SHORT COMMUNICATION

Non-randomness on the distribution and orientation of the naturally fallen cotton tree (*Bombax ceiba* L.) flowers on the ground

Dominic Zhongxian Gu
Chinese International School, 1 Hau Yuen Path, Braemar Hill, North Point, Hong Kong Special Administrative Region, Hong Kong, China

Abstract: Observation was made and is registered for the event of the naturally fallen cotton tree (*Bombax ceiba* L.) flowers on the ground in terms of the orientation and distribution of their openings to the cardinal directions. The data collected from the naturally fallen flowers on the ground were then organized into four arbitrary groups according to the cardinal directions for further analysis. The results show a clear trend of the flower openings to be aligned more to the East and West directions, indicating a non-random event on the probability of distribution. To compare and verify the collected data of cotton tree flowers, a simulation experiment was then conducted using the commercially available badminton shuttlecocks to examine their fall and their subsequent distribution and orientation. With repeated simulations, even though not perfectly random (25% for each of the four directions), the data of badminton shuttlecocks are much closer to a random event. The current results indicate that the distribution and orientation of the cotton tree flowers on ground are not a random event as anticipated, which may have fundamental biological and physical reasons deserving further investigations.
Keywords: Cotton tree, *Bombax ceiba*, randomness, physical law, simulation

Correspondence to: Dominic Zhongxian Gu, Chinese International School, 1 Hau Yuen Path, Braemar Hill, North Point, Hong Kong Special Administrative Region, Hong Kong, China; E-mail: dzg167@student.cis.edu.hk

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1 Introduction

Biology is intrinsically connected to physics and chemistry, and both of which have major roles to the morphology, physiology and biochemistry of the organism in many ways, e.g., physical appearance, colors, functional morphologies, and specific chemicals synthesized (Davis, 1966, 1967; D'Arcy and Keating, 1996; Endress, 1999). This connection can also be observed in other ways such as limiting the growing height of a tree due to transportation of water against gravity, the fall of trees after death and when the roots are weakened by many factors involved including infection by insects and pathogens (Krisdianto and Balfas, 2005; Raut et al., 2017; Said et al., 2013; Wang et al., 2016). As a unique species for example, the cotton tree (*Bombax ceiba* L.) is commonly seen in tropical and subtropical climates, with its flowers appearing in red or orange color in spring time when the tree has no green leaves, drawing attention of many investigations (Davis, 1966, 1967; Endress, 1999; Said et al., 2013; Sint et al., 2013). With its dark colored tree trunk and no green leaves, the aesthetic bright colors of the cotton tree flowers make them most appealing to the eye (Figure S1) (Joshi et al., 2013; Yang et al., 2022).

The cotton tree has attracted attention in scientific research because of its ecological significance in cities like Guangzhou, Macau and Hong Kong (Deng, 2004; Xing, 2013; Xing and Qiu, 2006) and, more recently, pharmaceutical values of the bioactive chemicals in different parts of the tree such as flowers (Kamble et al., 2017; Raut et al., 2017; Zhang et al., 2015) and tree barks (Faizi et al., 2011). This direction of research may lead to new biotechnological industry and development generating high profit, and to further research innovations producing the germ-free tree seedlings under laboratory conditions to allow a fast growth of the trees and a mass production of the young seedlings for the valued chemicals from the tree. In addition, its ecosystem function is also recognized for the importance in pollination by bats and insects, and for the nutritional value to the pollinating animals and insects (Raju et al., 2005).

Biology obeys the physical law and, in this case, symmetry is basic and universal in many cases from macro to micro-level organisms (Davis, 1966, 1967; D'Arcy and Keating, 1996). Cotton tree flowers have a unique anatomical structure and geometry. Assuming they all have identical anatomy and thus the same aerodynamics when falling after maturity and detachment from the tree due to gravity, the naturally fallen cotton tree flowers on the ground should theoretically follow the rules of classical physics and statistics to a random probability of their orientation and distribution. To my amazement, a crude observation of them shows that the orientation and distribution of the flowers on the ground around the trees are not likely to be a random probability event, thus this investigation was carried out to test the hypothesis in that the cotton tree flowers on the ground are randomly orientated statistically because of the identical flower structure and the absence of tree leaf to affect their falling path.

2 Materials and Methods

2.1 Description and data collections

This investigation was carried out in Spring 2022 along Daxue Road in the suburb of Shantou, Guangdong, China. There was no disturbance to the flowers on ground before the data collection by photography. Because the street is cleaned during the day, the cotton tree flowers on the ground at the time of photographing were the result of more recent falls, without apparent physical disturbance or any damages to the flowers. Before choosing a specific tree and also the flowers around it, a closer inspection was made to ensure that the area was not disturbed by people or other factors to result in visible non-natural orientations of the flowers on the ground (Supplementary materials Figure S2). The matured flowers of cotton trees fallen onto the ground and their non-disturbed natural layout were recorded by digital photography from each of the four cardinal directions for further analysis by assigning each of them to the four groups according to the direction of flower opening orientation to 0-90° (North-East, North designated as 0° and East as 90° in clockwise fashion), 90-180° (East-South), 180-270° (South-West), and 270-360° (West-North). Among the sampling trees and associated flowers, 3 of them are presented here for this communication, and they contain approximately 30-40 flowers at each tree and each location of sampling.

2.2 Simulation for verification

To make a comparison and also verification on the probability of the randomness of the object falling event, brand new badminton shuttlecocks (Star Sports, Shanghai, China) were used to simulate the fall and orientation of their layout on the ground. A total of 8 of them were laid flat randomly in terms of orientations of the badminton shuttlecock tails on a paperboard and were subsequently tossed up for about 30 cm to allow them to fall freely at a height of 2 meters above the ground. The layout of them on ground was photographed and the process was repeated 12 times to generate this set of simulation data for analysis, comparison and presentation. Same assignment of them into the 4 groups was made as that for cotton tree flowers.

3 Results and Discussion

Cotton trees are deciduous and the height can reach as tall as 25 meters in tropical and subtropical regions. The anatomy of cotton tree flowers is very unique and the tree physiology during its growth is also very interesting, with flowering period in February and March and fruiting period in April

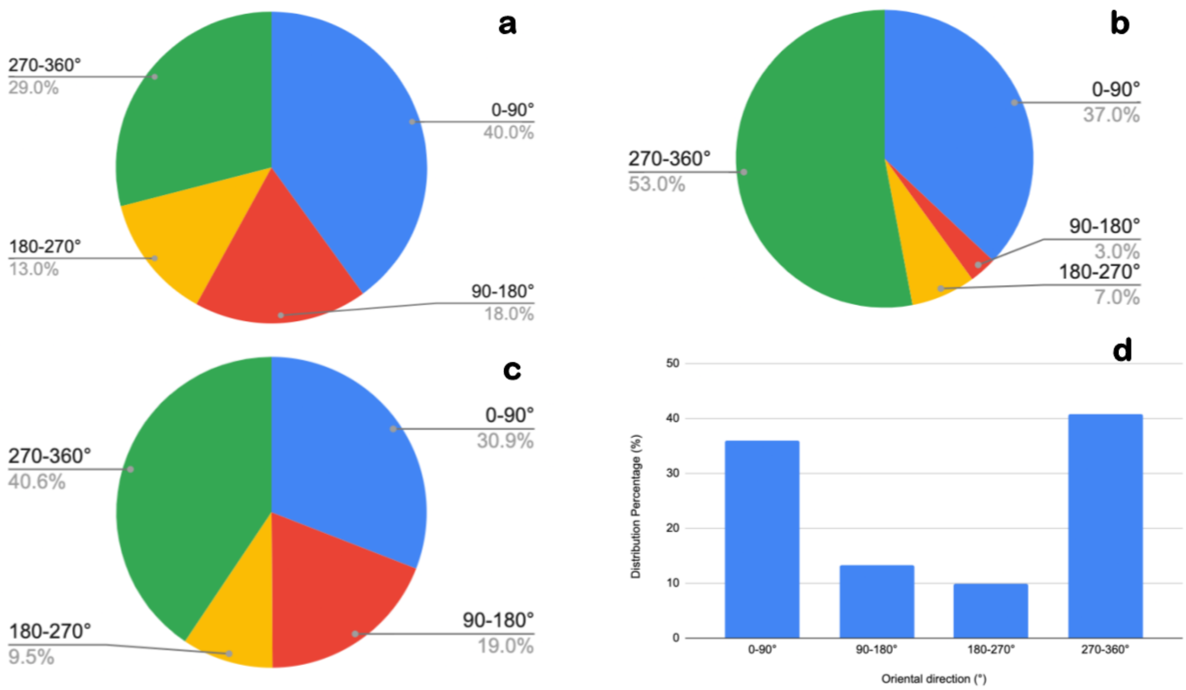

Figure 1. Distribution of the flower orientations to the designated cardinal directions (0-90° for North-East, 90-180° for East-South, 180-270° for South-West, and 270-360° for West-North) and the associated percentage of the flowers to each group in this investigation with three randomly selected samples (*a-c*); and the average of the data collected on probability of orientational direction (*d*).

and May in Southern China. Each flower has 5 petals in cup shape approximately 8-10 cm in diameter and 3-5 cm in length (Figure S1) (Deng, 2004; Xing, 2013; Xing and Qiu, 2006). The abundant flowers cover the leafless tree branches with their radiant red or orange color. This fact allows the first assumption that all these flowers are identical in their structure and thus their aerodynamics during the fall can also be the same or very similar.

Assuming a random probability event, the distribution of the flower orientations on ground to each of the 4 directional groups of this study should be allocated with a theoretical 25% probability statistically for the total of 100%. Based on the above assumptions, the data collected from this investigation showed a clear non-random probability of the distribution of the flower orientations with a bias toward the North to East (0-90°) and West to North (270-360°) directions (Figure 1) or to a comparatively less extent to the South (Figure 1). These results yield a preference for Northeast (0-90°) and Northwest (270-360°) with 36% and 40.9% on average, respectively (Figure 1d), which were significantly higher than the theoretical average of 25% probability for a random event of distribution. In addition, it is observed that a nearly even distribution between East and West demarcation line is obvious in two of the total tree samples, 53% vs. 47% and 50.1% vs. 49.9%, respectively (Figure 1b and 1c). This initial observation deserves further in-depth investigations for any biological significance and underlying reasons to support the data collected in this initial study (D'Arcy and Keating, 1996; Davis, 1966, 1967; Davis and Mariamma, 1965; Endress, 1999). In contrast, the distribution between South and North division line cannot be established for the data collected in a similar way for the East and West, further indicating the non-randomness of the flower orientation on ground after falling. The symmetry of the flower anatomy would not support such a result unless other reasons are available to explain for the flowers of *B. ceiba* L.

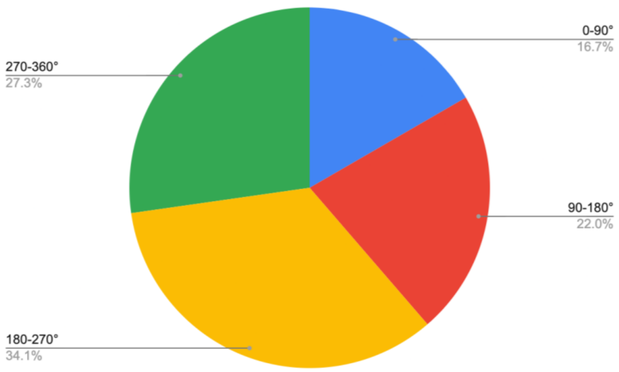

Figure 2. Simulation results using badminton shuttlecocks on the orientation and distribution with a total number of 12 trials. The grand average results are shown here.

To test the distribution randomness of the falling event by using badminton shuttlecocks in a further experiment, new commercial sport badminton shuttlecocks were used for simulation by tossing 8 of them each time to a total height of approximately 200 cm and then let fall onto the floor so that the orientations of the badminton shuttlecocks were recorded photographically in a similar fashion to the *B. ceiba* flowers and used for data processing to be illustrated in Figure 2. It is clear that badminton shuttlecocks show a result much closer to the theoretical probability of 25% for the mandatorily allocated four cardinal direction groups since the data were from 16.7% (the lowest value) for the 0-90° to 34% (the highest value) for 180-270°, compared with the mean value of 25% (Figure 2). This set of data shows that the orientation probability of the badminton shuttlecocks is comparatively closer to a random event statistically than that of the cotton tree flowers. The deviations from the random probability distribution of the *B. ceiba* are therefore evident and shall be further investigated for the underlying reasons for and causes of the phenomenon observed.

This information may have fundamental biological basis for the results observed because from this preliminary observation, the cotton tree flowers do not seem to obey the physical law on the randomness of the events driven by gravity. When examined closely, a more approximately East (0-180°) and West (180-360°) division seems to operate in the data collected. Given the results observed in this investigation, there must be some fundamental biological reasons to dictate such a pattern, which need be further investigated for the physical and/or biological bases.

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Conflict of Interest

Author declares no conflict of interest in this study.

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Supplymentary Material

Figure S1. A photograph of the cotton tree flowers showing their cup shape and appearance.

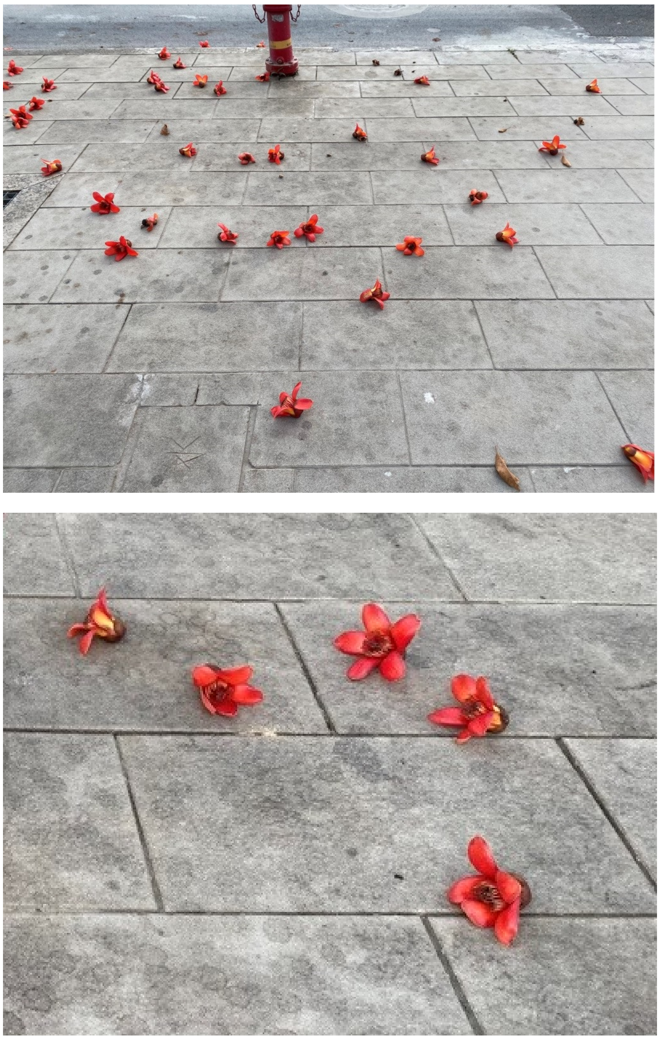

Figure S2. Photographs of the cotton tree flowers distributed around the tree on the ground used for analysis in this study (*top*) and a close-up of 5 flowers from this sampling (*bottom*).