

Online Content Methods, along with any additional Extended Data display items and Source Data, are available in the online version of the paper; references unique to these sections appear only in the online paper.

Received 26 September 2016; accepted 8 November 2017.

- Kim, G. & Westwood, J. H. Macromolecule exchange in *Cuscuta*-host plant interactions. *Curr. Opin. Plant Biol.* **26**, 20–25 (2015).
- Fei, Q., Xia, R. & Meyers, B. C. Phased, secondary, small interfering RNAs in posttranscriptional regulatory networks. *Plant Cell* **25**, 2400–2415 (2013).
- Baulcombe, D. C. VIGS, HIGS and FIGS: small RNA silencing in the interactions of viruses or filamentous organisms with their plant hosts. *Curr. Opin. Plant Biol.* **26**, 141–146 (2015).
- Weiberg, A., Bellinger, M. & Jin, H. Conversations between kingdoms: small RNAs. *Curr. Opin. Biotechnol.* **32**, 207–215 (2015).
- Nowara, D. *et al.* HIGS: host-induced gene silencing in the obligate biotrophic fungal pathogen *Blumeria graminis*. *Plant Cell* **22**, 3130–3141 (2010).
- Huang, G., Allen, R., Davis, E. L., Baum, T. J. & Hussey, R. S. Engineering broad root-knot resistance in transgenic plants by RNAi silencing of a conserved and essential root-knot nematode parasitism gene. *Proc. Natl Acad. Sci. USA* **103**, 14302–14306 (2006).
- Baum, J. A. *et al.* Control of coleopteran insect pests through RNA interference. *Nat. Biotechnol.* **25**, 1322–1326 (2007).
- Alakonya, A. *et al.* Interspecific RNA interference of SHOOT MERISTEMLESS-like disrupts *Cuscuta pentagona* plant parasitism. *Plant Cell* **24**, 3153–3166 (2012).
- Weiberg, A. *et al.* Fungal small RNAs suppress plant immunity by hijacking host RNA interference pathways. *Science* **342**, 118–123 (2013).
- Wang, M. *et al.* Bidirectional cross-kingdom RNAi and fungal uptake of external RNAs confer plant protection. *Nat. Plants* **2**, 16151 (2016).
- Zhang, T. *et al.* Cotton plants export microRNAs to inhibit virulence gene expression in a fungal pathogen. *Nat. Plants* **2**, 16153 (2016).
- Kim, G., LeBlanc, M. L., Wafula, E. K., dePamphilis, C. W. & Westwood, J. H. Plant science. Genomic-scale exchange of mRNA between a parasitic plant and its hosts. *Science* **345**, 808–811 (2014).
- Chen, H.-M. *et al.* 22-nucleotide RNAs trigger secondary siRNA biogenesis in plants. *Proc. Natl Acad. Sci. USA* **107**, 15269–15274 (2010).
- Cuperus, J. T. *et al.* Unique functionality of 22-nt miRNAs in triggering RDR6-dependent siRNA biogenesis from target transcripts in *Arabidopsis*. *Nat. Struct. Mol. Biol.* **17**, 997–1003 (2010).
- Dharmasiri, N. *et al.* Plant development is regulated by a family of auxin receptor F box proteins. *Dev. Cell* **9**, 109–119 (2005).
- Veronese, P. *et al.* The membrane-anchored BOTRYTIS-INDUCED KINASE1 plays distinct roles in *Arabidopsis* resistance to necrotrophic and biotrophic pathogens. *Plant Cell* **18**, 257–273 (2006).
- Lin, W. *et al.* Inverse modulation of plant immune and brassinosteroid signaling pathways by the receptor-like cytoplasmic kinase BIK1. *Proc. Natl Acad. Sci. USA* **110**, 12114–12119 (2013).
- Froelich, D. R. *et al.* Phloem ultrastructure and pressure flow: Sieve-element-occlusion-related agglomerations do not affect translocation. *Plant Cell* **23**, 4428–4445 (2011).
- Jekat, S. B. *et al.* P-proteins in *Arabidopsis* are heteromeric structures involved in rapid sieve tube sealing. *Front. Plant Sci.* **4**, 225 (2013).
- Mylona, P., Linstead, P., Martienssen, R. & Dolan, L. SCHIZORIZA controls an asymmetric cell division and restricts epidermal identity in the *Arabidopsis* root. *Development* **129**, 4327–4334 (2002).
- Pernas, M., Ryan, E. & Dolan, L. SCHIZORIZA controls tissue system complexity in plants. *Curr. Biol.* **20**, 818–823 (2010).
- ten Hove, C. A. *et al.* SCHIZORIZA encodes a nuclear factor regulating asymmetry of stem cell divisions in the *Arabidopsis* root. *Curr. Biol.* **20**, 452–457 (2010).
- Si-Ammour, A. *et al.* miR393 and secondary siRNAs regulate expression of the TIR1/AFB2 auxin receptor clade and auxin-related development of *Arabidopsis* leaves. *Plant Physiol.* **157**, 683–691 (2011).
- Allen, E., Xie, Z., Gustafson, A. M. & Carrington, J. C. MicroRNA-directed phasing during trans-acting siRNA biogenesis in plants. *Cell* **121**, 207–221 (2005).
- Axtell, M. J., Jan, C., Rajagopalan, R. & Bartel, D. P. A two-hit trigger for siRNA biogenesis in plants. *Cell* **127**, 565–577 (2006).
- Dawson, J. H., Musselman, L. J., Wolswinkel, P. & Dörr, I. Biology and control of *Cuscuta*. *Rev. Weed Sci.* **6**, 265–317 (1994).
- Robert-Seilanianz, A. *et al.* The microRNA miR393 re-directs secondary metabolite biosynthesis away from camalexin and towards glucosinolates. *Plant J.* **67**, 218–231 (2011).
- Lu, D. *et al.* A receptor-like cytoplasmic kinase, BIK1, associates with a flagellin receptor complex to initiate plant innate immunity. *Proc. Natl Acad. Sci. USA* **107**, 496–501 (2010).

Supplementary Information is available in the online version of the paper.

Acknowledgements This research was supported in part by awards from the US National Science Foundation (1238057 to J.H.W. and C.W.D.; 1339207 to M.J.A.) and the US National Institute of Food and Agriculture (135997 to J.H.W.).

Author Contributions S.S. and M.J.A. did the bioinformatics analysis. S.S., M.J.A. and N.R.J. prepared figures and tables. G.K., J.H.W., N.R.J., S.S., T.P. and M.J.A. cultivated and harvested plant specimens. E.W., G.K., C.W.D. and J.H.W. performed genome and transcriptome sequencing and assemblies. F.W., S.S. and N.R.J. did RNA blotting. S.S. and M.J.A. performed 5'-RLM-RACE and qRT-PCR. C.C. and T.P. constructed small-RNA-seq libraries. N.R.J. and V.B.-G. performed growth assays. M.J.A. and J.H.W. conceived the project. M.J.A. wrote and revised the manuscript.

Author Information Reprints and permissions information is available at www.nature.com/reprints. The authors declare no competing financial interests. Readers are welcome to comment on the online version of the paper. Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations. Correspondence and requests for materials should be addressed to M.J.A. (mja18@psu.edu).

Reviewer Information Nature thanks M. Albert, F. Tang and the other anonymous reviewer(s) for their contribution to the peer review of this work.