowledge. In contrast, farmers with education above matric are influenced more by information from pesticide dealers and personal experience. The source of information from extension workers has a mixed effect on the knowledge of farmers among all levels of education, except among middle-passed farmers, where it is the main factor affecting their knowledge (Fig 2). The scatter plots (Fig 3) showed that there are non-linear relationships between farmers' knowledge scores and their demographic traits. In relation to farming experience, knowledge rose slightly to a high around 40 years before sharply declining. On the other hand, orchard area showed an overall positive monotonic relationship, suggesting that higher levels of knowledge are correlated with bigger operational scale, whereas respondent age showed an initial slight negative trend that stabilized until middle adulthood (Fig 3). The results of logistic regression revealed that among different factors, age of the farmer, farming experience, and

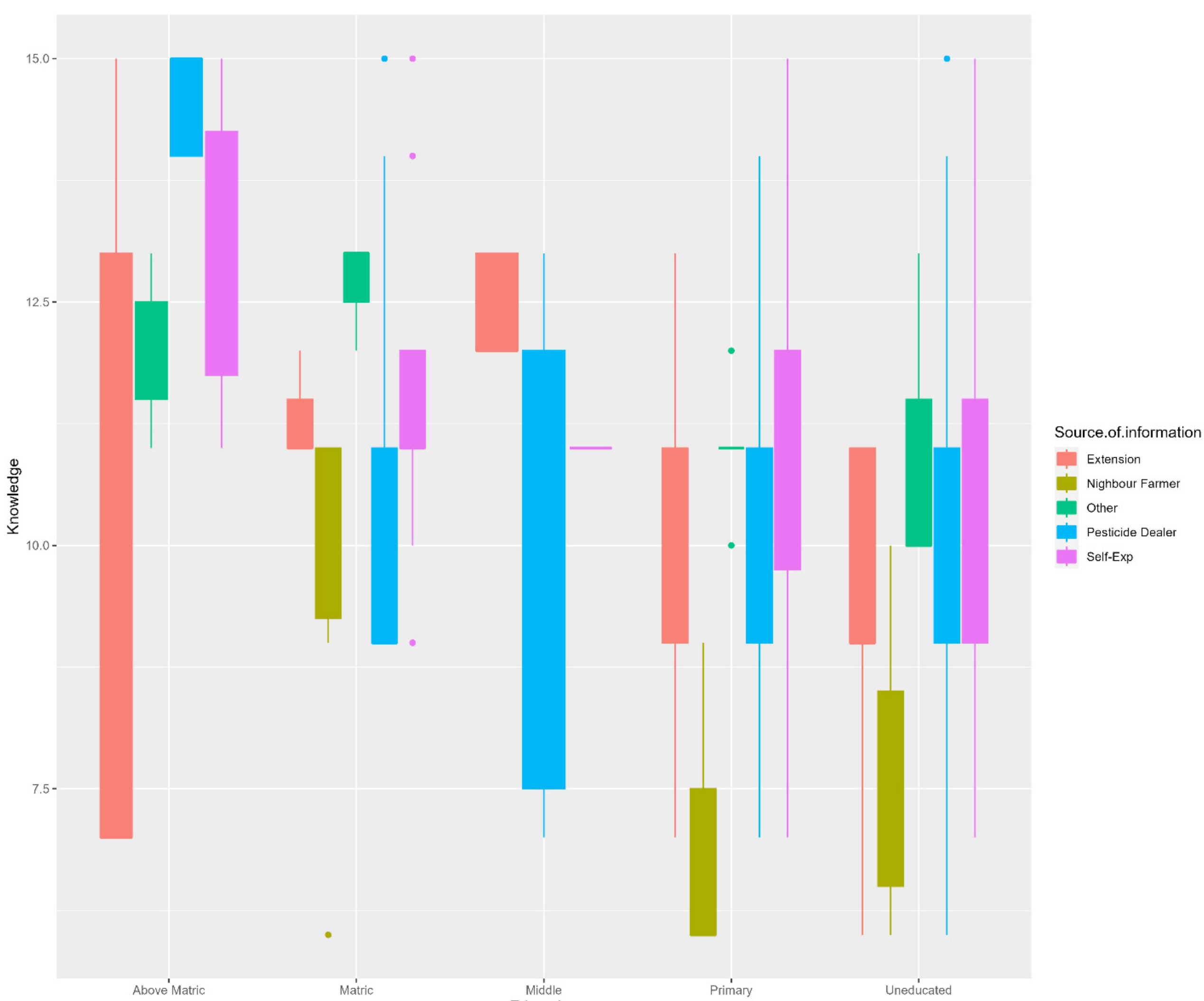

Fig 2. Boxplot for the assessment of knowledge level due to different education levels and the Source of information.

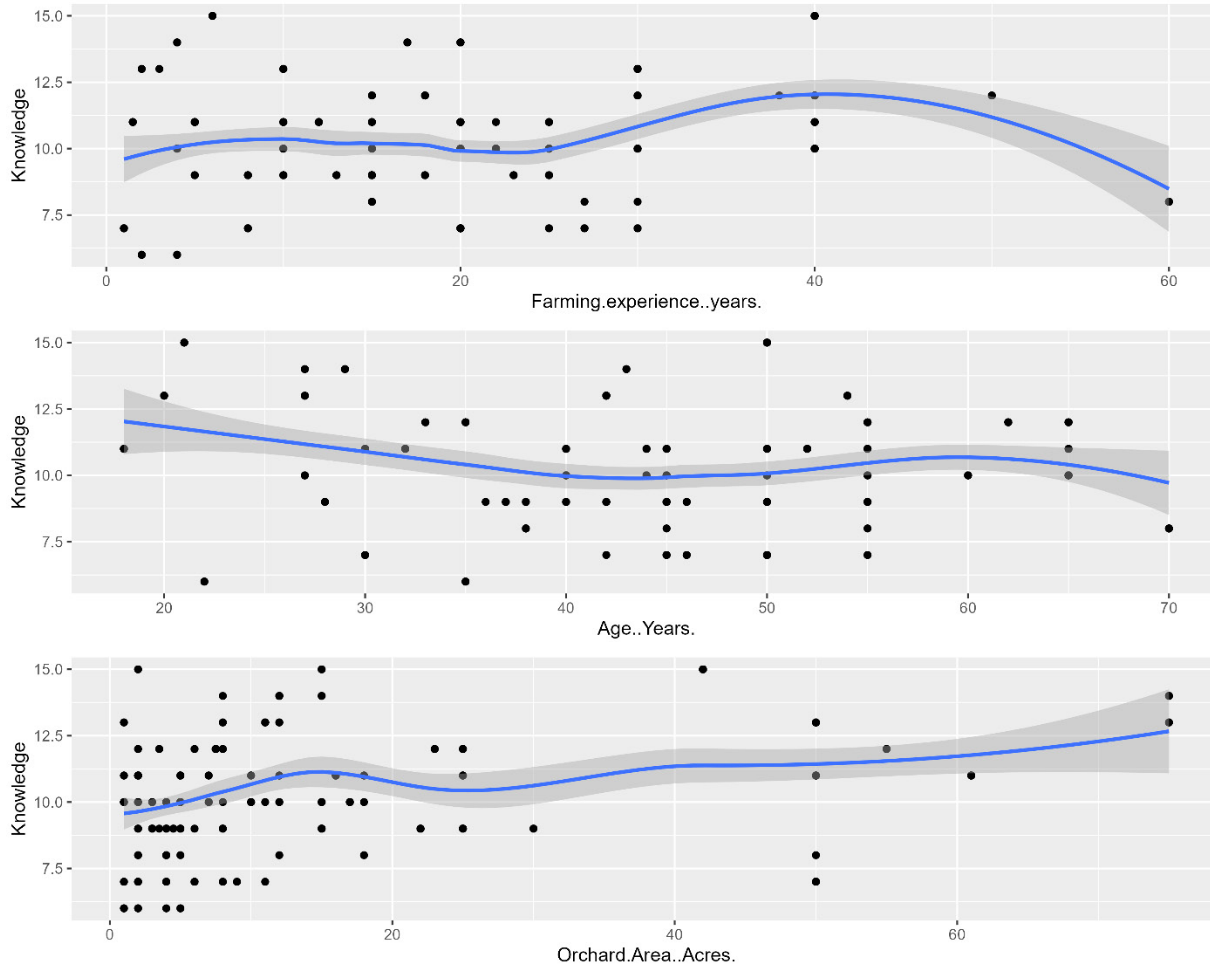

Fig 3. Relationship of Knowledge with Farming Experience, Age, and Orchard Areas. The blue line is the fitted LOWESS function. The grey-shaded area is the 95% Confidence band.

primary and matric education of farmers significantly impacted their knowledge about pollinators and pollination. There was no significant relationship between orchard area and farmers' knowledge (Table 3).

Discussion

In developing countries, inadequate knowledge and poor education prevent farmers from distinguishing between beneficial and harmful insects (Munyuli, 2011). Similarly, in this study, the majority of the farmers misidentified the dipteran pollinators as pests, especially *Episyrphus balteatus,* which was identified as a pest by the majority (78.93%) of the farmers. The majority of the farmers ranked the pollinators as beneficial insects, but they were unable to differentiate between beneficial and harmful insects. In this study, farmers in all districts were relatively familiar with two honeybee

Table 3. Logistic regression for identifying the Factors affecting adequate Knowledge.

Variables	Coefficient	Standard Error	p-value	OR	95% CI of OR	
					LL	UL
Constant	1.058	0.627	0.091	2.880		
Orchard Area	0.011	0.008	0.149	1.011	0.996	1.027
Age	-0.051	0.017	**0.003**	0.950	0.919	0.983
Education						
Above Matric	1.051	0.619	0.089	2.861	0.851	9.625
Matric	0.830	0.398	**0.037**	2.293	1.051	5.002
Middle	0.623	0.622	0.317	1.865	0.551	6.318
Primary	0.671	0.333	**0.044**	1.957	1.019	3.759
Uneducated	Ref					
Farming experience	0.071	0.018	**0.000**	1.074	1.036	1.113

OR: Odds ratios; LL: Lower Limit; UL: Upper Limit.

species (*Apis dorsata* and *Apis florea*), while their knowledge of non-bee pollinators was very poor. Ali et al. (2020) reported similar findings in their study of cucurbit farmers' pollinator awareness. In contrast, a study from Tanzania revealed that 77% of farmers stated that beneficial insects, including honeybees, were insect pests (Laizer et al., 2019).

Farmers' knowledge and perceptions of pollinators, particularly of non-bee species, are often limited in developing countries. Many studies revealed that although farmers recognize bees as important pollinators, their awareness of non-bee pollinators is poor (Ali et al., 2020; Osterman et al., 2021). In Zimbabwe and Uganda, farmers' ability to identify bees and understand pollination was influenced by factors such as education, farming experience, and information sources (Munyuli, 2011; Tarakini et al., 2020). Many farmers were unaware of the crucial role of pollinators in crop production, with over 90% of Ugandan coffee farmers not recognizing bees' importance for yield increase (Munyuli, 2011).

Because dipterans are common mango pollinators, farmers were asked only about dipteran habitat. In response, only a few respondents (6.79%) knew their habitat, i.e., they mentioned that flies live in stagnant water (Drone flies) and decaying organic matter (Blow and flesh flies). Although no study has compared farmers' knowledge of dipteran pollinator habitat, Ali et al. (2020) and Kasina et al. (2009) reported that some farmers have knowledge of bee habitat. Some farmers are aware of bee habitats, while only a few understand the diverse diet and habitat requirements of crop-pollinating Diptera in both larval and adult stages (Davis et al., 2023).

Most farmers in this study reported that pesticides kill pollinators; however, 44.29% of respondents reported applying pesticides during the flowering period of mango, when pollinators' exposure risk also increases. This may be linked to limited education, the knowledge-practice gap, and the sources of information on pesticide application. Few studies from Pakistan have shown this knowledge-practice gap among farmers, where they continue using pesticides despite awareness of their risks (Mubushar et al., 2019; Bakhtawer & Afsheen, 2021). Moreover, most farmers in Pakistan get information about agro-inputs from local pesticide dealers. Most of these pesticide dealers are non-technical and lack sufficient knowledge of agro-inputs, particularly pesticides, and their primary concern is pesticide sales. Laizer et al. (2019) reported that most farmers received pesticide recommendations for controlling insect pests and weeds from pesticide dealers, and about 43% had only primary education and had received no formal training in pesticide use and safety.

Following a briefing on the value of pollinators and how to conserve them, most farmers (85%) expressed a desire to either increase or maintain pollinator populations in their orchards. However, except for knowledge of reduced pesticide use to conserve pollinators, respondents were unaware of other pollinator conservation measures. In this study, the farmers' knowledge was significantly influenced by farming experience, age, and education (primary and matric). These results contrast with Ali et al. (2020), who reported that farming experience, age, and education did not influence farmers' knowledge of pollination, especially bee forage. Hevia et al. (2020) reported a strong influence of age and education on farmers' knowledge. Farmers' awareness of pollinators and pollination varies by crop, the extension services provided to them, and their level of education. The capability to identify bees and other pollinators is another important indicator of their knowledge (Kasina et al., 2009; Munyuli, 2011).

Different studies show that age, education, and farming experience play significant roles in shaping farmers' understanding and implementation of agricultural practices. Younger farmers, particularly those aged 20-30 years, are generally more eager to gain knowledge through training sessions and demonstrations (Sharma, 2017), while older farmers tend to adopt management practices at higher rates through personal experience (Sharma, 2017; Chennamadhava et al., 2024). Personal farming experience can have both beneficial (Gusti et al., 2022) and detrimental (Chennamadhava et al., 2024) impacts on farmers' knowledge. Additionally, factors such as financial stability, contact with extension agents, exposure to mass media, and involvement in social activities are also vital in shaping the farmers' knowledge (Lissaman et al., 2013; Chennamadhava et al., 2024).

The sustainability of agricultural ecosystems can be improved by raising knowledge and awareness about the importance of pollination services provided by pollinators (Eardley et al., 2006). Producing and using insects for pollination services necessitate more research and extension efforts in developing countries than in developed ones (Uma et al., 2012). Conferences, training, and demonstration plots are often regarded as the most effective extension tactics in developing countries such as Pakistan and Vietnam (Sattaka et al., 2017; Ali et al., 2020) to create awareness of the importance of conserving pollinators. Therefore, farmers need training to increase their knowledge of pollinators and their significant role in ecosystem functioning.

Conclusion

The current study confirmed that most farmers misidentify syrphid flies as fruit flies. Most farmers receive recommendations and information from local agro-input dealers rather than government extension workers. The study's conclusions highlight the need for extension agents as vital intermediaries to disseminate authentic scientific knowledge to the farmers. In this study, the lack of knowledge about pollinators warrants capacity building for farmers on pollinators and pollination services. Practical interventions such as enhancing farmer education through training programs on the importance of pollinators, their identification, safe pesticide use, and improving the quality of extension services are necessary for sustainable agriculture. Future studies should focus on location-specific assessments of farmers' knowledge and pollinator-friendly management practices, and on improving farmers' awareness through targeted training and extension interventions.

Authors' Contributions

A.A.: Conceptualization, investigation, writing-original draft, writing-review and editing.
A.S.: Conceptualization, methodology, supervision, writing-original draft, writing-review and editing.
W.A.: Conceptualization, investigation, writing-original draft, writing-review and editing.
H. K.: Methodology, formal analysis, writing-original draft, writing-review and editing.

All authors have read and agreed to the published version of the manuscript.

Acknowledgement

This research was financed by the Agriculture Linkage Program (ALP) of Pakistan Agriculture Research Council (PARC) under the project "Conservation of native bees through ecosystem approach for enhanced crop pollination".

References

Ahmad, B., Mahmood, A., Sami, A. & Haider, M. Z. (2023). Impact of climate change on fruits and crops production in South Punjab: farmer's perspective. Biological and Agricultural Sciences Research Journal, 2023: 22-22. https://doi.org/10.54112/basrj.v2023i1.22

Ahmad, A., Sajjad, A., Khurram, H. & Ali, M. (2025). Impact of farm management practices and landscape composition on pollinator communities in mango orchards: a study from Southern Punjab, Pakistan. New Zealand Journal of Crop and Horticultural Science, 53: 2908-2923. https://doi.org/10.1080/01140671.2025.2516613

Akram, W., Sajjad, A., Ali, S., Farooqi, M. A., Mujtaba, G., Ali, M. & Ahmad, A. (2019). Pollination of *Grewia asiatica* (Malvaceae) by *Megachile cephalotes* (Hym.: Megachilidae): Male vs. Female Pollination. Sociobiology, 66: 467-474. https://doi.org/10.13102/sociobiology.v66i3.4345

Ali, M., Sajjad, A., Farooqi, M.A., Bashir, M. A., Aslam, M. N., Nafees, M., Aslam, M. N., Adnan, M. & Khan, K. A. (2020). Assessing indigenous and local knowledge of farmers about pollination services in cucurbit agro-ecosystem of Punjab, Pakistan. Saudi Journal of Biological Sciences, 27: 189-194. https://doi.org/10.1016/j.sjbs.2019.07.001

Anderson, D. L., Sedgley, M., Short, J. R. T. & Allwood, A. J. (1982). Insect pollination of mango in northern Australia. Australian Journal of Agricultural Research, 33: 541-548. https://doi.org/10.1071/ar9820541

Bakhsh, K., Hassan, I. & Akhter, M. (2006). Profitability and cost in growing mango orchards. Journal of Agriculture and Social Sciences, 2: 1813-2235.

Bakhtawer & Afsheen, S. (2021). A cross-sectional survey of knowledge, attitude, and practices related to the use of insecticides among farmers in the industrial triangle of Punjab, Pakistan. PloS One, 16: e0255454. https://doi.org/10.1371/journal.pone.0255454

Bauer, D. M. & Wing, I. S. (2010). Economic consequences of pollinator declines: a synthesis. Agricultural and Resource Economics Review, 39: 368-383. https://doi.org/10.1017/s1068280500007371

Breeze, T. D., Boreux, V., Cole, L., Dicks, L., Klein, A. M., Pufal, G., Balzan, M. V., Bevk, D., Bortolotti, L., Petanidou, T., Mand, M., Pinto, M. A., Scheper, J., Stanisavljević, L., Stavrinides, M. C., Tscheulin, T., Varnava, A. & Kleijn, D. (2019). Linking farmer and beekeeper preferences with ecological knowledge to improve crop pollination. People and Nature, 1: 562-572. https://doi.org/10.1002/pan3.10055

Brittain, C. A., Vighi, M., Bommarco, R., Settele, J. & Potts, S. G. (2010). Impacts of a pesticide on pollinator species richness at different spatial scales. Basic and Applied Ecology, 11: 106-115. https://doi.org/10.1016/j.baae.2009.11.007

Carvalheiro, L. G., Seymour, C. L., Veldtman, R. & Nicolson, S. W. (2010). Pollination services decline with distance from natural habitat even in biodiversity-rich areas. Journal of Applied Ecology, 47: 810-820. https://doi.org/10.1111/j.1365-2664.2010.01829.x

Chennamadhava, M., Praveena, P., Lakshmi, T. & Reddy, P. M. (2024). Influential factors shaping farmers knowledge levels regarding critical interventions in dryland farming in drought prone region of Andhra Pradesh. International Journal of Environment and Climate Change, 14: 360-370. https://doi.org/10.9734/ijecc/2024/v14i94420

Dag, A. & Gazit, S. (2000). Mango pollinators in Israel. Journal of Applied Horticulture, 2: 39-43. https://doi.org/10.37855/jah.2000.v02i01.12

Davis, A. E., Bickel, D. J., Saunders, M. E. & Rader, R. (2023). Crop-pollinating Diptera have diverse diets and habitat needs in both larval and adult stages. Ecological Applications, 33: e2859. https://doi.org/10.1002/eap.2859

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), Pretoria, South Africa.

Eilers, E. J., Kremen, C., Smith Greenleaf, S., Garber, A. K. & Klein, A. M. (2011). Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS One, 6: e21363. https://doi.org/10.1371/journal.pone.0021363

Elisante, F., Ndakidemi, P. A., Arnold, S. E. J., Belmain, S. R., Gurr, G. M., Darbyshire, I., Xie, G., Tumbo, J. & Stevenson, P. C. (2019). Enhancing knowledge among smallholders on pollinators and supporting field margins for sustainable food

security. Journal of Rural Studies, 70: 75-86.
https://doi.org/10.1016/j.jrurstud.2019.07.004

Fajardo, A. J., Medina, J. R., Opina, O. S. & Cervancia, C. R. (2008). Insect pollinators and floral visitors of mango (*Mangifera indica* L. cv. Carabao). The Philippine Agricultural Scientist, 91: 372-382.

Gallai, N., Salles, J. M., Settele, J. & Vaissière, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics, 68: 810-821. https://doi.org/10.1016/j.ecolecon.2008.06.014

Garbach, K. & Morgan, G. P. (2017). Grower networks support adoption of innovations in pollination management: The roles of social learning, technical learning, and personal experience. Journal of Environmental Management, 204: 39-49.
https://doi.org/10.1016/j.jenvman.2017.07.077

Gusti, I. M., Gayatri, S. & Prasetyo, A. S. (2022). The affecting of farmer ages, level of education and farm experience of the farming knowledge about Kartu Tani benefits and methods of use in Parakan District, Temanggung Regency. Jurnal Litbang Provinsi Jawa Tengah, 19: 209-221.
https://doi.org/10.36762/jurnaljateng.v19i2.926

Hall, D. M. & Martins, D. J. (2020). Human dimensions of insect pollinator conservation. Current Opinion in Insect Science, 38: 107-114. https://doi.org/10.1016/j.cois.2020.04.001

Hall, D. M. & Steiner, R. (2019). Insect pollinator conservation policy innovations at subnational levels: Lessons for lawmakers. Environmental Science & Policy, 93: 118-128.
https://doi.org/10.1016/j.envsci.2018.12.026

Hanes, S. P., Collum, K. K., Hoshide, A. K. & Asare, E. (2015). Grower perceptions of native pollinators and pollination strategies in the lowbush blueberry industry. Renewable Agriculture and Food Systems, 30: 124-131.
https://doi.org/10.1017/s1742170513000331

Hegland, S.J., Nielsen, A., Lázaro, A., Bjerknes, A.L. & Totland, Ø. (2009) How does climate warming affect plant-pollinator interactions? Ecology Letters, 12: 184-195.
https://doi.org/10.1111/j.1461-0248.2008.01269.x

Hevia, V., García-Llorente, M., Martínez-Sastre, R., Palomo, S., García, D., Miñarro, M., Pérez-Marcos, M., Sánchez, J. A. & González, J. A. (2020). Do farmers care about pollinators? A cross-site comparison of farmers' perceptions, knowledge, and management practices for pollinator-dependent crops. International Journal of Agricultural Sustainability, 19: 1-15.
https://doi.org/10.1080/14735903.2020.1807892

Huda, A. N., Salmah, M. C., Hassan, A. A., Hamdan, A. & Razak, M. A. (2015). Pollination services of mango flower pollinators. Journal of Insect Science, 15: 113.
https://doi.org/10.1093/jisesa/iev090

IPBES (2016). The assessment report of the intergovernmental science-policy platform on biodiversity and ecosystem services on pollinators, pollination and food production. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.
https://doi.org/10.3724/sp.j.1003.2012.02144

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: 126-133. https://doi.org/10.3896/ibra.1.48.2.07

Kennedy, C. M., Lonsdorf, E., Neel, M. C., Williams, N. M., Ricketts, T. H., Winfree, R. & Kremen, C. (2013). A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems. Ecology Letters, 16: 584-599. https://doi.org/10.1111/ele.12082

Kevan, P. G. & Phillips, T. P. (2001). The economic impacts of pollinator declines: an approach to assessing the consequences. Conservation Ecology, 5: 8.
https://doi.org/10.5751/es-00272-050108

Kevan, P. G. & Viana, B. F. (2003). The global decline of pollination services. Biodiversity, 4: 3-8.

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences, 274: 303-313. https://doi.org/10.1098/rspb.2006.3721

Krishna, A. (2007). For reducing poverty faster: Target reasons before people. World Development, 35: 1947-1960.
https://doi.org/10.1016/j.worlddev.2006.12.003

Laizer, H. C., Chacha, M. N. & Ndakidemi, P. A. (2019). Farmers' knowledge, perceptions and practices in managing weeds and insect pests of common bean in Northern Tanzania. Sustainability, 11: 4076.
https://doi.org/10.3390/su11154076

Lissaman, W. J., Casey, M. & Rowarth, J. S. (2013). Innovation and technology uptake on farm. In Proceedings of the New Zealand Grassland Association, 75: 27-32.
https://doi.org/10.33584/jnzg.2013.75.2918

Menz, M. H., Phillips, R. D., Winfree, R., Kremen, C., Aizen, M. A., Johnson, S.D. & Dixon, K. W. (2011). Reconnecting plants and pollinators: challenges in the restoration of pollination mutualisms. Trends in Plant Science, 16: 4-12.
https://doi.org/10.1016/j.tplants.2010.09.006

Mubushar, M., Aldosari, F. O., Baig, M. B., Alotaibi, B. M. & Khan, A. Q. (2019). Assessment of farmers on their knowledge regarding pesticide usage and biosafety. Saudi Journal of Biological Sciences, 26: 1903-1910.
https://doi.org/10.1016/j.sjbs.2019.03.001

Munyuli, T. (2011). Farmers' perceptions of pollinators' importance in coffee production in Uganda. Agricultural Sciences, 2: 318-333.
https://doi.org/10.4236/as.2011.23043

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

Osterman, J., Landaverde-González, P., Garratt, M. P., Gee, M., Mandelik, Y., Langowska, A., Minarro, M., Cole, L. J., Eeraerts, M., Bevk, D., Avrech, O., Koltowski, Z., Trujillo-Elisea, F. I., Paxton, R. J., Boreux, V., Seymour, C. L. & Howlett, B. G. (2021). On-farm experiences shape farmer knowledge, perceptions of pollinators, and management practices. Global Ecology and Conservation, 32: e01949. https://doi.org/10.1016/j.gecco.2021.e01949

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O. & Kunin, W. E. (2010). Global pollinator declines: Trends, impacts and drivers. Trends in Ecology & Evolution, 25: 345-353. https://doi.org/10.1016/j.tree.2010.01.007

Ramírez, F. & Davenport, T. L. (2016). Mango (*Mangifera indica* L.) pollination: a review. Scientia Horticulturae, 203: 158-168. https://doi.org/10.1016/j.scienta.2016.03.011

Rawluk, A. & Saunders, M. E. (2019). Facing the gap: Exploring research on local knowledge of insect-provided services in agroecosystems. International Journal of Agricultural Sustainability, 17: 108-117. https://doi.org/10.1080/14735903.2019.1567244

Ricketts, T. H., Regetz, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., Bogdanski, A. & Viana, B. F. (2008). Landscape effects on crop pollination services: are there general patterns? Ecology Letters, 11: 499-515. https://doi.org/10.1111/j.1461-0248.2008.01157.x

Sattaka, P., Pattaratuma, S. & Attawipakpaisan, G. (2017). Agricultural extension services to foster production sustainability for food and cultural security of glutinous rice farmers in Vietnam. Kasetsart Journal of Social Sciences, 38: 74-80. https://doi.org/10.1016/j.kjss.2016.05.003

Senapathi, D., Carvalheiro, L. G., Biesmeijer, J. C., Dodson, C. A., Evans, R. L., McKerchar, M., Morton, R. D., Moss, E. D., Roberts, S. P., Kunin, W. E., & Potts, S. G. (2015). The impact of over 80 years of land cover changes on bee and wasp pollinator communities in England. Proceedings of the Royal Society B: Biological Sciences, 282: 20150294. https://doi.org/10.1098/rspb.2015.0294

Sharma, M. (2017). Effect of age and educational level of dairy farmers on knowledge and adoption of dairy farming practices in Kapurthala district of Punjab. International Journal of Farm Sciences, 6: 254-262.

Smith, B. M., Basu, P. C., Chatterjee, A., Chatterjee, S., Dey, U. K., Dicks, L. V., Giri, B., Laha, S., Majhi, R. K. & Basu, P. (2017). Collating and validating indigenous and local knowledge to apply multiple knowledge systems to an environmental challenge: a case-study of pollinators in India. Biological Conservation, 211: 20-28. https://doi.org/10.1016/j.biocon.2017.04.032

Sung, I. H., Lin, M. Y., Chang, C. H., Cheng, A. S., Chen, W. S. & Ho, K. K. (2006). Pollinators and their behaviors on mango flowers in southern Taiwan. Formosan Entomologist, 26: 161-170.

Sutherland, W. J., Gardner, T. A., Haider, L. J. & Dicks, L. V. (2013). How can local and traditional knowledge be effectively incorporated into international assessments? Oryx, 48: 1-2. https://doi.org/10.1017/s0030605313001543

Tarakini, G., Chemura, A. & Musundire, R. (2020). Farmers' knowledge and attitudes toward pollination and bees in a maize-producing region of Zimbabwe: Implications for pollinator conservation. Tropical Conservation Science, 13: 194008292 0918534. https://doi.org/10.1177/1940082920918534

Uma, P., Tej, P., Sharma, H., Pushkin, P., Aungsathwi, M., Tamang, N., Tan, K. & Munawar, M. (2012). Value of insect pollinators to Himalayan agricultural economies. ICIMOD, Kathmandu. https://doi.org/10.53055/icimod.576

SITIENTIBUS