

Research Article

Behavioral Ecology and Pollination Efficiency of the Solitary Buzz Pollinator (*Amegilla cingulata*)

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Abstract

Pollination is a fundamental ecological process that supports plant reproduction and contributes to ecosystem stability. While social bees have been extensively studied, solitary buzz-pollinating species remain comparatively under-researched. *Amegilla cingulata*, commonly known as the blue-banded bee, is an effective sonicator of poricidal anthers and plays a significant role in the pollination of economically important crops. However, there is limited in-depth, field-based research examining the relationship between its behavioural ecology and quantitative pollination outcomes. This study aimed to evaluate the nesting ecology, foraging behaviour and pollination efficiency of *Amegilla cingulata*, though in this specific case, to identify which of the factors was the most significant determinant of reproductive success as indicated by fruit mass. A field-based observational design was employed (N = 230). Ecological variables were categorized into nesting structure, foraging activity, and pollination performance indicators. Behavioural patterns were summarized using descriptive statistics. Pearson correlation analysis was conducted to assess the relationships between pollen transfer variables and reproductive output. Multiple linear regression analysis was used to identify predictors of fruit mass. Additionally, independent samples t-tests were performed to examine differences in pollen deposition across nest orientations. Nesting architecture was structurally homogenous with the major types of nests being branched and vertical ones. Total pollen deposition and mass of the fruit were found to have good positive relations ($r = .951$, $p < .001$). The regression analysis also supported that total pollen was the most significant parameter ($r = .950$, $p < .001$), which was adopted to predict the fruit mass because it explained over 90 percent of the variability in fruit reproductive output. There were insignificant predictive effects of behavioural variables such as foraging time and frequency of visitation. The angularity of the nest did not have much effect on the deposition of pollen. The findings indicate that, within this ecological system, pollen transfer efficiency is the primary determinant of reproductive success, rather than the intensity of foraging behaviour. In particular, effective pollen deposition was the strongest predictor of fruit mass, underscoring its central role in fruit development. These results highlight the ecological importance of solitary buzz-pollinators such as *Amegilla cingulata* in regulating plant productivity. Overall, the study emphasizes that the quality of pollination measured through efficient pollen delivery, matters more than behavioural intensity in determining reproductive outcomes.

Keywords

Behavioural Ecology, Pollination Efficiency, *Amegilla cingulata*, Buzz Pollination, Pollen Deposition, Fruit Mass, Solitary Bees, Plant-Pollinator Interactions

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1. Introduction

Pollination is a natural ecological process that promotes biodiversity and food production in every country. Animals are especially well pollinated by bees due to morphological specialization; floral constancy and pollen gathering adaptation. Social species such as honeybees have received sufficient attention, however, solitary species have become one of the least studied creatures despite their major ecological contributions.

Solitary bees are a heterogeneous species group that share independent nesting behaviour and different foraging behaviour [7]. A group of buzz-pollinating bees is one of the most significant subgroups in this assemblage, and they sonicate poricidal anthers (high-frequency thoracic vibrations a process called sonication or buzz pollination). The pollen collection behaviour is made more efficient and contributes to the reproductive success of most angiosperms through specialisation of behaviour [2]. The family Solanaceae has more than a few economically important crops that require buzz pollination to achieve optimal fruit set and yield of tomato and eggplant.

The *Amegilla cingulata* (blue-banded bee) is a solitary bee species which has been discovered to fly in fast rate, drop pollen by vibration and adapt in different habitats. Its behavioural ecology is hardly studied in detail despite its known pollinating ability. Recent research has mainly addressed the overall process of pollination in place of research on species-specific studies about nesting structure, foraging behaviour and quantitative efficiency of pollination.

Behavioural ecology provides a basic model of how organisms interact with environmental factors to maximise survival and reproduction. The nesting behaviour of solitary bees is a significant life-history element that affects the protection of the offspring, the microclimatic regulation and exposure to predation [11]. The adaptive changes in response to the local environmental pressures are evident in the structural characteristics such as the nest orientation, structure of tunnels and brood cells.

The same effect is visible on foraging behaviour, which affects the rate of pollen exchange and the efficiency of the energy exchange and frequency of visitation [22]. Floral information like morphology, colouring and kind of reward is going to play an important role in pollinator preference and plant pollinator interaction.

The current issues of the modern world like habitat destruction, urban sprawl, and climate change have contributed to the decline in diversity and abundance of pollinators. These pressures underscore the necessity of carrying out field-based research on non-domesticated pollinators [11]. Single bees contribute to the ecosystem with significant services and hence, they ought to be examined with a comprehensive ecology study to aid conservation planning and management of the bi-

odiversity. The behavioural ecology and pollination effectiveness of *Amegilla cingulata* are presumed to be tested in the field in the present research paper. Specifically, the authors examine nesting behaviour, foraging behaviour, floral preference and pollination success measures [24]. This research will be explained through a combination of behavioural observations and a statistical analysis that will help identify the ecological role and functional significance of this solitary buzz-pollinating species.

2. Materials and Methods

2.1. Study Species

The organism of interest in this study was *Amegilla cingulata*, which is a species of a solitary bee, able to extract pollen with the help of sonic vibrations [4]. Due to its ecological importance in pollination of flowering plants with poricidal anthers the species was chosen and has been reported to be found in a wide range of habitats. The observations are carried out in the natural field environment to establish the behavioural patterns that remain unperturbed.

2.2. Study Design

The study design was field based observational design, which was implemented to evaluate the ecology of the foraging activity and pollination performance as well as the nesting. Field notes were standardized in the case of systematic observations. A quantitative analysis could be conducted on each of the independent ecological records offered on the observational units.

2.3. Data Collection and Variables

The data obtained were classified into four broad groups that consisted of environmental variables, nesting ecology variables, foraging behaviour variables and pollination efficiency variables. The environmental parameters were the time of observation and date, the average ambient temperature (°C), and seasonal. The variables in nesting ecology were nest orientation (vertical and horizontal), nest inclination angle (degrees), nest architecture (branched and unbranched), nest distribution (solitary and aggregated), tunnel length and width (mm), the number of brood cells in a nest and the size and thickness of the brood cell [6]. The foraging behaviour variables included the numbers of foraging trips during an observation period, the average duration of a foraging trip (minutes), and the duration of stay at the nest after a foraging trip, the nature of floral reward, species and colour of the floral reward. Its variables of pollination efficiency were flower visits, pollen load, self-pollen load, total pollen load and fruit mass (g)

as a measure of pollination success.

2.4. Data Processing

All these were coded and were fed into the IBM SPSS Statistics to be statistically analysed. The categorical variables are numeric coded which was carried out to help in the quantitative assessment [9]. The screening of the data was done to make sure that there was no error committed and it aided in the elimination of inconsistencies and formatted the variables to be analysed properly.

2.5. Statistical Analysis

Descriptive statistics provided a measure of central tendency and dispersion of the nesting parameters, foraging activity and pollination indicators. The assessments of the behavioural preferences in the form of the nest orientation and the flower preferences were measured with the help of frequency analyses.

Pearson correlation coefficients were computed to determine whether the key ecological variables (e.g. foraging trips, frequency of visitation of the flowers, total pollen deposition, and the mass of the fruit) correlate. Linear regression analysis

is applied to identify the predictors of the efficiency of pollination, and the mass of fruits was provided as dependent variable [15]. The t tests that were done on the independent samples were to compare the pollen deposition between the two modes of nest orientation. The statistical significance issue was considered in the traditional alpha levels.

2.6. Ethical Considerations

Field observation was done in a non-invasive way. Nests or flower resources were not interfered with or destroyed, and no disturbance was observed and thus the action was not interfered with.

3. Results

The retained number of valid observations to be analysed was 230. No variables were eliminated; therefore, all the variables were investigated on the whole dataset. Descriptive profile showed that ecological and behavioural process of nesting and pollination in the population under study was relatively balanced. The nest structure variables provided biologically realistic values therefore indicating the consistency in the nest building behaviour among the individuals.

Table 1. Descriptive Statistics of Nesting, Foraging and Pollination Variables (N = 230).

Variable	Min	Max	Mean	SD	Skewness	Kurtosis
Tunnel Width (mm)	4	8	5.90	1.43	0.06	-1.32
Mean Cell Width (mm)	2	4	3.03	0.78	-0.05	-1.37
Number of Flower Visits	12	45	27.90	10.59	0.11	-1.34
Floral Reward (1=P, 2=N, 3=Both)	1	3	1.97	0.61	0.01	-0.31
Bee Pollen Deposited	90	279	180.96	54.07	0.07	-1.15
Mean Foraging Duration (min)	8	18	13.13	2.92	-0.02	-1.18
Total Pollen	117	354	230.80	59.32	0.15	-0.94
Fruit Mass (g)	29.90	70.40	49.83	9.48	0.10	-0.82
Tunnel Length (mm)	18	45	31.57	8.12	0.01	-1.17
Nest Angle (°)	25	90	69.80	17.22	-1.18	0.51

(Source: SPSS)

The measurements of the tunnels were discovered to be 5.90 $\pm$ 1.426mm with a minor dispersion and structural consistency in the excavation behaviour indicating that nesting females are known to possess a characteristic architecture. Similarly, the mean width of the brood cells was 3.03 $\pm$ 0.784 mm indicating that the brood chamber was uniform in design with minor structural variance among nests.

The mean length of the tunnel was 31.57 and standard deviation was 8.124 mm, which suggests a moderate range of the nest depth and flexibility of excavation, which may be explained by the variation in substrate or variability in micro-habitat. Mean nest inclination was 69.80 $\pm$ 17.222°, leaning more towards steep nest orientation. This trend may be associated with the stabilization of structure or the increased capacity to resist the environmental pressure.

The behavioural measures displayed active foraging ecology. The average number of times visited was 27.90 ± 10.588 visits/foraging bout, which shows there were relatively high instances of floral interactions. The average foraging time was 13.13 ± 2.920 min, and this means an average but constant time and energy use. The mean number of deposited pollens was 180.96 ± 54.067 units indicating that there was intense contribution towards pollination. In addition to other pollen contribution, total pollen deposition was at 230.80 ± 59.318 which shows that the severity of pollination was high amongst the observed population. The mean weight of fruit was 49.93 g, and standard deviation was 9.479 and this experienced moderate degree of variation with floral interactions.

The reliability of the data was also facilitated by distributional statistics. The skewness values of most of the continuous variables were very near to zero that represents a rough equilibrium distribution [3]. The values of kurtosis were generally in the negative indicating that the distributions were somewhat flatter than the normal distribution but not excessive at tails. All these trends are suggestive of ecologically stable behavioural responses and are supportive of the suitability of parametric analyses.

3.1. Categorical Ecological Patterns

The descriptive statistics of the categorical variables showed that there were some preferences regarding the behavioural pattern of the population. This was mostly in branched nests that bore an average of 0.760.430 meaning that 25 percent of the nests were branched nests. This nesting structure is also dominant as shown by skewness (-1.203). The average nest position was 1.34 -474 minus, or plus which implies the vertically oriented nest was dominant as compared to the horizontally oriented nest. The average of 0.57 ± 0.497 was recorded by Nest distribution and it means that the birds did not always nest separately because they formed a group to some degree. The mean reward type was 1.97 ± 0.612 which demonstrated that, nectar-dominant flowers were used most frequently, and mixed reward types were also very dominant in foraging.

Each one of these categorical distributions is indicative of stable behavioural patterns of resource preference and habitat use. The adaptive nesting strategies are proposed by a majority of the branched and vertically aligned nests, and the preference of the nectar-rich floral resources indicates the preference of the energy-efficient foraging opportunities.

Table 1. Descriptive Statistics of Categorical Nesting and Floral Variables (N = 230).

Variable	Mean	SD	Skewness	Kurtosis
Nest Type (1=Branched)	0.76	0.43	-1.20	-0.56
Nest Position (1=Vertical)	1.34	0.47	0.68	-1.55
Nest Distribution (1=Aggregated)	0.57	0.50	-0.27	-1.95
Floral Reward Type	1.97	0.61	0.01	-0.31

(Source: SPSS)

3.2. Relationships Among Pollen Dynamics, Behaviour, and Reproductive Output

Table 2. Pearson Correlation Matrix Among Pollination Variables (N = 230).

Variables	1	2	3	4	5
Total Pollen	—				
Fruit Mass (g)	.951**	—			
Number of Foraging Trips	.047	.041	—		
Floral Reward	.124	.116	.076	—	
Bee Pollen Deposited	.920**	.867**	.045	.063	—

Note. $p < .01$.

(Source: SPSS)

The analysis of correlations showed that the variables of pollen and reproductive outcomes had strong and biologically significant correlations. Total pollen deposition ($r = .951$, $p < .001$) is also among the strongest correlations between the fruit mass and the total pollen deposition. It implies that the fruit mass increases were directly associated with the pollen transfers increases, which renders successful pollen deposition to be extremely significant to the success of plants in reproduction.

The deposits of bee pollen were also positively and significantly related to total pollen ($r = .920$, $p < .001$) and fruit mass ($r = .867$, $p = .001$). It is also demonstrated in these relations that the transfer of bee pollen plays an important part in the overall pollination intensity and ecological productivity.

On the other hand, foraging trips, which measure behavioural effort, had only weak and significant relationships with total pollen ($r = .047$) and fruit mass ($r = .041$). It means that the quality or efficiency of the foraging events and not the frequency of visitation established the efficacy of the pollination.

This research suggests that the quantity of pollen transferred by pollinators can have a significant impact on overall reproductive productivity, and the pollinator as opposed to pollinator activity is characterizing in fruit development [17]. The correlation between the type of floral reward and the pollen, and the fruit variable were not significant, and it implies that the alteration of the type of reward did not directly influence the performance of the pollination in the system considered. It means that the composition of rewards did not significantly affect the reproductive outcomes in case of differences in floral resources.

The overall findings of these tendencies of correlations proves that the ecological activity of pollen transfer was the significant process that promoted reproductive success. Conversely, the actual pollen deposition effectiveness was relatively low in comparison with the contribution of more general behavioural indices, such as visit frequency.

3.3. Multiple Regression Analysis Predicting Fruit Mass

Multivariate linear regression was done to establish the relationship between variables of pollination and fruit mass. Total pollen, average foraging duration and number of visits to the flower were the predictors used in this model. The overall predictive value of the model was high ($R = .951$, $R^2 = .905$, Adjusted $R^2 = .904$) implying that it was established that the predictors chosen explained approximately 90.5% of the variance in fruit mass. The model was also statistically significant ($F = 718.750$, $p < .001$) which means that it is highly predictive. The coefficient analysis showed that the total pollen was the most significant predictor ($B = 0.152$, $t = .950$, $p < .001$). This means that an increase in the deposition of pollen also led to an increase in fruit mass in a direct proportion to the degree of pollen deposition, which thus lends weight to the centrality of the role played by pollen availability in the process of reproductive production.

Mean foraging duration, however, did not play an insignificant role ($B = -0.061$, $p > .05$), suggesting the absence of the direct relationship between longer foraging time and fruit development. Similarly, the number of flower visit contribution was also weak and not statistically significant ($B = 0.031$, $p > .05$). Collectively, these results indicate that the efficiency of pollination determined the reproductive success, but not behavioural strength. The adequacy of the regression model was confirmed by the diagnostics of the residual [8]. The predictive accuracy was high because the standard error of the estimate would be low (2.939). The residual independence was proved because the value of Durbin -Watson (2.048) was nearly equal to 2. The standardized residual values of the model ranged between -1.794 to 1.788 which means that there were no extreme outliers and that the model was stable.

Table 3. Multiple Linear Regression Predicting Fruit Mass (g).

Model Summary

R	R ²	Adjusted R ²	SE	Durbin–Watson
.951	.905	.904	2.94	2.048

Regression Coefficients

Predictor	B	SE	Beta	t	P
Constant	14.75	1.27	—	11.64	<.001
Total Pollen	0.152	0.003	.950	46.35	<.001
Mean Foraging Duration	−0.061	0.067	−.019	−0.918	.360
Number of Flower Visits	0.031	0.018	.034	1.662	.098

(Source: SPSS)

3.4. Comparative Analysis of Nest Orientation

Table 4. Independent Samples t-Test for Total Pollen by Nest Position.

Group Statistics

Nest Position	N	Mean	SD
Vertical	152	230.06	57.56
Horizontal	78	232.23	62.96

t-Test Results

t	df	p	Mean Difference	95% CI
-0.262	228	.793	-2.17	[-18.48, 14.14]

Levene's Test: $F = 2.079$, $p = .151$ (equal variances assumed)

(Source: SPSS)

An independent samples t-test was conducted to compare total pollen deposition between vertical and horizontal nests. The mean total pollen in vertical nests ($n = 152$) was 230.06 ± 57.562 , while horizontal nests ($n = 78$) had a slightly higher mean of 232.23 ± 62.958 . However, this difference was not statistically significant ($t = -0.262$, $p > .05$).

Confidence intervals showed substantial overlap between

groups, indicating that nest orientation did not significantly influence pollen deposition. Although vertical nesting was behaviourally more common, orientation did not translate into measurable differences in pollination efficiency. These findings suggest that nest placement may reflect structural or ecological preferences rather than factors directly affecting reproductive performance.

3.5. Ecological Trends from Graphical Interpretation

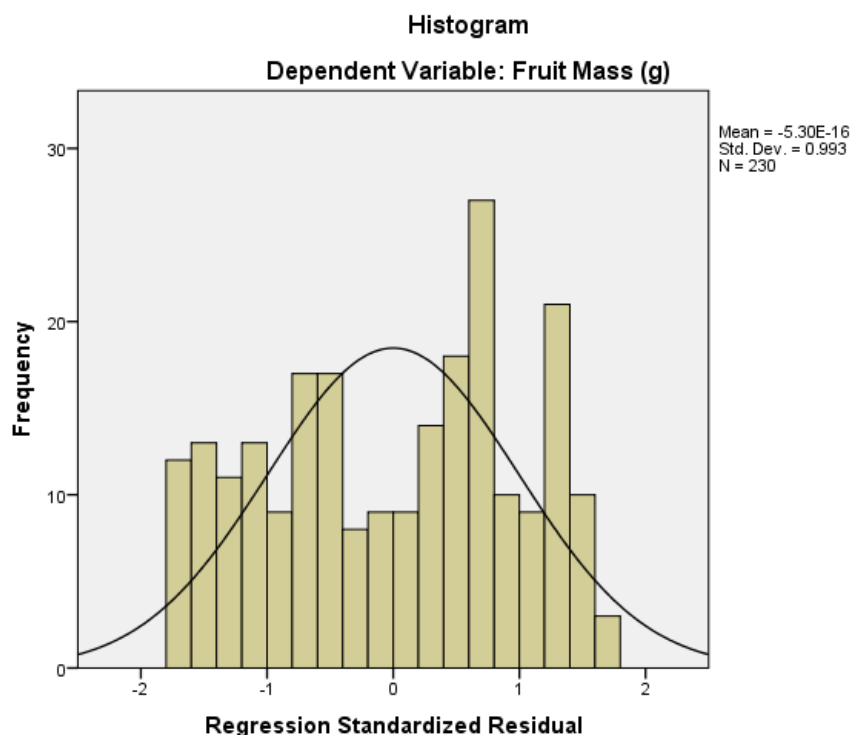


Figure 1. Fruit Mass (Histogram).

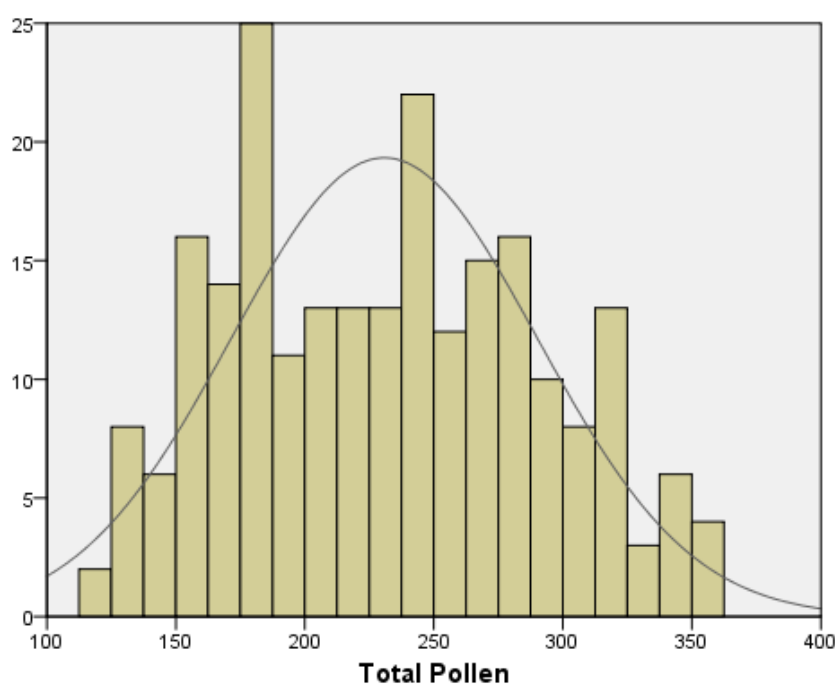
Table 5. Residual Diagnostics for Regression Model.

Statistic	Minimum	Maximum	Mean	SD
Predicted Value	33.06	68.76	49.83	9.02
Residual	-5.27	5.26	0.00	2.92
Standardized Residual	-1.79	1.79	0.00	0.99

(Source: SPSS)

As it is observed in the histogram, the distribution of mass of fruits is nearly normal meaning that there is statistically constant and environmentally consistent reproductive produc-

tion pattern among the target population. The lack of any extreme skew or outliers show that the success in such pollination was homogeneous and proves that the parametric inference is correct.



(Source: SPSS)

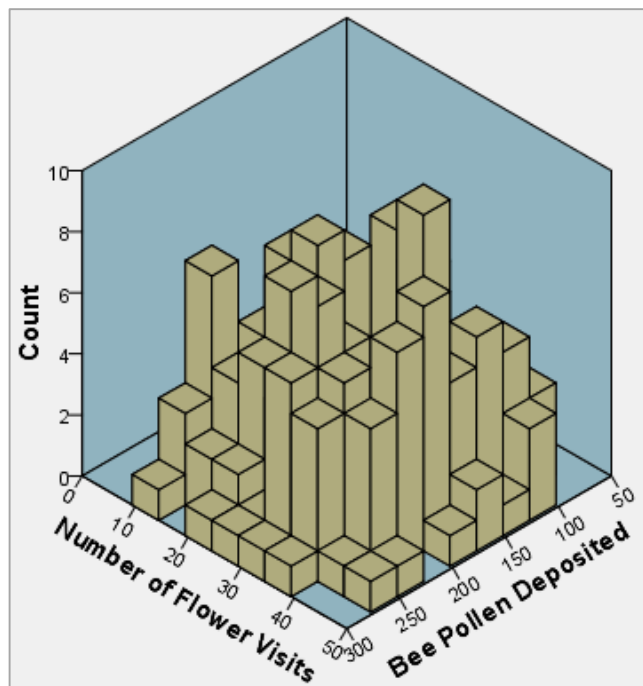
Figure 2. Total Pollen.

Graphical exploration also helped to support the statistical results. The appropriateness of the parametric analyses was justified by the fact that the histogram of total pollen had an approximately normal distribution. The weight of fruits was plotted in a dot with moderate variability without high extremes thus indicating that the observations do not have either excessively high or excessively low results of reproduction. Based on the descriptive results, the pie chart of the nest type determined the dominance of branched nests. Three-dimensional visualisation of floral visitation frequency and deposited bee pollen revealed that pollination was most prolific in mid-range values suggesting that there was a relative similar-

ity in pollination behaviour and not highly dispersed. Scatterplot and density plot of total pollen and fruit mass show that there is a high positive linear association that is graphical evidence that supports the high correlation and regression coefficients in the statistical findings. Flower colour graphical analysis even though it revealed diversification in floral interactions, colour was not revealed as a significant predictor of pollination success.

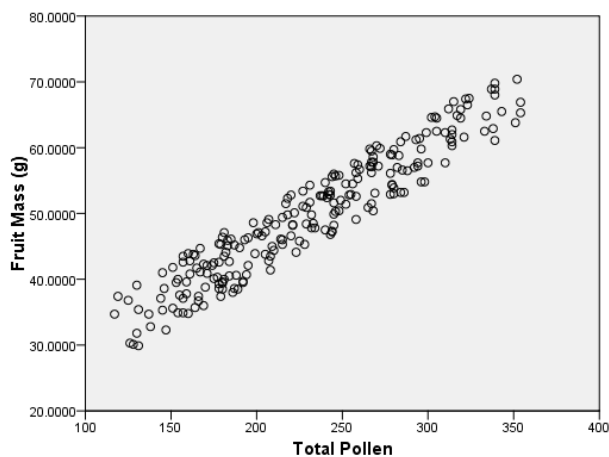
The overall pollen deposition in the form of graphs indicates the distribution of the pollen as a symmetrical distribution moderately dispersed among the measurements. This graphical trend advocates the enormous predictive capability

of total pollen on fruit mass that was achieved in the regression model.



(Source: SPSS)

Figure 3. Number of Flowers Visited and Bee Pollen Deposited.



(Source: SPSS)

Figure 4. Fruit Mass and Total Pollen.

The relationship between the increased visitation and the increased deposition of pollen is not linear as demonstrated in the three-dimensional graph. In this graph, it is emphasized that the qualitative nature of the transfer of pollen, and not the frequency of the visits, dictates the performance of pollination.

The strikingly high positive linear correlation between total pollen deposition and fruit mass is graphically supported by the extremely large Pearson correlation coefficient ($r = .951$).

The close clustering of the data points around an upward curve proves that the greater the efficiency of the pollen transfer, the more the fruit output directly increases, which further supports the fact that the amount of pollen is the most important predictor of fruit growth.

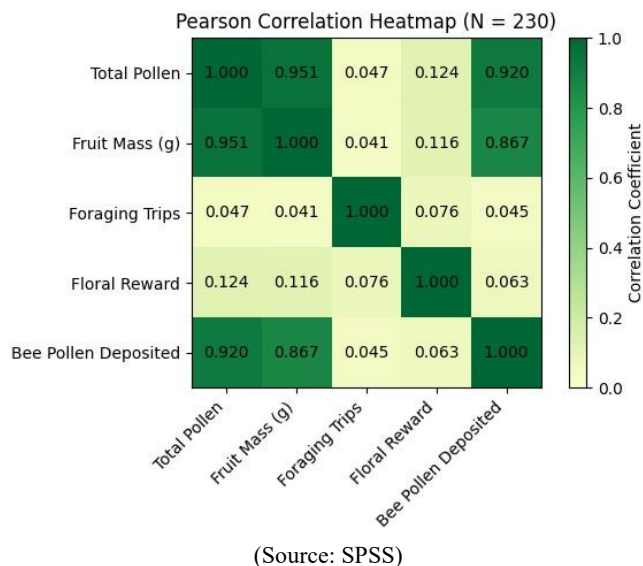


Figure 5. Correlation Heat Map.

The heatmap indicates that the positive correlation between Total Pollen and Fruit Mass ($r = .951$) and between Total Pollen and Bee Pollen Deposited ($r = .920$) is quite high, and it is right to conclude that the efficiency of pollen transfer is the most significant factor of the reproductive output. On the other hand, the behavioural variables of Number of Foraging Trips and Floral Reward Type show a non-significant correlation with the fruit mass supporting the argument that qualitative pollen deposition, rather than visitation frequency, is the success determinant of pollination.

In general, the statistical results indicate a consistent ecological trend whereby the nest structure is relatively stable, behavioural activity variability is moderate, and pollen transfer is the key factor of reproductive success. Descriptive statistics ensured the ecological ranges of the whole variables measured were biologically realistic. The results of correlation and regression analyses continually showed that overall pollen had the most powerful effect on the mass of fruits.

Conversely, behavioural phenotypes, including time spent foraging, nest orientation and visitation rate, were insignificant predictors in models [23]. All these findings point to the conclusion that reproductive output is largely dependent on quality and efficacy of pollen deposition and not on the degree of behavioural activity. Ecologically speaking, effective pollen exchange between pollinators turns out to be the focal process that supports the efficient forms of interaction between plants and pollinators in the ecosystem under consideration.

4. Discussion

The results at hand have made it extremely evident that the ecological process through which the reproductive success of the system in question is determined is not the intensity of behaviour but the efficiency of pollination. It was the fixed periodicity of the nesting plan of building and the relatively fixed behavioural action represented by descriptive regularities that made the pollinator have a substantially regulated nesting plan adapted to prevailing environmental conditions [19]. This evolution mechanism that might explain the excess of the structural stability, capability against the environmental perturbation and protection of brood would be the success of the branched and vertically oriented nests. However, the statistical significance of the variations in the total pollen deposition among the nest orientations do not show any statistical significance that means that such structural preferences are quite adaptive nesting behaviour but not the actual agents of the performance in pollination [22].

The end of the analysis, which is very significant was that there is a very close relation between mass of the fruits and overall pollen deposition. This huge proportion of correlation coefficient, together with the fact that the regression model can explain high level of variation means, confirms that the success of plants in reproduction depends largely on the efficiency of pollen transfer. Such findings are in line with the ecological theory in which successful carrying of the pollen is a more determinant of plant fitness than a visitation frequency [10]. Although the pollinating insects were also busy in the process of floral visitation, behavioural variables such as frequency of foraging trips and averages of foraging time were not seriously involved in the process of fruit development [19]. These patterns are indicative of the nature of the pollinator-flower interaction which occurs in the reproductive response in the number of visits.

Another indicator of the ecological importance of good pollen transport is that deposited bee pollen and total pollen are nearly related. The fact that the rates of covariance of these variables are quite high means that the effect of bee activity on the increase of the amount of viable pollen on which fertilization and later formation of fruit mass takes place is very significant [5]. This observation coincides with the behavioural ecology models that put a strong emphasis on the location specificity of the pollen as a functional adaptive character of efficient pollinators. Fruit mass has been moderately more, but this can scarcely be the variations in foraging labour or the nest construction.

Distributional statistics also make the ecological interpretations reliable. The continuous variables were roughly equal and had no extreme outliers, which indicated that there was security in the environment and predictability in behaviour in the observation. The negative kurtosis is the indicator of the ecological heterogeneity versus the statistical irregularity.

Overall, the information can be condensed to the following

ecological background; the successful reproduction is primarily goal-driven regarding the degree of the pollen being transported successfully [7]. The behavioural ones, e.g., frequency of visitation and the length of foraging appear to be auxiliary to the decisive one of efficiency of pollen transfer. The results indicate that it is time to start thinking about the mechanisms of pollen transfer in ecological research and not only about the fact of pollinator action. This study is therefore applicable in the broader idea of behavioural ecology where reproductive success depends on the quality and rather than the frequency of interaction.

5. Conclusion

The paper provides an insight into the behavioural ecology and pollination efficiency of a solitary buzz pollinator because it demonstrates that reproductive performance depends on the efficiency of pollen transfer and not the frequency of behavioural activity. In general, the adaptive behaviours to the environmental factors were comparable in nesting behaviour and foraging patterns. Compared to reproductive output, which demonstrated adaptive structural correlations, nest architecture and nest orientation had a modest direct impact on reproductive output, and it would be significant to mention that structural decisions, nevertheless, are better directly connected with protection and energy minimization than fruit production.

The main finding of the analyses is that total pollen deposition turned out to be the most effective predictor of the fruit mass justifying the prevalence of the pollination efficacy to demonstrate reproductive success. The important role in research is to investigate the effective pollinator and plant interactions since it was found that the relationship between the transfer of pollen and fruit production was close in statistics. In comparison, the role of behavioural variables (time spent foraging and frequency of visitations) in reproductive success was comparatively small.

In conclusion, it was shown in the analysis that the reproductive success of this system was founded on the successful pollen delivery as the main ecological process. It is also worth pointing out that the results help to understand the benefits of research on pollinator functional ecology better and emphasize the necessity to quantify ecological performance by the level of interaction efficiency, thereby improving the interpretation of plant-pollinator interactions.

Abbreviations

ANOVA	Analysis of Variance
df	Degrees of Freedom
IEP	Isoelectric Point
SPSS	Statistical Package for the Social Sciences
PD	Pollen Depositio

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Author Contributions

Debakanta Sahoo: Data curation, Writing – original draft

Aparna Yerra: Supervision, Investigation

Pallavi Mishra: Visualization, Resources

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Data Availability Statement

The data supporting the outcome of this research work have been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Debakanta Sahoo is a Zoology academician and researcher from Odisha, India, with more than five years of teaching experience as a Lecturer in Zoology and over three years of experience as a Laboratory Assistant-cum-Store Keeper in Zoology. He is currently pursuing his Ph.D. in the

Department of Life Sciences at GIET University. He completed his M.Sc. in Zoology from S.C.S. (Autonomous) College under Utkal University. His areas of research include Animal Behaviour, Ecology, and Toxicology, with special emphasis on buzz pollinators and the ecological impacts of pesticides. Mr. Sahoo has pre-

sented his research work at several national and international conferences and has published research papers in the field of zoological sciences. He is also actively involved in awareness campaigns related to pollinator conservation and wildlife protection.



Aparna Yerra is currently working as an Assistant Professor at GIET University. She completed her M.Sc. and Ph.D. in Biotechnology from GITAM University. Her research contributions primarily focus on polyamines and sericulture, and she has published several research articles in these

areas. She has presented her research work at numerous national and international conferences and received the Young Scientist Conclave Award in recognition of her contributions. She was subsequently selected for the DST-SERB National Post-Doctoral Fellowship, during which she worked on silk-based biomaterials. Aparna also served as a Research Scientist at MNR Medical College and worked as a faculty member at the Central University of Andhra Pradesh. Her current research interests are centred on sericin protein and silk-based biomaterials, with a focus on their biomedical applications.



Pallavi Mishra working as Assistant Professor of Zoology at SCS Autonomous College, Puri, Odisha with more than 15 years of teaching and research experience in the field of biological sciences. She obtained her Ph.D. in Zoology from Utkal University, where her doctoral research focused on

the role of oxidative stress in the cardiac system under hypo- and hyperthyroid conditions. Her Research interest includes oxidative stress biology, molecular biology, environmental toxicology, microbiology, and biomedical sciences. Dr. Mishra has served as Principal Investigator for research projects funded by the Government of Odisha, including studies on antibiotic-resistant genes in earthworm casts and the development of chitosan biochar composites for water purification and oil adsorption. She has published several research papers in reputed Scopus-indexed journals and is currently guiding Ph.D. scholars in the field of zoological sciences.

Research Field

Debakanta Sahoo: Animal Behaviour, Ecology, and Toxicology

Aparna Yerra: sericin protein and silk-based biomaterials

Pallavi Mishra: oxidative stress biology, molecular biology, environmental toxicology, microbiology, and biomedical sciences