



Assessing pollinator communities of chickpea (*Cicer arietinum* L.): Diversity, abundance, and pollination efficacy in Jaipur District, Rajasthan, India

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Abstract

This comprehensive study investigated the diversity, abundance, and pollination efficacy of insect pollinators associated with *Cicer arietinum* (chickpea) across six agroecological sites in the Jaipur district of Rajasthan, India. It is considered the most ecologically suitable crop with highly nutritional value and economic importance. A total of 11 pollinator species were recorded, with *Apis florea* emerging as the most abundant and effective pollinator, followed by *Apis dorsata* and *Campsomeriella collaris*. At the same time, *Apis mellifera*, *Nomia latrelle*, and *Eristalis tenax* were reported as the least abundant (0.5 insects/m²/5 minutes) pollinators. Pollinator community structure showed site-specific differences in the species composition and was influenced by local habitat conditions like floral resource availability and climatic factors. *Apis florea* showed the highest and *Danus chrysippus* the lowest, pollination efficacy. Diversity indices, including Simpson's and Shannon-Wiener, suggested that chickpea agroecosystems maintained moderately diverse and functionally significant pollinator communities. The study highlighted the importance of maintaining overall pollinator diversity and its conservation for diverse pollinator communities to sustain and enhance chickpea productivity. The findings of this study have significant implications for pollinator conservation, agricultural sustainability, and ecosystem function, emphasizing the need for site-specific management strategies to promote pollinator health and agroecosystem resilience. Overall, this research contributed to understanding the complex relationships between pollinators, crops, and ecosystems.

Keywords: Abundance, *Cicer arietinum*, diversity, insect pollinators, pollination efficacy

Introduction

Cicer arietinum, commonly known as chickpea, is an annual legume pulse native to dry and semi-arid regions. It belongs to the family Fabaceae, subfamily Faboideae, and tribe Ciceraceae. It is believed to be the world's oldest cultivated crop and domesticated around 8500 B.C. [20]. Chickpea (*Cicer arietinum* L.) is a nutrient-rich pulse consumed across the globe, primarily cultivated under rainfed conditions in semi-arid and temperate regions [2]. With a global cultivation area of 14.56 million hectares, chickpea production reaches nearly 15 million tons annually [6]. Major chickpea-producing countries include India, Australia, Pakistan, Central America, and East Africa [13], with India being the largest producer, contributing 11.4 million tons from 9.9 million hectares [6]. Within India, the state of Madhya Pradesh leads in chickpea cultivation, accounting for 39% of the total production, followed by Maharashtra (14%), Rajasthan (14%), Andhra Pradesh (10%), Uttar Pradesh (7%), and Karnataka (6%) [22]. Chickpea is the second most widely consumed legume globally, cultivated in over 50 countries. It offers numerous health benefits, especially for diabetics, and is rich in essential nutrients, including vitamins A, C, E, K, and B-complex vitamins, along with minerals such as iron, zinc, magnesium, and calcium, all of which positively influence human health [14]. Due to its high protein content, abundant non-starch polysaccharides, low-calorie count, low allergenicity, and high digestibility, chickpea is an affordable protein source for low-income populations and vegetarians [2, 11, 26]. *Cicer arietinum* is known for its exceptional heat and drought

tolerance, making it particularly suitable for cultivation in regions like Rajasthan, India, where extreme temperatures prevail.

Pollination is a critical ecological process that enhances crop productivity. While only about 5% of plants are capable of self-pollination, a vast majority (95%) rely on animal-mediated pollination [21]. The decline in natural pollination often correlates with reduced crop yields. Among the insect pollinators, bees constitute one of the most specialized and significant groups. The evolutionary radiation of flowering plants is believed to have occurred in parallel with that of bees [3]. The act of transferring pollen grains from the anther of the stamen to the stigma of the carpel is termed pollination, which is essential for gamete fusion and subsequent seed and fruit development [19]. Approximately 84% of the 300 globally cultivated commercial crops depend on insect pollination, underscoring the ecological and economic values of pollinators [18]. Bees and other beneficial insects pollinate two-thirds of all crops and most wild-blooming plants, contributing more than \$200 billion in pollination services to agroecosystems worldwide [4]. Foraging is the process by which insects travel from plant to plant to search for food [10]. This activity is vital for pollination in both cultivated and wild plant communities. It is estimated that bees are responsible for nearly 80% of the planet's pollination, helping to sustain critical ecosystems [1]. Furthermore, bees pollinate 70 of the top 100 food crops cultivated by humans, which account for about 90% of the global nutritional supply [5].

Material and Methods

1. Study area

The sampling was carried out in Jaipur District, Rajasthan, India. The location spans from 26°23'N to 27°51'N in latitude and from 74°55'E to 76°05'E in longitude. It is a subtropical dry climatic ecosystem with an average temperature ranging from 5°C (winter) to 40°C (summer), average relative humidity from 10% to 75%, and an average precipitation of about 24.48 cm.

2. Sample collection

The collection of insect pollinators on *Cicer arietinum* L. (Fabaceae) was carried out with a hand-sweeping net, once a week from 6 am to 6 pm after a regular interval of 2 hours. Insects were captured in 6 different sites in the study area because of variations in geographical and anthropological conditions. Specimens were collected in insect-killing bottles filled with a piece of cotton soaked with Ethyl acetate or p-dichlorobenzene. Freshly trapped small specimens were wrapped in a tissue paper envelope to keep them dry, along with p-dichlorobenzene as a preserving agent. Collected specimens were brought to the laboratory as soon as possible to avoid stiffness and brittleness.

3. Estimation of diversity

The diversity of insect pollinators was analyzed by calculating the diversity indices like Shannon-Wiener entropy, Simpson index, and Simpson index of diversity.

Simpson index

The Simpson index estimates the probability of encountering various insect species during field sampling, representing the sum of squared relative proportions of insect pollinator abundance [9]. It is also known as the Probability of Interspecific Encounter (PIE) or Gini-Simpson index.

Simpson Index (D) = $\sum_{i=1}^s P_i^2$

Simpson Index of Diversity 1-D

n = Number of insect species

N = Total number of insects in the sample

Pi = (n/N)

S = Total number of species in the sample

Shannon-Wiener entropy

It measures the uncertainty or randomness of a distribution,

considering both richness and evenness. It was estimated as:

Shannon-Weiner Diversity Index (H) = $-\sum p_i \ln p_i$

p_i: The proportion of individuals (n/N) making species *i*.

Pielou's evenness index

It was used to measure the species diversity and evenness within an ecological community. It is calculated as:

J = $H / \ln S$ or **J** = $-\sum p_i \ln p_i / \ln S$

J = Pielou Index

H = Shannon-Wiener Index of Diversity

S = Species Richness

4. Whittaker plot

Relative species abundance was estimated by plotting the Rank-abundance curve (Whittaker plot), which is a result of species richness and evenness. All the species found in the sample had been ranked according to the relative abundance of insect pollinators. Relative abundance is the percentage of the abundance of each species in the community. Species rank was taken on the x-axis and relative abundance on the y-axis for plotting the Whittaker plot [23]. It is a presentation of species abundance relative to their importance in diversity.

Relative abundance = $n/N \times 100$

n = number of members of a species and N = total of insect species in a community

5. Species accumulation curve

Species accumulation curves (SAC; or species-richness curves, collector's curves, species effort curves) were used to estimate the number of species in a particular area.

6. Pollination efficacy of insect pollinators

The pollination effectiveness of bees was quantified by calculating the pollination index. Insect pollinator abundance was quantified as the number of pollinators per square meter (m²) observed over 5 minutes (pollinators/m²/5 minutes). It was estimated as:

Pollination index (PI) = Abundance of pollinators × Loose pollen grains on insect body.

The number of loose pollens = Count of pollens × dilution/number of 1mm square counted in Neubauer chamber.

Table 1: Diversity of insect pollinators on *Cicer arietinum*

Sr. No.	Insect pollinators	Site A	Site B	Site C	Site D	Site E	Site F	Mean Abundance (Insects/m ² /5 minutes)
1	<i>Apis dorsata</i>	7	2	4	0	2	0	2.5
2	<i>Apis florea</i>	9	14	11	3	8	0	7.5
3	<i>Apis mellifera</i>	0	1	0	0	0	2	0.5
4	<i>Amegilla zonata</i>	2	0	4	0	0	0	1.0
5	<i>Amegilla cingulata</i>	0	5	2	0	0	0	1.67
6	<i>Nomia latreille</i>	0	2	0	1	0	0	0.5
7	<i>Vespa orientalis</i>	1	0	0	4	1	3	1.5
8	<i>Eristalis tenax</i>	0	0	1	2	0	0	0.5
9	<i>Musca domestica</i>	5	0	0	7	6	4	3.67
10	<i>Danaus chrysippus</i>	0	0	0	3	1	2	1.0
11	<i>Campsomeriella collaris</i>	0	0	0	0	8	6	2.33
	Mean	2.18	2.18	2.0	1.81	2.36	1.54	2.067
	Cumulative species richness	5	7	8	9	11	11	

Results

A study across six sites (A-F) recorded 11 insect pollinator species, including bees, wasps, flies, and butterflies (Table 1). Site E had the highest pollinator abundance (2.36 insects/m²/5 minutes) and species richness (11 species), making it the most favorable site for pollinators. *Apis florea* was the most abundant species, dominating Sites A and B. *Musca domestica* was also relatively abundant, particularly at Sites D and E. Species richness varied across sites, with Sites E and F supporting 11 species, and Site A having the lowest species richness (5 species). Sites A and B showed higher abundance but lower species richness, indicating dominance by certain species. Sites C and D had more

balanced species distributions but with varying levels of abundance.

Each site exhibited unique patterns of pollinator activity, likely influenced by local environmental factors. Site E's high species richness and abundance suggest a diverse and favorable pollinator community. In contrast, Site F's lower abundance despite similar species richness highlights the importance of considering both abundance and richness when evaluating pollinator communities. The study's findings can inform site-specific conservation efforts and highlight the need to consider local environmental factors when managing pollinator communities.

Table 2: Diversity analysis of insect pollinators on *Cicer arietinum*

Sr. No.	Insect pollinators	n	n/N= Pi	Square of Pi	ln Pi	Pi ln Pi
1	<i>Apis dorsata</i>	2.5	0.110278	0.012161	-2.20475	-0.24314
2	<i>Apis florea</i>	7.5	0.330834	0.109451	-1.10614	-0.36595
3	<i>Apis mellifera</i>	0.5	0.022056	0.000486	-3.81417	-0.08412
4	<i>Amegilla zonata</i>	1.0	0.044111	0.001946	-3.12105	-0.13767
5	<i>Amegilla cingulata</i>	1.67	0.073666	0.005427	-2.60821	-0.19214
6	<i>Nomia latreille</i>	0.5	0.022056	0.000486	-3.81417	-0.08412
7	<i>Vespa orientalis</i>	1.5	0.066167	0.004378	-2.71557	-0.17968
8	<i>Eristalis tenax</i>	0.5	0.022056	0.000486	-3.81417	-0.08412
9	<i>Musca domestica</i>	3.67	0.161888	0.026208	-1.82085	-0.29477
10	<i>Danaus chrysippus</i>	1.0	0.044111	0.001946	-3.12105	-0.13767
11	<i>Campsomeriella collaris</i>	2.33	0.102779	0.010564	-2.27517	-0.23384
			$\sum Pi^2=$	0.173539	$\sum Pi \ln Pi=$	-2.03723
Species richness (S): 11						
$\sum Pi^2: 0.173539$		$\sum Pi \ln Pi: -2.03723$				
Simpson index (D): 0.173539		Shannon-Wiener entropy (H): $-(\sum Pi \ln Pi)$				
Simpson index of diversity (1-D): 0.826461		H: 2.03723				
Pielou's Evenness index (E): $H/ \ln S$		E: 0.8496				

The species richness (S) was found to be 11, meaning there are 11 different insect species in the community (Table 2). The abundance of each species in terms of the number of individuals observed. For instance, *Apis dorsata* has an abundance of 2.5 individuals, while *Apis florea* has 7.5. The Simpson index was found to be 0.173539. This indicates that the insect community is relatively diverse, as the probability that two randomly selected individuals are from the same species is relatively low. The Shannon-Wiener entropy was 2.03723, which indicates moderate to high

diversity in the insect community. This suggests that there is a relatively high degree of uncertainty regarding which species a randomly chosen individual might belong to. The Simpson Index of Diversity is 0.826461. This confirms that the insect community is highly diverse, meaning there's a high likelihood that two randomly selected individuals will belong to different species. Pielou's Evenness Index was found to be 0.8496, which indicates that the insect species are relatively evenly distributed across the community.

Table 3: Rank abundance curve (Whittaker plot)

Ranks	1	2	3	4	5	6	7	8	9	10	11
Abundance	7.5	3.67	2.5	2.33	1.67	1.5	1	1	0.5	0.5	0.5
Model	5.2256	4.0312	3.1098	2.399	1.8506	1.4276	1.1013	0.84958	0.65539	0.50558	0.39002

The rank abundance curve represented the abundance or the number of individuals observed for each insect pollinator. The values were ordered from the most abundant to the least abundant (Table 3). The first species in this list had the highest abundance of 7.5 individuals. The last species listed had the lowest abundance, with 0.5 individuals observed. The rank abundance curve of insect pollinators observed on *Cicer arietinum* (Fig. 1) revealed a characteristic steep decline in species abundance with increasing rank. A total of 11 pollinator species were recorded, with a few species showing markedly higher abundance compared to others.

The curve displayed a negatively skewed distribution, indicating that pollinator communities were dominated by a small number of highly abundant species, while the remaining species occurred at relatively low frequencies. The shape of the curve suggests low evenness within the pollinator assemblage, reflecting an uneven distribution of individuals among species. This pattern is typical of pollination systems where ecological roles are concentrated among dominant taxa, potentially influencing both the resilience and efficiency of pollination services within the system.

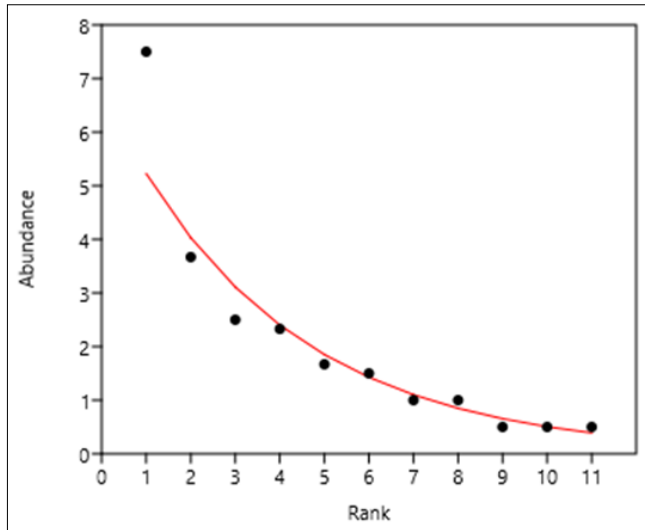


Fig. 1: Rank abundance curve of insect pollinators on *Cicer arietinum*

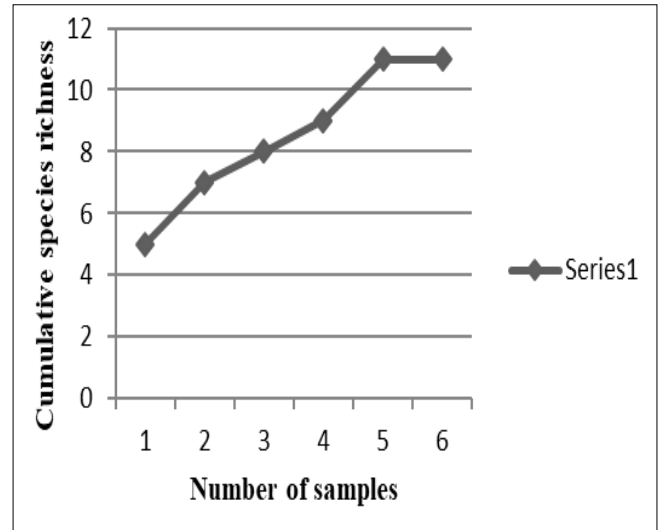


Fig. 2: Species accumulation curve of insect pollinators on *Cicer arietinum*

Table 4: Pollination efficacy of Insect pollinators on *Cicer arietinum*

Sr. No.	Insect pollinators	Abundance Insects/m ² /5 minutes	Number of loose pollen grains attached to the body	Pollination index
1	<i>Apis dorsata</i>	2.5	79358	198395
2	<i>Apis florea</i>	7.5	62556	469170
3	<i>Apis mellifera</i>	0.5	66832	33416
4	<i>Amegilla zonata</i>	1.0	51966	51966
5	<i>Amegilla cingulata</i>	1.67	49729	83047.43
6	<i>Nomia latreille</i>	0.5	41505	20752.5
7	<i>Vespa orientalis</i>	1.5	3686	5529
8	<i>Eristalis tenax</i>	0.5	5247	2623.5
9	<i>Musca domestica</i>	3.67	2206	8096.02
10	<i>Danaus chrysippus</i>	1.0	1738	1738
11	<i>Campsomeriella collaris</i>	2.33	38957	90769.81

Apis florea is the most abundant pollinator, with 7.5 insects per square meter in 5 minutes (Table 4). It also carries a high number of pollen grains (62,556), resulting in the highest pollination index (469,170). This indicates its significant role in pollination. *Apis dorsata* despite its lower abundance (2.5 insects/m²/5 min), carries the highest number of pollen grains per individual (79,358), leading to a high pollination index (198,395). This suggests that while it is less frequently observed, it is highly effective in pollination. *Apis mellifera* has a very low abundance (0.5 insects/m²/5 min) but carries a relatively high amount of pollen (66,832 grains). However, its pollination index (33,416) is lower due to its scarcity. *Amegilla zonata* and *Amegilla cingulata* show moderate abundance and pollen attachment. *Amegilla cingulata* has a slightly higher pollination index (83,047.43) than *Amegilla zonata* (51,966), indicating its better efficiency in pollination. *Nomia latreille* is relatively rare (0.5 insects/m²/5 min) and carries fewer pollen grains (41,505), resulting in a lower pollination index (20,752.5). *Vespa orientalis* is moderately abundant (1.5 insects/m²/5 min) but carries significantly fewer pollen grains (3,686), resulting in a very low pollination index (5,529), suggesting that it plays a minor role in pollination. *Eristalis tenax* and *Musca domestica* (Housefly) are not as effective as bees. The housefly has a higher abundance (3.67 insects/m²/5 min) but carries a small amount of pollen (2,206 grains), leading to a low pollination index (8,096.02). Hoverflies have an even lower index (2,623.5), indicating minimal contribution to

pollination. *Danaus chrysippus* despite its presence (1.0 insect/m²/5 min), carries the least amount of pollen (1,738 grains), making it the least effective pollinator in this dataset. *Campsomeriella collaris* shows relatively high effectiveness, with a moderate abundance (2.33 insects/m²/5 min) and a significant amount of pollen attachment (38,957 grains), leading to a relatively high pollination index (90,769.81).

Discussion

The present study provides comprehensive insights into the diversity, abundance, and pollination efficacy of insect pollinators associated with *Cicer arietinum* across six different agroecological sites. A total of 11 pollinator species were recorded, with substantial variation in species composition and abundance across sites, reflecting the influence of local environmental conditions on pollinator assemblages.

Site E exhibited the highest pollinator richness and abundance, indicating it may offer favourable floral resources, habitat conditions, or microclimatic features that support diverse pollinator communities. In contrast, Site A, despite relatively high abundance, showed the lowest species richness, suggesting a community structure dominated by a few highly abundant taxa such as *Apis florea*. These findings align with previous research indicating that habitat heterogeneity and resource availability are critical drivers of pollinator diversity and distribution [15, 16]. The Simpson Index (D = 0.1735) and

Shannon-Wiener Entropy ($H = 2.0372$) confirm moderate to high diversity in the pollinator community, consistent with patterns observed in legume crops where both generalist and specialist pollinators contribute to floral visitation [12]. The relatively high Pielou's Evenness Index ($E = 0.8496$) further indicates that while some species are more dominant, the pollinator assemblage is not highly skewed, promoting functional redundancy and resilience in the pollination system.

Rank abundance analysis highlighted a steep decline in species abundance with increasing rank, pointing to the dominance of a few species, primarily *Apis florea* and *Musca domestica*, and a long tail of less abundant pollinators. Such a pattern is typical in agroecosystems where floral resources and nesting sites favor certain generalist taxa [25]. Despite their lower abundance, species like *Apis dorsata* and *Campsomeriella collaris* demonstrated high pollination indices, emphasizing the importance of considering both abundance and functional efficacy in evaluating pollinator contributions.

The species accumulation curve plateaued at 11 species by the fifth sampling effort, suggesting that sampling intensity was adequate to capture the majority of pollinator diversity associated with *Cicer arietinum*. This provides confidence in the representativeness of the data and supports its utility for ecological assessments and management planning.

Pollination efficacy data underscored the disproportionate role of certain species in pollen transfer. *Apis florea*, the most abundant species, exhibited the highest pollination index, reinforcing its central role in chickpea pollination. However, *Apis dorsata*, despite lower numerical dominance, emerged as a highly effective pollinator due to its large body size and substantial pollen load, corroborating findings from other legume systems [24]. This highlights the value of integrating qualitative measures of pollination (e.g., pollen transport) with quantitative data on abundance. In contrast, flies and butterflies, including *Musca domestica* and *Danaus chrysippus*, were less effective pollinators, reflecting lower pollen carriage and interaction frequency. These taxa may contribute to incidental pollination but are unlikely to drive significant reproductive success in *Cicer arietinum*.

Overall, the study emphasizes the ecological importance of maintaining diverse pollinator communities in chickpea agroecosystems. Site-specific pollinator diversity and efficacy differences suggest that local environmental factors, such as floral resource availability, pesticide use, and nesting site accessibility, may significantly shape pollinator community structure and function. Conservation strategies should therefore prioritize habitat heterogeneity, floral continuity, and the protection of key pollinator taxa to enhance pollination services and agricultural sustainability.

Conclusion

This study underscores the significant variability in insect pollinator diversity, abundance, and pollination efficacy across six agroecological sites cultivating *Cicer arietinum* in the Jaipur district of Rajasthan. Among the eleven recorded pollinator species, *Apis florea* emerged as the most abundant and effective pollinator, while species such as *Apis dorsata* and *Campsomeriella collaris* also contributed notably to pollination despite their lower abundance. These findings reinforce the importance of considering both quantitative (abundance) and qualitative (efficacy) metrics when assessing pollinator contributions.

Site-specific differences revealed that while Site E supported the highest diversity and abundance of pollinators, Site F, despite its high species richness, showed the lowest overall insect abundance, suggesting that pollinator community structure is influenced by local habitat conditions, floral resource availability, and possibly climatic and anthropogenic factors. In contrast, Site A exhibited lower species richness and was dominated by a few species, indicating a less even pollinator distribution. Diversity indices such as Simpson's and Shannon-Wiener suggest that chickpea agroecosystems in the region maintain moderately diverse and functionally significant pollinator communities. Importantly, the study highlights that less abundant species can still play critical roles in pollination, underscoring the ecological value of maintaining overall pollinator diversity. The results advocate for the conservation and management of diverse pollinator communities to sustain and enhance chickpea productivity. Future research should aim to explore the specific environmental and anthropogenic factors shaping pollinator assemblages, as well as develop strategies to protect and enhance pollinator habitats within agricultural landscapes.

Significance

This research provides pivotal insights into the diversity, abundance, and pollination efficacy of insect pollinators associated with *Cicer arietinum* (chickpea) across six agroecological sites. The study's findings have significant implications for pollinator conservation, agricultural sustainability, and ecosystem function, highlighting the importance of maintaining biodiversity for ecosystem health and agricultural sustainability. By identifying key pollinator species, the research informs conservation priorities and emphasizes the protection of species providing essential ecosystem services. Additionally, the study demonstrates the need for site-specific management strategies to improve habitat quality, increase floral resources, and reduce threats. Overall, the findings reinforce the critical role of pollinators in chickpea production, advocating for integrative strategies to support pollinator health, enhance crop yields, and promote agroecosystem sustainability.

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