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RESEARCH HIGHLIGHT

FE spotlight: Testing pollen presentation theory in a buzz-pollinated plant

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Pollen Presentation Theory (PPT) proposes that animal-pollinated flowering plants should optimize how much pollen is exported per pollinator visit (Harder & Thomson, 1989; Thomson et al., 2000). Although elegantly simple in theory, few empirical studies of PPT have been published since it was first proposed nearly 50 years ago. Here, Vallejo-Marín and Lundgren (2025) examine PPT in *Solanum rostratum*. Their work is among the first to test PPT and, moreover, to do so in a buzz-pollinated plant for which anther dehiscence is controlled mechanically. Single visit experiments have shown that not all pollen from a flower is released simultaneously (Harder, 1990; Thostesen & Olesen, 1996; Young & Stanton, 1990). While this foundational research demonstrates that dispensing mechanisms exist, it does not explore how pollen dispensation changes with pollinator visitation rate or effort—the dispensing schedule. Thus, a key prediction of PPT has not yet been empirically demonstrated. Yet characterizing dispensing schedules is difficult, because it involves tracking how much pollen remains in the anthers and the time a pollinator spends foraging on a flower. Vallejo-Marín and Lundgren (2025) ultimately find a creative solution by characterizing the relationship between the amount of pollen dispensed by a flower and the amount of time a pollinator spends foraging.

The export of pollen by flowers is a major contributor to plant fitness (Johnson & Harder, 2023; Morales & Traveset, 2008). All else being equal, more pollen exported from anthers is expected to result in more pollen arriving at stigmas and will thus enhance male fitness. Accordingly, we should expect selection for floral traits that maximize pollen export (Harder & Barclay, 1994). However, the relationship between pollen export and pollination is not necessarily straightforward for plant species pollinated by animals. As animals collect more pollen from a flower, proportionally more pollen may be lost before being transferred to stigmas, due to pollinator grooming behaviour (Harder, 1990; Minnaar et al., 2019) or lack of pollinator constancy (Bruninga-Socolar et al., 2022). Additionally, as the amount of pollen deposited increases, more may be dislodged from an already-full stigmatic surface (Muchhala & Thomson, 2012). Furthermore, pollen is a key food for many pollinators such as bees, beetles and flies, which causes conflict between the interests of plants and pollinators and can further exacerbate pollen loss before pollination (Minnaar et al., 2019). It is thus reasonable to expect that there is strong pollinator-driven selection on flowering plants to optimize how much pollen is exported per pollinator visit ('pollen presentation theory'; Harder & Thomson, 1989; Thomson et al., 2000). The theory predicts that when pollinators are abundant, pollen release should be gradual, thus restricting pollen collection by individual visitors (Harder & Thomson, 1989). Pollen presentation theory can thus shed light on the evolution and adaptive value of diverse floral traits involved in the packaging and dispensing of pollen, such as anther morphology, dehiscence type, heteranthery, the timing of floral anthesis and pollen morphology (Dellinger et al., 2019; Johnson & Harder, 2023).

To characterize how pollen dispensation changes with pollinator foraging effort, Vallejo-Marín and Lundgren (2025) conducted experiments in a laboratory test arena, with commercially reared bumble bees (*B. terrestris*) foraging for pollen via buzzing (De Luca & Vallejo-Marín, 2013) the poricidal anthers of *Solanum rostratum* flowers. The authors found that poricidal anthers gradually released pollen over time, suggesting that there is a dispensing mechanism and providing strong experimental support for PPT. A major challenge, even within controlled experimental conditions, is in ascertaining the initial quantity of pollen within the flower, which, as the authors show, can vary greatly among flowers. Future work involving quantifying pollen collected by the bee and lost to the environment could thus be highly informative to determining pollen fate and thus costs involved in PPT. Critically, this study directly links mechanism (duration of buzzing) to functional consequence (pollen removal). This work thus more precisely quantifies dispensing curves, which are what affects plant fitness through the male pathway. Vallejo-Marín and Lundgren (2025) also demonstrated that foraging behaviour changes with pollen availability, with bees producing shorter buzzes when there was less pollen available after multiple visits to the flower. Thus, the authors supply evidence that dispensing mechanisms modify the effectiveness and energetics of pollen collection by foraging pollinators, as pollen is depleted. This result is exciting because it suggests the shape of pollen dispensation curves can be described by predictions of optimal foraging theory—which proposes that pollinators are sensitive to the costs and benefits of foraging and modify their behaviour to maximize their benefit (Mayberry et al., 2024; Waddington & Holden, 1979).

Buzz-pollinated systems such as this one are excellent model systems in which to test predictions of PPT, because dimensions of the trait of interest involved in pollen extraction can be directly quantified, enabling precise linking of mechanism and function. Buzz-pollinated systems are taxonomically diverse and geographically widespread (Russell et al., 2024; Russell et al., 2026) and amenable to testing under controlled situations, facilitating experimental validation. This study also provides a strong foundation for exploring how environmental conditions and flower traits beyond anthers may influence PPT. For instance, flowers that alter nectar production in response to pollinator visitation (Maldonado et al., 2023) might potentially tune pollen dispensation curves in relation to the effectiveness of their pollinators. Furthermore, pollen dispensation curves may be influenced by environmental temperature, which could result in more rapid dehiscence or drying of the tapetum (resulting in easier release of pollen from the anthers; Corbet et al., 1988). In sum, the work of Vallejo-Marín and Lundgren (2025) sets the stage for exciting future research directions regarding the evolution of floral traits involved in pollen dispensation and for empirical and theoretical research integrating predictions made under optimal foraging theory and pollen presentation theory, which altogether should enhance our understanding of how plant–pollinator mutualisms are maintained.

AUTHOR CONTRIBUTIONS

Kaitlyn Q. Pankratz and Avery L. Russell wrote the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

No data were used in this manuscript.

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REFERENCES

Bruninga-Socolar, B., Winfree, R., & Crone, E. E. (2022). The contribution of plant spatial arrangement to bumble bee flower constancy. *Oecologia*, *198*(2), 471–481. https://doi.org/10.1007/s00442-022-05114-x

Corbet, S. A., Chapman, H., & Saville, N. (1988). Vibratory pollen collection and flower form: Bumble-bees on Actinidia, Symphytum, Borago and Polygonatum. *Functional Ecology*, *2*(2), 147. https://doi.org/10.2307/2389689

De Luca, P. A., & Vallejo-Marín, M. (2013). What's the "buzz" about? The ecology and evolutionary significance of buzz-pollination. *Current Opinion in Plant Biology*, *16*, 429–435. https://doi.org/10.1016/j.pbi.2013.05.002

Dellinger, A. S., Pöllabauer, L., Loreti, M., Czurda, J., & Schönenberger, J. (2019). Testing functional hypotheses on poricidal anther dehiscence and heteranthery in buzz-pollinated flowers. *Acta ZooBot Austria*, *156*, 197–214.

Harder, L. D. (1990). Pollen removal by bumble bees and its implications for pollen dispersal. *Ecology*, *71*(3), 1110–1125. https://doi.org/10.2307/1937379

Harder, L. D., & Barclay, R. M. R. (1994). The functional significance of Poricidal anthers and buzz pollination: Controlled pollen removal from Dodecatheon. *Functional Ecology*, *8*(4), 509. https://doi.org/10.2307/2390076

Harder, L. D., & Thomson, J. D. (1989). Evolutionary options for maximizing pollen dispersal of animal-pollinated plants. *The American Naturalist*, *133*(3), 323–344. https://doi.org/10.1086/284922

Johnson, S. D., & Harder, L. D. (2023). The economy of pollen dispersal in flowering plants. *Proceedings of the Royal Society B: Biological Sciences*, *290*(2008), 20231148. https://doi.org/10.1098/rspb.2023.1148

Maldonado, M., Fornoni, J., Boege, K., Pérez Ishiwara, R., Santos-Gally, R., & Domínguez, C. A. (2023). The role of within-plant variation in nectar production: An experimental approach. *Annals of Botany*, *132*(1), 95–106. https://doi.org/10.1093/aob/mcad082

Mayberry, M. M., Naumer, K. C., Novinger, A. N., McCart, D. M., Wilkins, R. V., Muse, H., Ashman, T.-L., & Russell, A. L. (2024). Learning to handle flowers increases pollen collection for bees but does not affect pollination success for plants. *Behavioral Ecology*, *35*(6), arae083. https://doi.org/10.1093/beheco/arae083

Minnaar, C., Anderson, B., De Jager, M. L., & Karron, J. D. (2019). Plant–pollinator interactions along the pathway to paternity. *Annals of Botany*, *123*(2), 225–245. https://doi.org/10.1093/aob/mcy167

Morales, C. L., & Traveset, A. (2008). Interspecific pollen transfer: Magnitude, prevalence and consequences for plant fitness. *Critical Reviews in Plant Sciences*, *27*(4), 221–238. https://doi.org/10.1080/07352680802205631

Muchhala, N., & Thomson, J. D. (2012). Interspecific competition in pollination systems: Costs to male fitness via pollen misplacement. *Functional Ecology*, *26*(2), 476–482. https://doi.org/10.1111/j.1365-2435.2011.01950.x

Russell, A. L., Buchmann, S. L., Ascher, J. S., Wang, Z., Kriebel, R., Jolles, D. D., Orr, M. C., & Hughes, A. C. (2024). Global patterns and drivers of buzzing bees and poricidal plants. *Current Biology*, *34*(14), 3055–3063.e5. https://doi.org/10.1016/j.cub.2024.05.065

Russell, A. L., Zenil-Ferguson, R., Buchmann, S. L., Jolles, D. D., Kriebel, R., & Vallejo-Marín, M. (2026). Widespread evolution of poricidal flowers: A striking example of morphological convergence across flowering plants. *Evolution*, *80*(1), 240–253. https://doi.org/10.1093/evolut/qpaf220

Thomson, J. D., Wilson, P., Valenzuela, M., & Malzone, M. (2000). Pollen presentation and pollination syndromes, with special reference to *Penstemon*. *Plant Species Biology*, *15*(1), 11–29. https://doi.org/10.1046/j.1442-1984.2000.00026.x

Thostesen, A. M., & Olesen, J. M. (1996). Pollen removal and deposition by specialist and generalist bumblebees in *Aconitum septentrionale*. *Oikos*, *77*, 77–84.

Vallejo-Marín, M., & Lundgren, A. (2025). Gradual pollen release in a buzz-pollinated plant: Investigating pollen presentation theory under bee visitation. *Functional Ecology*, *1365-2435*, 70189. https://doi.org/10.1111/1365-2435.70189

Waddington, K. D., & Holden, L. R. (1979). Optimal foraging: On flower selection by bees. *The American Naturalist*, *114*(2), 179–196. https://doi.org/10.1086/283467

Young, H. J., & Stanton, M. L. (1990). Influences of floral variation on pollen removal and seed production in wild radish. *Ecology*, *71*(2), 536–547. https://doi.org/10.2307/1940307

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