Study of the size of inflorescences of *Lantana Camara*

Visualizing trends in the variation of the same and commenting on the 'optimum size' of the local species' inflorescence

Juee Dhar*, Abhishek Thawait**

Abstract

Studies of inflorescence function are beginning to link morphological and ecological aspects, although a comprehensive understanding of inflorescence structure and function yet remains quite understudied. By linking the appearance of the floral display to the branching pattern of the inflorescence and understanding the constraints on inflorescence form from both functional and structural aspects, functional studies may continue to bridge the gap between ecology and morphology. This study aims to look into one such structural parameter, i.e. the number of flowers in the inflorescence and work our way through the hypothesis that this is a valid parameter that contributes to the reproductive allocation of our model species, *Lantana camara.*

Key words : Inflorescences, reproductive allocation, hypothesis testing, pollination

---

Introduction

Our model organism: *Lantana camara*

L. Camara is an extremely adaptable species that can live in a wide range of environments; once introduced into a habitat, it quickly spreads. It has become an invasive species that has the potential to out compete native species, reducing biodiversity. Its toxicity to cattle, as well as its capacity to develop dense thickets that, if left unchecked, can drastically limit farmland productivity, might pose issues if it invades agricultural areas.

L. camara has small tubular shaped flowers, which each have four petals and are arranged in clusters in terminal areas stems. Flowers come in many different colours, including red, yellow, white, pink and orange, which differ depending on location in inflorescences, age, and maturity. After pollination occurs, the colour of the flowers changes (from yellow to pinkish, in the type of L. camara under observation); this is believed to be a signal to pollinators that the pre-change colour contains a reward as well as being sexually viable, thus increasing pollination efficiency.

* 19MS102, DBS, IISER Kolkata
** 19MS160, DBS, IISER Kolkata

Why study inflorescences?

An inflorescence is a group or cluster of flowers arranged on a stem that is composed of a main branch or a complicated arrangement of branches. Inflorescences are described by many different characteristics including how the flowers are arranged on the peduncle, the blooming order of the flowers and how different clusters of flowers are grouped within it. These terms are general representations as plants in nature can have a combination of types. These structural types are largely based on natural selection. The development of plants depends on the activity of their meristems, groups of dividing cells located at the growing points. These meristems can continue to add new structures to the plant throughout its life history, giving it the potential for indeterminate growth. By changing a few of the key features of meristems, it is possible to account for much of the evolutionary variation in plant form, such as variation in inflorescence architecture and floral symmetry.

Reproductive allocation in inflorescences

Pollinator behaviour inside and across plants has a significant impact on the mating outcomes of animal-pollinated plants. In plants that display multiple flowers simultaneously, all open flowers can act together to attract pollinators, enhancing pollen export, import, and potential mate diversity. Large floral displays also allow self-pollination among a flower, which reduces the amount of pollen that would otherwise be exported to other plants and, in self-compatible species, decreases both the production of outcrossed seeds and the average offspring performance due to inbreeding depression. The consistency of the movement patterns of pollinators within inflorescences can create variation in the mating environment among flowers, which may select for gradients in sex allocation among flowers or even segregation of the sex roles within inflorescences. Given the various consequences of pollinator behaviour on plant mating, the individual and combined effects of plant characteristics on these behaviours, such as the number of flowers open at once, should instinctively have a significant impact on plant reproductive performance. Intuitively, plants with a large number of flowers on display, should attract more pollinators than those with a small number of flowers, and pollinators prefer to visit more flowers on huge displays. So, the pattern and size of these inflorescences help draw crucial conclusions about the overall reproductive allocation of the plant.

An analogy : Clutch sizes in avian species

The number of eggs laid in a single brood by a nesting pair of birds is referred to as clutch size. The numbers laid by a species in a particular place are usually well defined by evolutionary trade-offs involving a variety of parameters, including resource availability and energy constraints. The clutch size of most birds, however, is not the same for all members of a species. Individuals lay a particular number of eggs, although this amount varies from one person to the next in the community. This difference in clutch size is significant. It's unclear why they stop laying at a particular amount or how they know they've achieved it. When food supply is abundant, a large clutch can be an advantage since all of the young can be raised successfully with good chances of survival. When food supply is limited, however, a large clutch can be a disadvantage, as a small amount of food shared by a large number of chicks can reduce survival chances for the entire brood. Birds have an optimum clutch size, therefore, that will result in the maximum number of surviving chicks.

We drew a parallel to show the presence of such an optimum size of inflorescence which like the egg is an reproductively active, quantifiable entity and wanted to visualize any trends in the number of reproductively active flowers within inflorescences like the well studied example of avian clutch sizes.

Effects of inflorescence size on visits from pollinators

In studies of the pollinator behaviour for *Corydalis ambigua*, it has been observed that *C. ambigua* is self-incompatible and that seed set was significantly affected by the behavior of the pollinating queens. Plants with larger inflorescences were visited more often than those with fewer flowers. Fecundity also increased with increasing size of inflorescences. Visitation time (duration of foraging) rather than the frequency of visitations (number of visits) was critical for higher fecundity. Hence, plants with larger inflorescences, which provide a conspicuous signal to pollinators and offer greater rewards in terms of nectar, received longer visits by pollinators and those plants exhibited higher fecundity.

This study truly emphasizes the critical importance of the parameter that inflorescence size can be, potentially a driving factor for the co-evolution of pollinators alongside the species of interest. Hence, the study of inflorescences is extremely relevant and a source of many interesting questions; and we choose to set some humble aims for our own study, as given below.

Aim

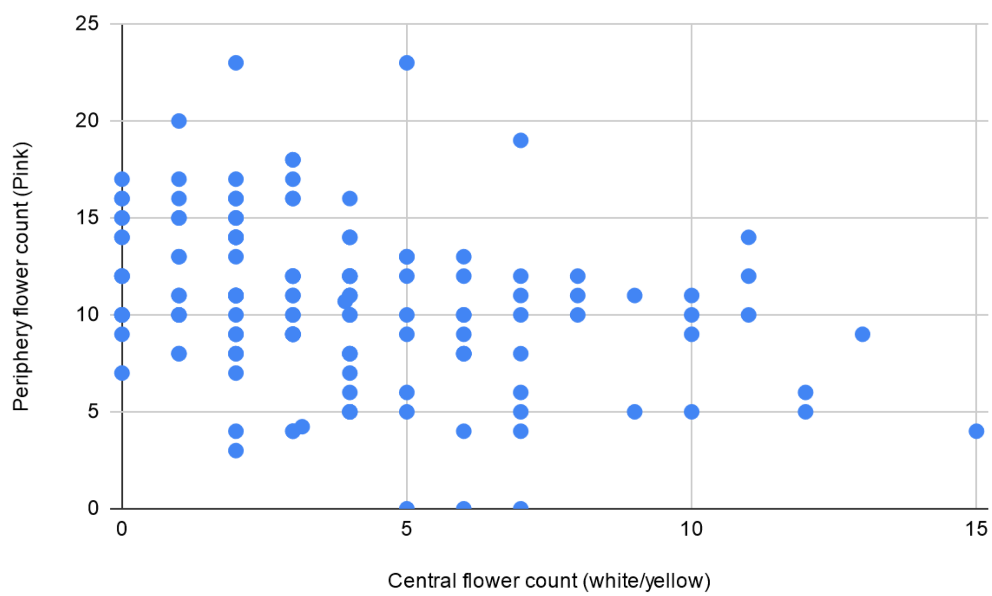
1. To conduct a primary data collection to study the number of flowers in inflorescence of *Lantana camara*.
2. Observe trends in the number of flowers in the different inflorescence of *L. camara*, visualize the trends empirically and find the mean, median and mode number of flowers in a cluster to possibly model some convergence to an ‘optimum size’ of inflorescence.
3. Discuss what could be the possible reasons for this variability in size of the inflorescence and allocation of reproductive resources within and among inflorescences.
4. ~~Conduct a comparative analysis to comment on the variability of size of inflorescence of some other wildflower species and compare it against our model organism, L. camara~~.
5. To question if the inflorescence size is a significant parameter that accounts for the reproductive allocation.

Methodology

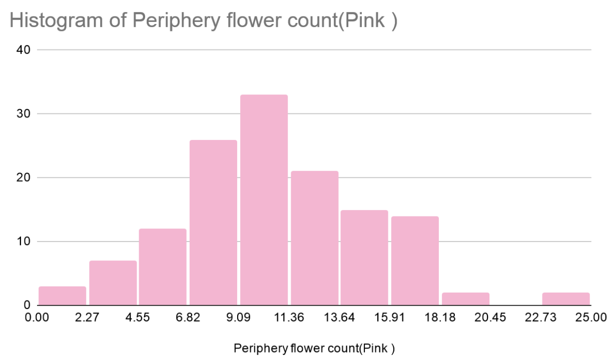
1. Choose the site under study.
   - Our readings were primarily taken from Lantana plants on either sides of the road behind the Nivedita hostel. Choose plants which have many inflorescences in safe distance (for sake of convenience).
2. Start taking the readings.
   - Try to choose inflorescences that are in full bloom and we observed only white and pink lantanas (we also spotted yellow lantanas in the campus, but we restricted our study to this particular phenotype for sake of simplicity).
3. Randomly pick a flower and count the number of flowers which are white/yellow (ones in the middle of the cluster) and the number of pink flowers(ones near the periphery) separately.
4. To avoid multiple counting of the same inflorescence, pluck the inflorescence off the plant (or just twist the stem).
5. Then we convert this field data into a .csv and plot the required graphs and yield the measures of central tendency using google sheets/excel itself.
   - We did start our data analysis using python, one of the google collab notebooks is added here, but decided against it.

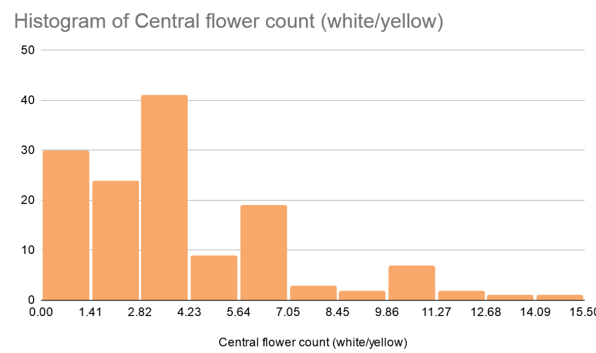
Results

The entire observations are tabulated in this google sheet.



Each point on the scatter plot simply shows the composition of an individual inflorescence.





Measures of central tendency and deviation

	White/yellow	Pink
Mean	3.918518519	10.6962963
Median	3	11
Mode	2	10
Standard deviation	3.162400023	4.23255696

We observe lesser standard deviation in the white/ yellow flowers (central), potentially due to some evolutionary driving force over these sexually viable parts of the inflorescence, as compared to the pink flowers (peripheral).

Hypothesis testing : Chi squared test

Our null hypothesis is that the number of white/yellow flowers in an inflorescence and the pollination depend on one another and show a convergence toward the mean value, while our alternative hypothesis is that these parameters are fairly independent.

We know that,

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where $O_i = \ observed\ value, E_i = \ Expected\ value$

Expected value = mean number of white/yellow flowers = 3.918518519

We used excel's inbuilt functionality of the CHITEST to calculate the chi squared value

χ^2 = **341.9924**

Here the degree of freedom of the system = 134 ; Critical value = 162.016; level of significance = 0.05.

	P										
DF	**0.995**	**0.975**	**0.20**	**0.10**	**0.05**	**0.025**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
121	84.686	92.446	133.861	141.315	147.674	153.338	155.051	160.100	164.814	170.647	174.816
122	85.520	93.320	134.915	142.398	148.779	154.464	156.183	161.250	165.980	171.831	176.014
123	86.356	94.195	135.969	143.480	149.885	155.589	157.314	162.398	167.144	173.015	177.212
124	87.192	95.070	137.022	144.562	150.989	156.714	158.445	163.546	168.308	174.198	178.408
125	88.029	95.946	138.076	145.643	152.094	157.839	159.575	164.694	169.471	175.380	179.604
126	88.866	96.822	139.129	146.724	153.198	158.962	160.705	165.841	170.634	176.562	180.799
127	89.704	97.698	140.182	147.805	154.302	160.086	161.834	166.987	171.796	177.743	181.993
128	90.543	98.576	141.235	148.885	155.405	161.209	162.963	168.133	172.957	178.923	183.186
129	91.382	99.453	142.288	149.965	156.508	162.331	164.091	169.278	174.118	180.103	184.379
130	92.222	100.331	143.340	151.045	157.610	163.453	165.219	170.423	175.278	181.282	185.571
131	93.063	101.210	144.392	152.125	158.712	164.575	166.346	171.567	176.438	182.460	186.762
132	93.904	102.089	145.444	153.204	159.814	165.696	167.473	172.711	177.597	183.637	187.953
133	94.746	102.968	146.496	154.283	160.915	166.816	168.600	173.854	178.755	184.814	189.142
134	95.588	103.848	147.548	155.361	162.016	167.936	169.725	174.996	179.913	185.990	190.331
135	96.431	104.729	148.599	156.440	163.116	169.056	170.851	176.138	181.070	187.165	191.520
136	97.275	105.609	149.651	157.518	164.216	170.175	171.976	177.280	182.226	188.340	192.707
137	98.119	106.491	150.702	158.595	165.316	171.294	173.100	178.421	183.382	189.514	193.894
138	98.964	107.372	151.753	159.673	166.415	172.412	174.224	179.561	184.538	190.688	195.080
139	99.809	108.254	152.803	160.750	167.514	173.530	175.348	180.701	185.693	191.861	196.266
140	100.655	109.137	153.854	161.827	168.613	174.648	176.471	181.840	186.847	193.033	197.451

Clearly,

341.9924 > 162.016, i.e. χ^2 > Critical value

Here hence we can reject the proposed null hypothesis.

Hence we reject the possibility that the number of central flowers (sexually viable) in a lantana inflorescence and the pollination depend on one another and show a convergence toward the mean value. The size of an inflorescence (i.e. the no. of flowers in an individual inflorescence) seeming doesn't converge to some optimal number of sexually viable flowers (which makes sense given the graph for the white/yellow doesn't tend to a gaussian).

Reminder: Since our sample size is very small, we can't make any irrefutable conclusions !

Discussion

With the above analysis, we rule out the notion that the number of sexually viable flowers in a lantana inflorescence and pollination are linked, and we see a trend toward the mean value. The number of sexually viable flowers in an inflorescence does not converge to some optimal number. This could be because of inadequate sampling or could imply that the number of flowers in an inflorescence is effectively immaterial to the reproductive allocation of the *L. Camara* population, which is certainly a bold claim to make. It is also inconsistent with studies done with other model organisms, which draws a positive correlation between the number of inflorescences and foraging behaviours of pollinators; which implies the reproductive allocation of the plant's dependence on the size of inflorescence.

Is this a species wide (or genus wide) commonality ? Or is this just a fault in sampling ? One can raise these questions as possible critics to our study and this must pique the interest of the reader, giving us further directions to study this relationship between inflorescence size and reproductive allocation.

Limitations

1. Some of the observed inflorescences weren't in full bloom and we had to leave out some of the buds in our data collection process (hence the sampling was not completely random).
2. In some inflorescences we found it harder to distinguish between the central and peripheral flowers (they have more of a gradient of colours going from the center to the edge) on the basis of colour which might have resulted in some sampling error.
3. Lantana inflorescences are extremely fragile, a flower or two might have fallen or blown by wind before or while taking readings and might have not been noticed, again resulting in some sampling error.
4. The sample size studied was small and is hence quite unrepresentative, hence us trying to visualize a gaussian in the trend of pink (i.e. reproductively active) flowers is not a robust claim.

Further Directions

1. Amplify the sample size for the above experiment.
2. To study the overall distributions of the lantana inflorescences spatially, with respect to each other and use pattern recognition to spot any pattern of growth and development of the entire plant.
3. To study the architecture of inflorescence, so as to explain the differential coloration and the placement of the white flowers in the center and pink ones to the periphery, evolutionarily.
4. Do a comparative study between different species of the genus and then compare them to some remotely related wildflower species and see if the number of flowers in an inflorescence could be a useful phylogenetic parameter.
5. Observing pollinator behaviour over inflorescences of different sizes and commenting on the effect of the same n visitation time and frequency of visitation.

Bibliography

1. Weiss, Martha. R. (1990). "FLORAL COLOR CHANGES AS CUES FOR POLLINATORS".
2. Dudash, M. R., Hassler, C., Stevens, P. M., & Fenster, C. B. (2011). Experimental floral and inflorescence trait manipulations affect pollinator preference and function in a hummingbird-pollinated plant. American Journal of Botany,
3. Ohara, M., Higashi, S. Effects of inflorescence size on visits from pollinators and seed set of Corydalis ambigua (Papaveraceae). Oecologia (1994)
4. Singer S, Sollinger J, Maki S, Fishbach J, Short B, Reinke C, Fick J, Cox L, McCall A, Mullen H. 1999. Inflorescence architecture: a developmental genetics approach. The Botanical Review
5. Brody, A., Mitchell, R. Effects of experimental manipulation of inflorescence size on pollination and pre-dispersal seed predation in the hummingbird-pollinated plant Ipomopsis aggregata . Oecologia 110, 86–93 (1997)
6. Bruce K. Kirchoff, Regine Claßen-Bockhoff, Inflorescences: concepts, function, development and evolution, Annals of Botany, Volume 112, Issue 8, November 2013
7. Enrico S. Coen, Jacqueline M. Nugent; Evolution of flowers and inflorescences. Development 1 January 1994
8. Graham H. Pyke, Optimal foraging in hummingbirds: Rule of movement between inflorescences, Animal Behaviour, Volume 29, Issue 3, 1981,
9. Eldon Greij Why birds have different clutch sizes ? (https://www.birdwatchingdaily.com/news/science/why-birds-have-different-clutch-sizes/)