Geomagnetic and visual cues guide orientation in the nocturnal fall armyworm (*Spodoptera frugiperda*), the world's most invasive insect

Yibo Ma[1,4], Guijun Wan[1], Yi Ji[1], Hui Chen[1,2], Boya Gao[1], Eric J. Warrant[2], Jason W. Chapman[1,3], Gao Hu[1]

1 State Key Laboratory of Agricultural and Forestry Biosecurity, College of Plant Protection, Nanjing Agricultural University, Nanjing 210095, China
2 Lund Vision Group, Department of Biology, Lund University, Sölvegatan 35, 22362 Lund, Sweden.
3 Centre for Ecology and Conservation, University of Exeter, Penryn, Cornwall TR10 9FE, United Kingdom.
4 AGNeurosensorik/Animal Navigation, Institute of Biology and Environmental Sciences, Faculty V, Carl von Ossietzky Universit at Oldenburg, 26129 Oldenburg, Germany (current affiliation)

Numerous species of larger nocturnal moths, particularly in the family Noctuidae, undertake long-distance multigenerational migrations in the Northern Hemisphere. However, the navigational mechanisms employed by nocturnal insect migrants remain to be elucidated in most species. We recently found that fall armyworms (*Spodoptera frugiperda*), a highly invasive species that has colonized nearly all potentially habitable regions of the globe over the past decade, exhibit seasonally appropriate migratory headings when flown outdoors in virtual flight simulators. Specifically, populations from the year-round range in Southwest China (Yunnan) head northward in the spring and southward in the fall, with this seasonal reversal controlled by photoperiod. However, the mechanism that fall armyworms use to select seasonally appropriate headings remains unknown. The geomagnetic field (GMF) is a ubiquitous source of compass information and thus might be expected to be the primary compass cue used by night-flying migratory moths. We developed an indoor experimental system to investigate the integration of geomagnetic and visual cues in the seasonal orientation of the fall armyworm. Our results demonstrate that fall armyworms require both geomagnetic and visual cues for accurate migratory orientation, with visual cues being indispensable for magnetic orientation. When visual and geomagnetic cues are placed in conflict, moths become disoriented, although not immediately, indicating that sensory recognition of the conflict requires time to process. We also show that the absence of visual cues leads to a significant loss of flight stability, which likely explains the disruption in orientation. These findings are consistent with previous work on the Australian Bogong moth, extending the evidence for an essential and conserved role of visual cues in stabilizing magnetic orientation across nocturnal migratory moths.

This work was supported by the National Key Research and Development Program of China (2021YFD1400700) and the Fundamental Research Funds for the Central Universities (KJJQ2025013) to G.H., and the National Natural Science Foundation of China to (32202289) B.Y.G.