Economic benefits of animal pollination to Punjab agriculture

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Summary

Indian Punjab is gradually becoming the promised land of diversified farming with beekeeping as an important component, as farmers are looking for ways to get out of the paddy-wheat cycle. With this consideration, the present study estimated that the contribution of animal pollinators toward state agriculture. The economic value due to pollination service (EVP) was Rs 1391.2 crores forming about a 2 per cent share in the EV of output from state agriculture. Among the entomophilous crops, the insect pollination was essential for 2; great for 3; modest for 4 and of little importance to another 4 crops. About 42 per cent of the non-animal pollination-dependent crops accounted for a major share in the EV *i.e.* 97.87 per cent of the total agriculture output of the state. The share of cereals was the highest in the EV *i.e.* 86.79 per cent followed by vegetables (5.50%), fruits (5.32%), cotton (1.69%), sugarcane (0.35%), oilseeds (0.32%) and gram (0.01%) while based on dependence rate, the EVP was the highest in fruits (49.78%) followed by vegetables (21.49%), cotton (19.85%) and oilseeds (8.88%) and there existed no EVP for cereals and sugarcane and gram. The crops having great dependence on pollination contributed the maximum (Rs 741.13 crore) *i.e.* about 53 per cent to the EVP and about 1 per cent to the EV in the state agriculture. There is a strong need to realize the potential of this segment and formulate crop and commodity-specific strategies for optimum utilization of animal pollination inputs followed by crop diversification to high-value commodities. Punjab agriculture faces challenges on the production front and increased production cost needs such as "micro concepts" with "macro-economic" impacts.

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Introduction

Agriculture and the cycle of life are connected by pollination, considered to be essential for maintaining the ecological balance and the foundation of food production. Pollinators without threatening the environment are the proven providers of ecosystem services, enhancing biodiversity and raising food production by cross-pollination. All these services have been envisaged by the United Nations Environment Program, 2011 from modern agriculture for achieving the much-desired world's future food security, under threat from climate change. As some plants fully rely on vectors for the transportation of their pollen during cross-pollination, pollinators play a crucial role in the crop production process. Animal pollination affects food production directly as well as indirectly and is essential for the supply of human food along with animal feed resources (Kumari 2022). Further, in light of issues like climate change, changing land use, habitat degradation, and the growing human population, there is an escalating demand for food security. Animal-pollinated crops constitute about one-third of the human diet globally (Klein et al.2007; Haldhar et al. 2021a). In 2005, the economic value of global pollination was estimated to be EUR 153 billion formed about 10 per cent of the total agricultural output of food for human consumption. On average, one tonne of crop production that does not rely on pollination by insects is worth roughly EUR 151, as opposed to EUR 761 for crops that do.

Scientists have utilized a variety of techniques to calculate the annual benefit of various ecological expenses suffered by native insects in the United States, which forms more than USD 57 billion, of which USD 3.07 billion is a result of bee pollination. It has been estimated that the economic benefits from insect pollination from the selected 12 entomophilous crops were Rs 2997 crores annually (Goyal 1993; Chaudhary 1999) and the quantum of incidental gains by pollination from existing honey bee colonies was Rs 1470 (ibid). Insects are considered to be responsible for 80–85 per cent of the entire pollination, with a share of honeybees being 75–80 per cent (Johannsmeier & Mostert 2001; Haldhar et al. 2021b; Yadav et al. 2023). 48 of the most important crops on earth are pollinated by honey bees, native bees, and flies every season, which has a substantial impact on the world economy. For instance, pollination generates USD 16 billion in revenue annually in the USA alone, of which three-fourths can be directly linked to the accessibility of honey bees.

India is blessed with a variety of flora and fauna, especially honey bees and is home to three of the four honey bee species in the world. Of the total value of Indian agriculture, the share of animal-pollinated crops is

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32.74 per cent with 8.72 per cent being the direct contribution of insect pollination, besides spillover benefits of increased seed production, quality traits, efficiency in breeding (Calderone 2012) which unluckily are considered to be at risk (Palmer et al.2004). Considering the importance of beekeeping as part of the integrated farming system (IFS) and to provide a booster shot to sweet revolution, the Indian government approved the allocation of Rs. 500 crores for the National Beekeeping and Honey Mission (NBHM) for three years (2020-21 to 2022-23) as a part of the Atma Nirbhar Bharat scheme. India with 66,280 MT of production per year is ranked as the sixth largest producer of honey in the world contributing 3.74 per cent share in the world honey produced.

Agriculture remains the largest source of livelihood for the Indian Economy and about 55 per cent of its population depends upon the agricultural sector. Around 50 million hectares of land under bee-dependent crops need at least 150 million colonies for cross-pollination in India (Panigrahi 2010). Punjab has witnessed commendable growth of apiculture as an agro-based subsidiary occupation and also as the most important component of agricultural diversification (Makkar et al. 2015). Punjab ranks third in honey production of 18500 MT (13.89 per cent of national production) from 4.0 lakh colonies. Beekeeping, being entirely honey-centric, lacks emphasis on pollination services and thus for stagnant Indian agriculture, this "micro concept" of utilising honey bees in planned crop pollination has the potential "macro-economic" impact (Chaudhary 2017; Haldhar et al. 2022). Though Punjab state is leading in honey production there exists a vast scope for apicultural development. According to the Department of Horticulture of Punjab, the state is capable of supporting even 10 lakh colonies which can be increased within the next 4 to 5 years to achieve production of 45,000 MT with increased honey yield per colony from the present level of 40 kg to 50 kg and thus leading to increased net returns and profit. In this background, the present study was carried out to quantify the economic benefits of animal pollination to Punjab agriculture.

Materials and Methods

The present study for Punjab state is based on secondary data collected from different published sources. Data for the production of 24 major crops and commodities for the agricultural year 2019-20 was taken from the Statistical Abstract of Punjab, 2020 and grouped under seven groups *i.e.* cereal crops (Rice, Wheat, Maize, Barley and Bajra), oilseeds (Rapeseed & mustard, Sesamum and Groundnut), pulses (gram), fibres (cotton), sugarcane, fruits (Amla, Banana, Guava, Kinnow, Litchi, Mango, Sweet orange, Water melon and Musk melon) and vegetables (Chillies, Peas, Potato, Tomato). Further, the farm gate price for the selected crops was culled from the report 'Farm Harvest Prices of Principal Crops in India, 2022' and that for other commodities from the AGMARKNET portal by the Directorate of Marketing & Inspection, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Government of India.

Economic value of pollination (EVP): To calculate the EVP, firstly the economic value of production (EV) of different crops and commodities was derived by multiplying the quantum of production (crop and commodity) with the farm harvest prices as shown in equation 1.

$EV = Q_t * FHP$ 1

where

EV = Value of annual crop and commodity output in economic terms,

Q_t = Annual production quantum of crop

FHP = Farm harvest price.

Further, the EVP service was calculated by multiplying the economic value (equation 1) of annual crop or commodity production thus obtained with respective dependence rate (DR) as shown in Table 1.

$EVP = EV * DR$ 2

where

DR = Dependence rate.

Based on the guidelines for the EVP services at a national scale by FAO (Gallai and Vaissiere 2009, Vaissiere *et al*. 2011), dependence rate (DR) values have been assigned to all the crops (Table 1) except that are wind pollinated (especially cereals) or with vegetative reproduction or parthenocarpy where a separate category of "no increase" has been designated with a DR of zero value.

Table 1. Dependence rate on animal pollination for different crop groups

Crop Group	Dependence Rate (DR)
Essential	0.95
Great	0.65
Modest	0.25
Little	0.05
No increase	0.00

Source: Chaudhary 2017

The data gathered for farm gate prices and production for the selected major crops and commodities was converted to their respective EVs and EVPs and categorized into different categories accordingly for further analysis.

Results and Discussion

Among the 24 major crops and commodities under study, 14 (58.33%) needed animal pollination for the production in the form of seeds, fruits, nuts, etc. (Table 2). The remaining ten crops were observed to be dependent on pollination for their production as they were mainly either self or wind-pollinated or parthenocarpic or were consumed in the vegetative stage.

Table 2. Economic value of pollination (EVP) services for major crops and commodities in Punjab

S. No.	Crops/ commodity	Production (000Mt)	Dependence on animal pollinators	Dependence Rate	Economic value (Rs crore)	
					Crop output	Pollination service

1	Rice	12675	No increase	-	23258.6	0.0
2	Wheat	17616	No increase	-	32607.2	0.0
3	Barley	23.4	No increase	-	35.7	0.0
4	Maize	410	No increase	-	675.3	0.0
5	Bajra	0.3	No increase	-	4.4	0.0
A	**Cereals**				56581.2	0.0
1	Rapeseed & mustard	45.9	Great	0.65	185.8	120.8
2	Sesamum	1	Modest	0.25	7.3	1.8
3	Groundnut	3.6	Little	0.05	18.3	0.9
B	**Oilseeds**				211.5	123.5
C	**Cotton**	1206.3	Modest	0.25	1104.6	276.2
D	**Sugarcane**	730	No increase	-	226.3	0.0
E	**Pulses** (Gram)	1.8	No increase	-	7.1	0.0
1	Amla	8913	Unknown	-	15.6	0.0
2	Banana	5679	Noincrease	-	9.9	0.0
3	Guava	217739	Great	0.65	498.0	323.7
4	Kinnow	1328996	Little	0.05	1957.5	97.9
5	Litchi	50092	Modest	0.25	261.7	65.4
6	Mango	118784	Little	0.05	457.5	22.9
7	Sweet Orange	26919	Modest	0.25	106.7	26.7
8	Watermelon	34552	Essential	0.95	38.1	36.2
9	Musk Melon	114810	Essential	0.95	126.1	119.8
F	**Fruits**				3471.1	692.6
1	Chillies	16955	Little	0.05	45.8	2.3
2	Peas	466813	No increase	0	1290.1	0.0
3	Potato	2869951	No increase	0	1795.5	0.0
4	Tomato	256877	Great	0.65	456.4	296.6
G	**Vegetables**				3587.8	298.9
H	**Total**				65189.60	1391.2

Dwelling further into the degree of dependence, among the 14 entomophilous crops the insect pollination was essential for only two crops *i.e.* in their absence, a reduction in yield of 90-100 per cent occurred. Another 3 crops were greatly dependent (reduction in yield by 40-90%) and another for 4 were dependent on the modest level (10-25% yield reduction). Pollinators were of little importance to 4 crops as without animal-assisted pollination, a reduction of up to 10 per cent in yield was observed. The selected major crops and commodities had an economic value (EV) of Rs 65189.6 crore to the state and their economic value due to pollination service was Rs 1391.2 crores which formed about 2 per cent share in the EV.

However, in economic terms value, the trend reversed as 42 per cent of the non-pollination dependent crops accounted for a major share in the EV *i.e.* 97.87 per cent i.e. Rs 63798.42 crores of the total agriculture production of the state (Rs 65189.6 crores). The major reason behind this trend was the paddy-wheat monoculture prevalent in the state under the prevailing conditions of electricity pricing and assured marketing making them the most remunerative crops in *Kharif* and *Rabi* seasons respectively. Crop category-wise analysis revealed that among the 7 categories, the share of cereals was the highest in the EV i.e. 86.79 per cent followed by vegetables (5.50%), fruits (5.32%), cotton (1.69%), sugarcane (0.35%), oilseeds (0.32%) and gram (0.01%) as shown in Figure 1.

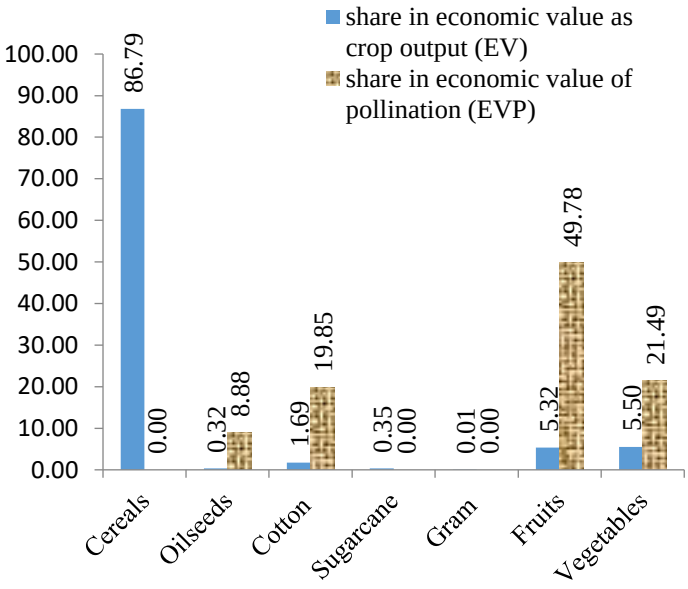

Figure 1. Economic value of major crops/commodities in Punjab agriculture (% share)

Based on the dependence rate, i.e. contribution of insect pollination to crop's yield (economic value of crop production that might have been lost in the absence of pollinators), the scenario changed as the share of EV due to pollination (EVP) was the highest in fruits (49.78%) followed by vegetables (21.49%), cotton (19.85%) and oilseeds (8.88%) and there existed no EVP for cereals and sugarcane and gram. Crop-wise analysis for the economic value (EV) of output to ultimately determine the economic value of pollination (EVP)was also carried out and the results are indicated in this section. *Cereals:* This category comprises five major crops, four of them cereals (rice, wheat, barley and maize) and one millet *i.e.* bajra is the major staple food and the single largest contributor to the total agricultural output value in the state. Being self or wind-pollinated crops, they do not require animal pollination *i.e.* no increase was there in this category because of animal pollination.

Oilseeds: All the major selected oilseeds (rapeseed & mustard, sesamum and groundnut) were dependent on animal pollination with the pollination dependence being great for rapeseed and mustard which are known for their high-quality oil. In mustard, with production of 45.9 Metric tonnes (Mt), valued at Rs 185.88 crores, the EV of animal pollination is huge at Rs 120.8 crores along with other benefits like seed number and weight, oil content and early maturity. The dependence on animal pollination was found to be modest in sesamum having the additional benefit of seed production and was little in groundnut. The EVP contributed about 58 per cent of the EV of the oilseeds in the state. Besides individual variations in insect pollination benefits, oilseeds as a category, is extremely dependent on pollination for its production and quality improvement and the contribution to the tune of 8.88 per cent in yield, valued at Rs 123.5 crores is an indication of this fact.

Fruits: They are a hugely important source of quality human nutrition especially sugars, vitamins, minerals, etc. besides being export earners. Their contribution to the state agriculture is vital with a share of 5.32 per cent (Rs 3471.1 crore) and the EVP being (Rs 692.6 crores forming about half of the state EVP). Fruits as a segment benefitted significantly from animal pollination as two of them were essentially dependent on insect pollination, one greatly dependent and for twothe dependence was moderate and low, respectively. The share of EVP to EV for the state was about 20 per cent for the category.

Vegetables: Vegetables as a group contributor to the state agriculture (5.50%, Rs 3587.8 crores). Among the selected 5 major vegetables, tomato was greatly dependent on animal pollination (EVP of Rs 296.6 crore and EV Rs 456.4 crore) while chillies had little dependence (EVP- 2.3 crore and EV 45.8 crore) with the additional benefit of increased fruit weight by animal pollination. In the case of peas and potatoes, no increase in EV and EVP was observed due to pollination services.

Based on dependence on animal pollination, the selected crops were assigned a group. Analysis of data for EV and EVP for these groups indicated that the crops having great dependence on pollination contributed the maximum (Rs 741.13 crore) *i.e.* about 53 per cent to the EVP and about 1 per cent to the EV in the state agriculture. Further, the modest group with a contribution of Rs 307.1 crore had about 27 per cent share in the EVP followed by essential (Rs 155.72 crore, 0.24 %) and little (Rs 124.59 crore, 0.19%).

Table 3. Economic value of animal pollination based on dependence rate of crops to Punjab agriculture

Crop category	Economic value based on crop's dependence rate on animal pollination (Rs crores)				
	Essential	Great	Modest	Little	Total
Cereals	0	0	0	0	0
Oilseeds	0	120.81	1.79	0.92	123.52
Cotton	0	0	276.20	0	276.2
Sugar	0	0	0	0	0
Pulses	0	0	0	0	0
Fruits	155.72	323.69	92.11	120.75	692.27
Vegetables	0	296.63	0	2.92	299.55
Total	155.72	741.13	370.1	124.59	1391.54
% of EVP	11.19	53.27	26.60	8.96	100.03
% of EV	0.24	1.14	0.57	0.19	2.13

Conclusions

The apiculture market is estimated to register a CGR of 4.3 per cent during the period 2020–25, with Asia–Pacific as the dominant producer. Though Punjab state is leading in honey production there exists a huge scope for apicultural development for increased net returns and profit. In the state, the economic value of pollination to agriculture (EVP) is about Rs 1391 crores annually which forms about a 2 per cent share in the EV of output from state agriculture. In addition to this, these quantitative benefits also lead to substantial spillover benefits and a tremendous increase in quality traits and ecosystem services. It has the potential to rejuvenate the agriculture sector at an almost negligible cost. There is a strong need to recognize its potential and formulate crop and commodity-specific strategies for optimum utilization of animal pollination inputs followed by crop diversification to high-value commodities like fruits, vegetables, and oilseeds for improving the crop productivity and quality of the state agriculture.

Declaration of Interests

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are within the manuscript.

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