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MATHEMATICAL INTERPRETATION OF AESTHETIC VALUE OF FLORAL STRUCTURE AND MODE OF POLLINATION IN SOME ANGIOSPERM PLANTS

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ABSTRACT:

The beauty of the flower can be quantified through golden ratio analysis. Objects with shape which is in golden ratio seem to be more attractive. Compared to anemophilous flowers, entomophilous flowers are more attractive to perform the function of inviting the pollinators. If length to breadth ratio of petals in a flower is very much nearer to the golden ratio, then that flower will be more attractive and vice-versa and sample survey studies have been substantiated this fact. It was found that the ``closeness" of length to breadth ratio of petals to golden ratio is an indication of the range of beauty of flowers.

KEY WORDS: *Golden Ratio, Aesthetic significance, Statistical analysis, Homogeneous strata, Simple Random Sampling, Method of grouping, Negative correlation, Aesthetic Point, Aesthetic Value, Mode, Mean.*

INTRODUCTION:

Beauty or aesthetics is an abstract idea about the shape, size, arrangement, colour etc., of the living and non-living things in the world. As it is an abstract or qualitative entity, it varies from person to person, sex to sex culture to culture and society to society. The most important purpose or function of beauty is related to reproduction, especially sexual reproduction in living organisms. The physiological process of sexual reproduction begins with the attraction between opposite sex and that is based on beauty. Beauty or attractive potential of the floral parts has a vital role in the process of pollination (eg:- entomophilous pollination-pollination by insects, zoophilous pollination -pollination by animals, etc.) which is an inevitable part of sexual reproduction in plants. This qualitative or abstract phase of beauty in the sociological or biological frame can be shifted to quantitative or concrete space. This can be done by introduction of the mathematical concept ``golden ratio" to interpret the concept of beauty quantitatively.

The golden ratio otherwise known as the Divine Proportion or "Phi" is a mathematical ratio with special properties and aesthetic significance. The golden ratio is believed to be the most aesthetically pleasing and harmonious means of design. Statistical analysis indicates that ``The people involuntarily give preference to proportions that approximate to the Golden Section (Golden ratio)" [11]. Beauty is a relative concept and it varies from region to region and person to person. As mathematics gives a precise definition of everything, so it does for beauty. It can be seen that the logos of famous brands, for example, Pepsi, Toyota, National Geographic, etc., follow the rule of golden ratio because of its eye catchiness [2].

By aesthetic value (AV) we mean the average point of each flower obtained from the survey and by aesthetic point (AP) we mean the points given to the flowers as per the aesthetic sense of the individuals participated in the survey.

Golden ratio is an element of beauty. So as deviation of length to breadth (of the petals of the flowers) ratio from golden ratio decreases, the beauty of the flower increases. Hence people's preference also increases which results in the increase in AV.

The correlation coefficient (r) between the deviation from golden ratio and aesthetic value can be calculated to find the degree of linear relation between these two, given by

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2 \sum_{i=1}^{n}(Y_i - \overline{Y})^2}}$$

If a negative correlation is obtained it indicates that beauty preference decreases with increase in deviation from golden ratio. A t-test for significance of correlation coefficient will help to test whether the obtained correlation is significant.

STUDY AREA:

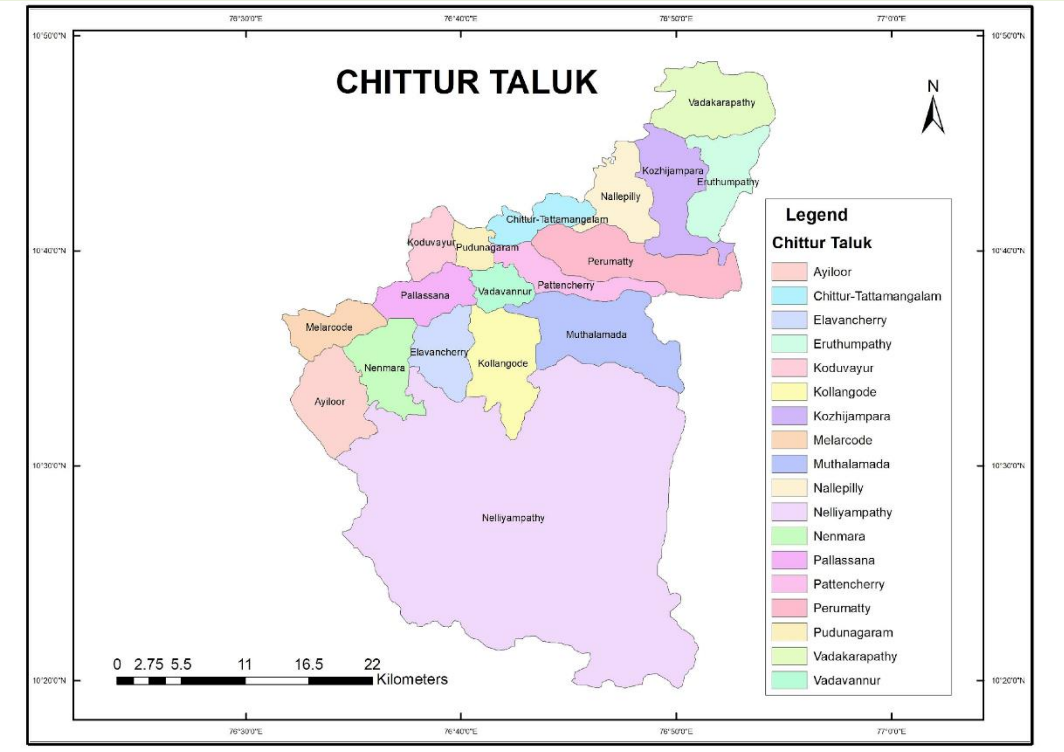


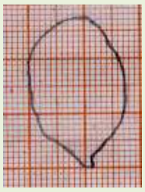
Figure 1: Map of Chittur Taluk

The study area is located in Chittur Taluk of Palakkad District covering Chittur-Thattamangalam Municipal area. The location maps (Figure 1) illustrate the spatial location of the district and taluk with respect to Kerala state. The Chittur Taluk is situated from $10^{0}19'0''$N to $10^{0}49'0''$N latitude and from $76^{0}30'0''$E to $76^{0}52'0''$E longitude.

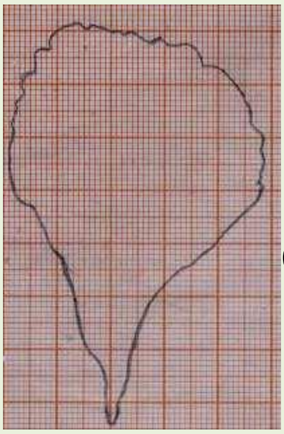
MATERIALS AND METHOD:

The flowers of various angiosperm plants in the study area were collected randomly and the identity of the collected specimens was confirmed using pertinent literature [7]. Collected and identified flowers were grouped into two, anemophilous flowers [agent of pollination is wind] and entomophilous flowers [agent of pollination is insects] according to the description of the structure of floral parts in the relevant literature.

The outlines of the petals, the floral part which performs the function of attracting the pollinating agents, were depicted on graph sheets and the length and breadth of the petals were measured to calculate the golden ratio of each petal. The length to breadth ratio was compared with the golden ratio.

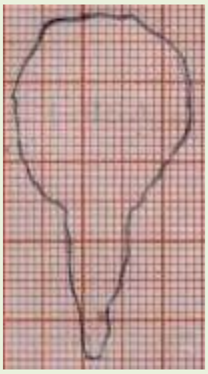



(a) *Catharanthus roseus* (b) *Cassia fistula*

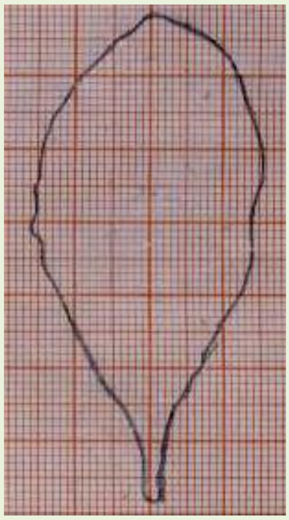


(c) *Hibiscus rosa- sinensis*

(d)*Caesalpinia pulcherrima*




(f) *Combretum indicum*

(e) *Allamanda cathartica* (g) *Nerium oleander* (h) *Bauhinia purpurea*

Figure 2: Hand-drawn petals of different flowers in a graph paper

Table 1: Some of the insect pollinated (Entomophilous) flowers in the campus and its golden ratio calculated using Figure 2

Sl.No	Name of the Plant	Family	Length (*l*)	Breadth (*b*)	*l*/*b*
1	*Catharanthus roseus* (L.) G. Don.	Apocynaceae	2.5	1.85	1.35
2	*Cassia fistula* L.	Fabaceae	2.75	1.7	1.6176
3	*Hibiscus rosa- sinensis* L.	Malvaceae	7.4	4.7	1.57
4	*Caesalpinia pulcherrima* (L.)Sw.	Fabaceae	1.9	1.1	1.72
5	*Allamanda cathartica* L.	Apocynaceae	4.3	2.2	1.95
6	*Combretum indicum* (L.)DeFilipps.	Combretaceae	1.6	0.8	2.0
7	*Nerium oleander* L.	Apocynaceae	3.3	1.6	2.06
8	*Bauhinia purpurea* L.	Fabaceae	6.65	3.02	2.2

From table 1 we observe that the length to breadth ratio of Cassia fistula L.[1] is close to golden ratio when compared to that of other flowers. That is Cassia fistula is more beautiful among these flowers. To verify the result obtained from the above table a statistical survey was conducted among the students of Govt. College, Chittur, Palakkad. There are 1778 students in the college among which 1197 are girls and 581 are boys. The aesthetic sense differs for boys and girls in general. The student population in the college is heterogeneous and hence is divided into three homogeneous strata Arts having 867 students, Science having 702 students and Commerce having 209 students [15, 23, 4, 3]. 49 students were selected from the Arts stream, 40 students from the Science stream and 12 students from the Commerce stream giving proper weight to each stream, making a total of 101. From each stratum the students were selected to the sample by the method of simple random sampling using the official nominal roll of the students prepared and kept in the office of Govt. College Chittur during the academic year 2017-2018. Then a survey was conducted within the sample. In the survey, the eight flowers mentioned above were shown to each student of the sample and were asked to assign 8 points to the flower which they prefer the most, 7 to the next and so on till 1 to the least.

Mean is the average of a set of numerical values, as calculated by adding them together and dividing by the number of terms in the set. *Mode* is a statistical term that refers to the most frequently occurring number found in a set of numbers, [20]. The mode is found by collecting and organizing data in order to count the frequency of each result. The result with the highest number of occurrences is the mode of the set [12,13]. Since the data has irregularities, mode is calculated by the *method of grouping*. In this method, column (i) represents the original frequencies, column (ii) is obtained by combining the frequencies two by two, column (iii) is obtained by leaving the first frequency and combining the remaining frequencies two by two. Column (iv) is obtained by combining the four by four and column (v) is obtained by leaving the first two frequencies and combining the remaining frequencies four by four. Then the maximum frequency in each column is noted and the aesthetic point corresponding to each maximum frequency are listed. The aesthetic point which is most repeated is considered as the mode [8].

Entomophily or insect pollination is a form of pollination whereby pollen of plants, especially of flowering plants, is distributed by insects. Flowers pollinated by insects typically advertise themselves with attractive shape and size, bright colours, sometimes with conspicuous patterns leading to rewards of pollen and nectar; they may also have an attractive scent which in some cases mimics insect pheromones. Anemophily or wind pollination is a form of pollination whereby pollen is distributed by wind. Features of the wind pollination syndrome include a lack of scent production, a lack of showy and attractive floral parts, reduced production of nectar and the production of enormous numbers of pollen grains. This distinguishes them from entomophilous species.

RESULT AND DISCUSSION:

The first clear definition of what has later become known as the ``*Golden Ratio*'' was given around 300 B.C. by Euclid [11] as a formalized deductive system. He defined a proportion derived from a simple division of a line into what he called its ``*extreme and mean ratio*''. In Euclid's words: `A straight line is said to have been cut in extreme and mean ratio when, as the whole line is to the greater segment, so is the greater to the lesser'.

In 1509 Luca Pacioli in his book [16] named this ratio as the "Divine Proportion" with illustrations from Leonardo Da Vinci. Pacioli in [16] discussed the mathematical aspects of golden ratio, its application in arts and architecture.

The golden ratio is what we define as complex proportions artist, architects, and engineers at the tie did not use anything more complex than proposed proportions [17]. The precise value of the Golden Ratio is the never-ending, never-repeating number 1.6180339887 . . . The Greek Mathematician Hippasus of Metaporitum discovered, in the fifth century B.C., that the Golden Ratio is a number that is neither a whole number (like the familiar 1, 2, 3, . . .) nor even a ratio of two whole numbers(like the fractions ½, 2/3 , . . .). It is represented by the Greek letter 'τ ' meaning 'the cut' or 'the section'. At the beginning of the twentieth century, the American Mathematician Mark Barr gave the ratio the name of phi, the first Greek letter in the name of Phidias because he used Golden Ratio in many of his sculptures. This term was first used by the German Mathematician Martin Ohm in the 1835 second edition of his book Die Reine Elementar - Mathematik (The pure elementary mathematics). Golden Ratio gained popularity only around the 1830s. Another definition for the golden ratio is "A number used to indicate each of the years of the lunar cycle" as given in 1900 edition of the French encyclopedia. It is highly unlikely that either the ancient Babylonians or the ancient Egyptians discovered the Golden Ratio and its properties.

Golden ratio was instituted by the Greeks in the 4th century B.C.that culminated in the publication of Euclid's 'Elements' around 300 B.C. In this book, golden ratio is frequently mentioned as "extreme and mean ratio". Euclid's definition in Book VI of extreme and mean ratio is such that (larger segment)/(shorter segment) is equal to (whole line/larger segment) (Figure 3) [6].

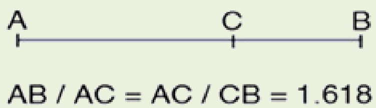


Figure 3: Golden Ratio in Line SegmentTable 2: Some of the main flowers in the campus

Name of the Plant \ AP	1	2	3	4	5	6	7	8	AV
Allamanda cathartica	11	8	12	13	20	16	12	9	4.62
Bauhinia purpurea	16	22	8	14	8	15	9	10	4.05
Caesalpinia pulcherrima	13	13	8	14	14	13	12	14	4.58
Cassia fistula	7	7	7	13	11	12	15	29	5.5
Catharanthus roseus	20	13	13	11	11	16	10	7	4.02
Combretum indicum	9	19	20	10	10	6	15	12	4.29
Hibiscus rosa- sinensis	8	5	12	12	11	15	19	19	5.26
Nerium oleander	17	15	21	14	16	8	9	1	3.61

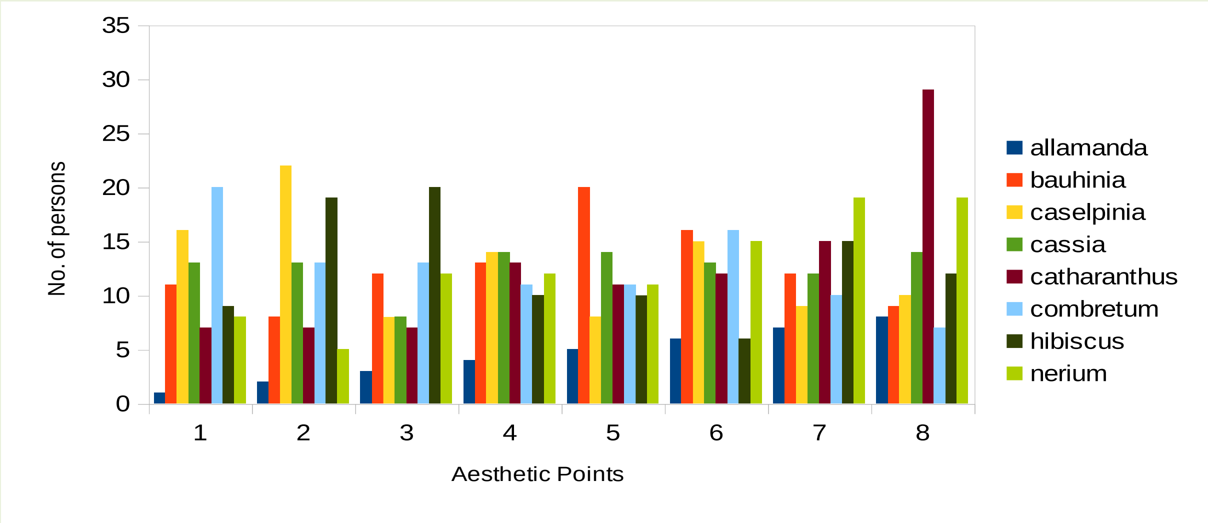


Figure 4: Graphical representation of survey conducted with grades on x-axis and the number of persons on y-axis

Table 3: Mode of the data collected

AP	*Allamanda*					*Bauhinia*					*Caesalpinia*					*Cassia*				
1	11					16					13					7				
		19					38					26					14			
2	8					22					13					7				
			20	44				30	60				21	48				14	34	
3	12					8					8					7				
		25					22					22					20			
4	13					14					14					13				
			33		61			22		45			28		49			24		43
5	20					8					14					11				
		36					23					27					23			
6	16					15					13					12				
			28	57				24	42				25	53				27	67	
7	12					9					12					15				
		21					19					26					44			
8	9					10					14					29				

AP	*Catharanthus*					*Combretum*					*Hibiscus*					*Nerium*				
1	20					9					8					17				
		33					28					13					32			
2	13					19					5					15				
			26	57				39	58				17	37				36	67	
3	13					20					12					21				
		24					30					24					35			
4	11					10					12					14				
			22		51			20		46			23		50			30		59
5	11					10					11					16				
		27					16					26					24			
6	16					6					15					8				
			26	44				21	43				34	64				17	44	
7	10					15					19					9				
		17					27					38					10			
8	7					12														

Since the data obtained from the survey is dependent on the aesthetic sense of individuals and the observations in the data is not clustered around AV, we have considered the mode of AP's. In the case when some flowers have the same mode, we opted AV to compare the results. From Table 3, we can see that most of the people's choice was those flowers whose *l*/*b* ratio is near to golden ratio which we have calculated see Table 1. The mathematical concept of Golden Ratio has been used in defining the biological and artistic concepts like beauty, structural stability, etc.[18, 5, 9].

Table 4: Table showing the relationship between deviation from the golden ratio (corrected to five decimals) and AV

Sl.No	Name of the flower	l/b-ratio	Golden Ratio	Deviation from Golden Ratio	AV
1	*Cassia fistula*	1.6176	1.618034	0.000434	5.5
2	*Hibiscus rosa-sinensis*	1.57	1.618034	0.048034	5.26
3	*Allamanda cathartica*	1.95	1.618034	0.331966	4.62
4	*Caesalpinia pulcherrima*	1.72	1.618034	0.101966	4.58
5	*Combretum indicum*	2.0	1.618034	0.381966	4.29
6	*Bauhinia purpurea*	2.2	1.618034	0.581966	4.05
7	*Catharanthus roseus*	1.35	1.618034	0.268034	4.02
8	*Nerium oleander*	2.06	1.618034	0.441966	3.61

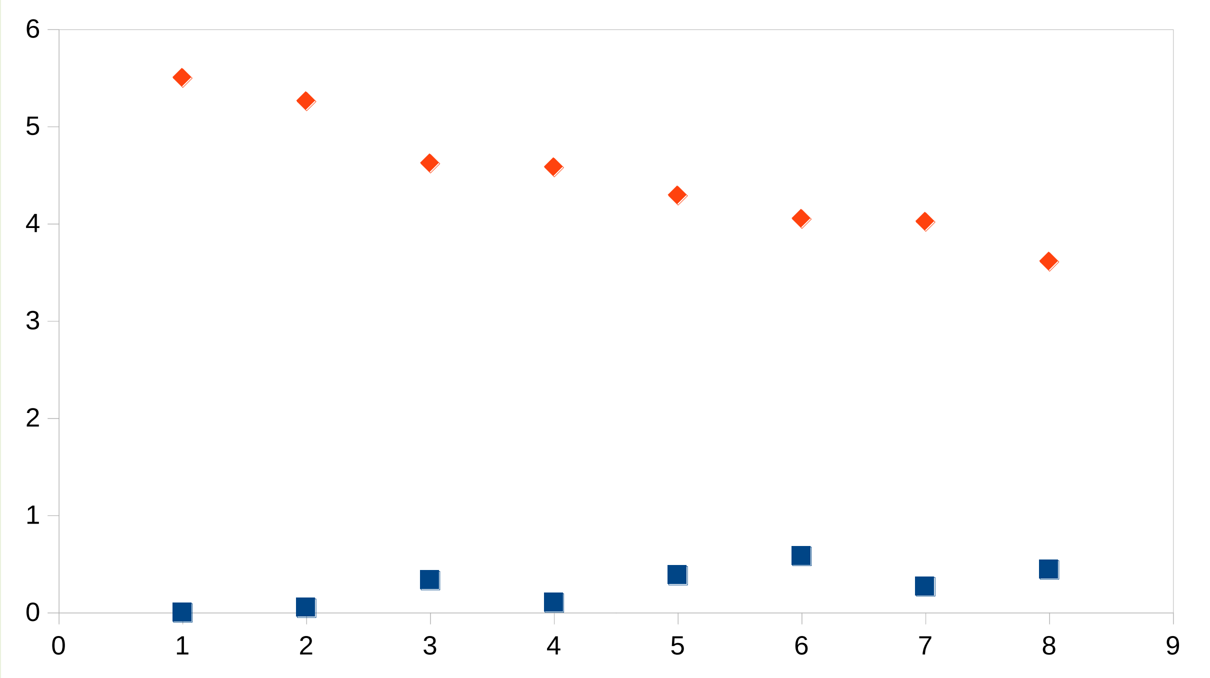


Figure 5: Graphical representation of Table 4, with blue dots showing the deviation from golden ratio and red dots showing AV

Objects with golden ratio are with more attractive potential. The relationship between length to breadth ratio of flower parts of Angiosperms and golden ratio is an indicator of the beauty of the flowers.

Significance of AV

We can see the negative correlation between aesthetic value and deviation of length to breadth ratio from golden ratio using the graph shown in the Figure 5. To confirm the result we use the standard t-test. We first give the procedure for conducting the standard t-test. We have used the symbols and standard notations from [8].

The procedure for t-test:

• The null hypothesis to be tested for possible rejection is H_0 : r = 0 against the alternative H_1 : r $\neq 0$.

• The test statistic to be taken is $t = \frac{r'(n-2)^{\frac{1}{2}}}{(1-(r')^2)^{\frac{1}{2}}} \sim t_{n-2}$ where r is the sample correlation coefficient and n is the number of pairs of observation based on which r ′ is calculated.

• H_0 is to be rejected if |t| > $t_{\frac{\alpha}{2}}$ where $t_{\frac{\alpha}{2}}$ is to be obtained from t tables for (n−2) degrees of freedom.

Next we justify the result by using the standard t -test. Take note that the correlation coefficient r = −0.8289

Result. *Aesthetic Value justifies Golden Ratio.*

Justification of the Result:
Using the formula, we have t = 3.6296 and from the t-table we can see that $t_{0.05}$ = 2.447. Hence t >$t_{0.05}$, so that we reject H_0 and accept H_1 , which implies that the AV and deviation of length to breadth ratio from golden ratio are negatively correlated. So Aesthetic Value justifies Golden Ratio. Hence the result.

CONCLUSION:

The traditional concept regarding the beauty as a qualitative character has to be transformed by adapting mathematical concepts like the golden ratio, Fibonacci sequence etc., in defining the biological and artistic concepts like beauty, attraction, structural stability etc. Similar studies can be done by considering inflorescence instead of the petals considered in this article.

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