Title

Insufficient Evidence of Purported Lunar Effect on Pollination in Ephedra

Permalink

https://escholarship.org/uc/item/8rr3m49z

Journal

JOURNAL OF BIOLOGICAL RHYTHMS, 30(5)

ISSN

0748-7304

Author

Margot, J-L

Publication Date

2015-10-01

DOI

10.1177/0748730415591662

Peer reviewed

JOURNAL OF BIOLOGICAL RHYTHMS, VOL. 30, NO. 5, 454-456, DOI: 10.1177/0748730415591662

INSUFFICIENT EVIDENCE OF PURPORTED LUNAR EFFECT ON POLLINATION IN *EPHEDRA*

JEAN-LUC MARGOT[1,2]
[1]Department of Earth, Planetary, and Space Sciences
[2]Department of Physics and Astronomy,
University of California, Los Angeles,
595 Charles E. Young Drive, Los Angeles, CA 90095
jlm@astro.ucla.edu

(Received May 2, 2015; Accepted May 26, 2015)
Includes corrigendum

ABSTRACT

It has been suggested that the timing of pollination in *Ephedra foeminea* coincides with the full moon in July. The implication is that the plant can detect the full moon through light or gravity and that this trait is an evolutionary adaptation that aids the navigation by pollinating insects. Here we show that there is insufficient data to make such a claim and we predict that pollinations of *E. foeminea* do not in general coincide with the full moon.

Keywords: evolution, plant science, Moon, anemophily, entomophily, false positive, type I error, file drawer effect

1. INTRODUCTION

Rydin and Bolinder (2015) observed peak pollination dates of *E. foeminea* in Asprovalta, Greece, in 2011, 2012, and 2014. They performed a linear regression between 3 pairs of points recording the day of month (DOM) of the July full moon (x=3, 12, 15) and of the peak of pollination (y=1, 11, 14). The linear regression equation is y=-2.23077+1.08974*x. The authors relied on the correlation coefficient (r^2=0.9996, p=0.013) to claim an association between pollination and the full moon. However, the significance of the correlation coefficient in this context is meaningless. If pollination had occurred at other times (e.g., DOM 6, 24, 30), the correlation coefficient would indicate a perfect correlation (r^2=1) despite the lack of any association with the full moon (i.e., DOM 3, 12, 15).

To properly assess the coincidence of an event with the full moon, a useful metric is the time interval Δ in fractional days between the event and the preceding or subsequent full moon. (A DOM time scale is not robust with respect to month boundaries or daylight savings time). We can use the following notation to represent the authors' data: $|\Delta_1| = 2$, $|\Delta_2| = 1$, $|\Delta_3| = 1$, with an average distance given by $\bar{\Delta} = \Sigma_{i=1}^{3}|\Delta_i|/3 = 4/3$. Lower values of $\bar{\Delta}$ indicate better coincidence.

2. LIKELIHOOD OF OBSERVED COINCIDENCE

The duration of the lunar cycle at the time of observations never exceeded 29.5 days. Therefore Δ can take 1 of 29 values between -14 and +14. Let us draw 3 integers between -14 and 14 with replacement and calculate the corresponding value of $\bar{\Delta}$. There are a total of $29^3 = 24389$ possible outcomes. Of those, 129 have $\bar{\Delta} \leq 4/3$, which can be demonstrated by having a computer generate the 24389 combinations and count those that satisfy the criterion. Therefore, by chance alone, one would expect 129/24389 or about 1/189 studies to exhibit as good a coincidence with the full moon as that observed by the authors.

3. IMPACT OF MISSING 2013 DATA AND FUTURE OBSERVATIONS

Rydin and Bolinder (2015) did not report a pollination date for 2013. In the absence of additional information, we can only assume that the corresponding Δ would take 1 of 29 values between -14 and 14. All 29 situations have an equal probability of 1/29, such that consideration of the missing 2013 data does not affect the overall probability of 1/189, as expected. If an additional data point becomes available, we can show that 7 outcomes ($|\Delta| = 0-3$) will strengthen the coincidence, 2 outcomes ($|\Delta| = 4$) will leave it roughly unchanged, and all 20 other outcomes ($|\Delta| = 5-14$) will weaken the coincidence. If the process is random, it may take several years before the apparent coincidence with the full moon deteriorates. Values of $|\Delta| = 7$ in the future will yield a coincidence similar to that observed by chance alone in 1/59 studies (first instance), then 1/35 studies (second instance). Alternatively, if the average value $\bar{\Delta}$ remains at its current level of $4/3$ with additional observations, the confidence in a lunar effect will increase to 1/1037 studies (first instance), then 1/5615 studies (second instance).

4. OBSERVATIONAL UNCERTAINTIES

Although the authors did not specify uncertainties for the timing of the pollination peaks, the language in their article suggests that the uncertainty is no less than a day. (In 2011, "drop production peaked during the next couple of days." In 2012, "production peaked during the first days of July." In 2014, "peaked during this day and the next few days.") How do these uncertainties affect the results? An offset of a single day in any one of the three observations yields $\bar{\Delta} = 5/3$ (1/106 studies by chance alone). Offsets of one day in 2/3 and 3/3 of the observations yield $\bar{\Delta} = 6/3$ (1/65 studies) and $\bar{\Delta} = 7/3$ (1/42 studies), respectively. Offsets of two days in 2/3 and 3/3 of the observations yield $\bar{\Delta} = 8/3$ (1/29 studies) and $\bar{\Delta} = 10/3$ (1/16 studies), respectively. We have assumed offsets that decrease the correlation although offsets can also increase it.

5. THE FILE DRAWER EFFECT

Rydin and Bolinder (2015) reported a result that seemed, at face value, unlikely to be due to chance alone (i.e., 1/189, ignoring observational uncertainties). They may very well have "detected" an effect that is not present (a type I error). Studies affected by type I errors tend to be overrepresented in the literature because the studies that fail to show a connection are more likely to remain unpublished – a publication bias known as the file drawer effect. To evaluate the significance of the coincidence observed by Rydin and Bolinder (2015), the important question is not whether 1/189 is much less than 1, but whether N/189 is much less than 1, where N is the total number of similar studies in which a coincidence with the full moon could have been noticed or reported. The vast literature on plant phenology indicates that N/189 is larger than 1. One would therefore *expect* to see several instances of excellent correspondence between plant development phases and lunar phases, *even if the moon has absolutely no effect on plants*.

6. EXAMPLES OF FALSE POSITIVES

Table 1 lists the coincidence with the full moon, as measured by the $\bar{\Delta}$ metric, for several samples constructed to match the characteristics of the Rydin and Bolinder (2015) sample. In each case, the timing of a specific phase in plant development is compared to the closest full moon. Three data points from a 3- to 6-year period are shown, with time measured by year and day of year (DOY). These examples have a far greater level of significance than that reported by Rydin and Bolinder (2015), but observations at other times allow us to conclusively rule out a lunar influence. We predict that a similar conclusion will be reached for *E. foeminea*.

7. CAN *E. FOEMINEA* REALLY DETECT THE FULL MOON?

Rydin and Bolinder (2015) invoked the detection of lunar tides by *E. foeminea* as a possible mechanism for the observed coincidence, which reveals a common misconception about tides. Because of the form of the gravity potential, the gravity signals at new moon and full moon are roughly equivalent, and one would not expect a gravity trigger at full moon that does not also act at new moon. In addition, the lunar tidal signal is weak compared to that of ordinary objects in the vicinity (Margot 2015). The strength of tides depends on the distance d and mass m of the tide-raising body, as follows (e.g., Murray and Dermott 1999):

$$F \propto \frac{m}{d^3}. \tag{1}$$

For instance, the effect of the botanist's car parked 10 m away from the field site is ~1000 times stronger than the lunar tide:

$$\frac{F_{\rm car}}{F_{\rm moon}} = \left(\frac{1300 \text{ kg}}{7.35 \times 10^{22} \text{ kg}}\right)\left(\frac{3.84 \times 10^8 \text{ m}}{10 \text{ m}}\right)^3 \simeq 10^3, \tag{2}$$

and the effect of the botanist making an observation 1 m away from the plant is ~50,000 times stronger than the lunar tide:

$$\frac{F_{\rm person}}{F_{\rm moon}} = \left(\frac{65 \text{ kg}}{7.35 \times 10^{22} \text{ kg}}\right)\left(\frac{3.84 \times 10^8 \text{ m}}{1 \text{ m}}\right)^3 \simeq 5{\times}10^4. \tag{3}$$

The effect of lunar tides on plants has been studied (e.g. Vesala et al. 2000). Controlled studies could be perfomed by moving ordinary masses around a plant bed and recording gravimeter data.

Rydin and Bolinder (2015) also suggested that *E. foeminea* can detect the light of the full moon and produce pollination drops accordingly. Studies of the effect of lunar illumination on plant flowering have yielded conflicting results (e.g., Bünning and Moser 1969; Kadman-Zahavi and Peiper 1987). Ground illumination from a full moon at zenith is ~ 0.27 lux, whereas direct sunlight is $\sim 10^5$ lux (Seidelmann 1992). Controlled studies in a laboratory setting could replicate appropriate illumination conditions and should be performed before a lunar influence is asserted.

8. CONCLUSIONS

The fact that 3 pollination peaks of *E. foeminea* coincided roughly with the full moon does not constitute sufficient evidence that the moon exerts any influence on the timing of pollination. Correlation is not causation and this particular correlation is likely spurious. Additional observations of the pollination dates will settle the matter.

REFERENCES

E. Bünning and I. Moser. Interference of moonlight with the photoperiodic measurement of time by plants, and their adaptive reaction. *Proceedings of the National Academy of Sciences*, 62(4):1018–1022, 1969.

D. R. Cayan, S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, and D. H. Peterson. Changes in the Onset of Spring in the Western United States. *Bull. Amer. Met. Soc.*, 82:399–415, 2001.

J. Dierenbach, F-W. Badeck, and J. Schaber. The plant phenological online database (ppodb): an online database for long-term phenological data. *International Journal of Biometeorology*, 57(5):805–812, 2013.

A. Kadman-Zahavi and D. Peiper. Effects of moonlight on flower induction in pharbitis nil, using a single dark period. *Annals of Botany*, 60(6): 621–623, 1987.

J. L. Margot. No Evidence of Purported Lunar Effect on Hospital Admission Rates or Birth Rates. *Nursing Research*, 64:168–175, 2015. doi:10.1097/NNR.0000000000000086.

R.A. Marsham. Indications of Spring. *Phil. Trans. R. Soc. Lond.*, 79: 154–156, 1789.

C. D. Murray and S. F. Dermott. *Solar System Dynamics*. Cambridge University Press, 1999.

C. Rydin and K. Bolinder. Moonlight pollination in the gymnosperm *Ephedra* (Gnetales). *Biol. Lett.*, 11(20140993), 2015.

P. Kenneth Seidelmann, editor. *Explanatory Supplement to the Astronomical Almanac*. University Science Books, 1992.

T. Vesala, S. Sevanto, P. Paatero, E. Nikinmaa, M. Peramaki, T. Ala-Nissila, J. Kaariainen, H. Virtanen, J. Irvine, and J. Grace. Do tree stems shrink and swell with the tides? *Tree Physiology*, 20(9):633–635, 2000.

Table 1
Phases in plant development and correspondence with the full moon.

Species	Phase	Years	DOY	Full moon	$\bar{\Delta}$	Expect.
A. pratensis[1]	general blossom	1978, 1980, 1981	142, 150, 139	142, 150, 139	0	1/24389
D. glomerata[2]	general blossom	1963, 1965, 1966	158, 165, 154	158, 165, 154	0	1/24389
S. vulgaris[3]	first leaf	1984, 1985, 1986	106, 65, 55	106, 65, 55	0	1/24389
S. vulgaris[4]	first bloom	1974, 1976, 1978	155, 134, 142	155, 134, 142	0	1/24389
A. campestre[5]	leafing	1782, 1783, 1785	117, 108, 114	117, 107, 114	1/3	1/3484
P. x yedoensis[6]	peak bloom	1961, 1965, 1966	92, 105, 95	91, 105, 95	1/3	1/3484
E. foeminea[7]	peak pollination	2011, 2012, 2014	195, 183, 192	196, 185, 193	4/3	1/189

[1] Records of the flowering of the meadow foxtail (*Alopecurus pratensis*) obtained by the German meteorological service (DWD) at the Reichenbach (Oberlausitz) station, Germany (Dierenbach et al. 2013).

[2] DWD records of the flowering of the orchard grass (*Dactylis glomerata*) at the Grosspostwitz station, Germany (Dierenbach et al. 2013).

[3] Western Regional Phenology Network (WRPN) records of the common lilac (*Syringa vulgaris*) at the Stonington, CO station, USA (Cayan et al. 2001).

[4] WRPN records of the common lilac (*Syringa vulgaris*) at the Medicine Lake, MT station, USA (Cayan et al. 2001).

[5] Records of the leafing of the maple tree (*Acer campestre*) by Robert Marsham, F.R.S., near Norwich, Norfolk, UK (Marsham 1789).

[6] US National Park Service records of the peak bloom date of the Yoshino cherry (*Prunus x yedoensis*) in Washington, DC. The peak bloom date is defined as the day when 70% of the blossoms in a well-defined area are open.

[7] Rydin and Bolinder (2015).