

Yasuhiro Sato, Ph.D.

Last update on 1 April 2024

Curriculum Vitae

First Name: Yasuhiro

Family Name: Sato

Birthday: 7 April 1988

Nationality: Japan

Gender: Male; Pronoun: he/him

Current affiliation: Faculty of Environmental Earth Science, Hokkaido University

Institutional address: N10W5 Kita-ku, Sapporo, Hokkaido 060-0810, Japan

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ORCID: 0000-0002-6466-723X

ResearcherID: N-7939-2013

Google scholar citations: <https://scholar.google.co.jp/citations?user=HbrGYr8AAAAAJ&hl=en>

Personal website: <https://yassato.github.io/>

Education

- 23 March 2016. PhD in Science (Biosciences), Center for Ecological Research, Graduate School of Science, Kyoto University, Japan (supervisor: Prof. Dr. Hiroshi Kudoh) [PhD defended on 28 January 2016]
- 25 March 2013. MSc in Science (Biosciences), Center for Ecological Research, Graduate School of Science, Kyoto University, Japan (supervisor: Prof. Dr. Hiroshi Kudoh)
- 24 March 2011. BSc in Agriculture (Bioresource Sciences), Laboratory of Insect Ecology, Faculty of Agriculture, Kyoto University, Japan (supervisor: Assistant Prof. Dr. Takayoshi Nishida)

Employment history

- April 2024–Present. Tenure-track Assistant Professor in the Group of Ecological Genetics, Section of Environmental Biology, Faculty of Environmental Earth Science, Hokkaido University, Japan
- April 2021–March 2024. Senior research and teaching assistant (Oberassistent) at the Department of Evolutionary Biology and Environmental Studies, University of Zurich, Switzerland (PI: Prof. Dr. Kentaro K. Shimizu)
- October 2017–March 2021. Junior Group Leader of Precursory Research for the Embryonic Science and Technology (PRESTO) program of the Japan Science and Technology Agency (JST) at Ryukoku University, Japan (host: Associate Prof. Dr. Atsushi J. Nagano)
- April 2016–September 2017. Independent Postdoctoral Fellow of the Japan Society for the Promotion of Science (JSPS) at Ryukoku University, Japan (host: Senior Lecturer Dr. Atsushi J. Nagano)
- April 2015–March 2016. Research Fellow of the Japan Society for the Promotion of Science (JSPS) for PhD students at Kyoto University, Japan (host: Prof. Dr. Hiroshi Kudoh)
- June 2013–March 2014. Research Assistant at the Center for Ecological Research, Kyoto University, Japan

Visiting and guest position

- October 2017–March 2024. Guest researcher of Research Institute for Food and Agriculture, Ryukoku University, Japan
- August 2017–December 2024. Affiliated member of University Research Priority Program for Global Change and Biodiversity (URPP GCB), University of Zurich, Switzerland <https://www.gcb.uzh.ch/en/aboutus/people.html>
- June 2016–September 2016. Visiting postdoctoral researcher, Evolutionary and Ecological Genomics Group (Shimizu Lab), University of Zurich, Switzerland
- April 2016–March 2020. Affiliated scientist of the Center for Ecological Research, Kyoto University, Japan

Approved funding and fellowships

1. November 2023–October 2024. ‘Using open data to reveal the genomic basis that underpins positive plant-plant interactions’, Spark rapid funding, Grant ID:CRSK-3_221418, Swiss National Science Foundation (SNSF), Switzerland (a single lead applicant; total budget 100,000 CHF = 103,616 EUR upon the currency rate of the starting date)
2. April 2023–March 2027. ‘Joint analysis of plant-plant interactions using field GWAS and RNA-Seq’, Grant-in-aid for Early-career Scientists, Grant ID:JP23K14270, Japan Society for the Promotion of Science (JSPS), Japan (a single lead applicant; direct cost 3,600,000 JPY + indirect cost 1,080,000 JPY = 32,116 EUR upon the currency rate of the starting date)
3. April 2020–March 2023. ‘Theoretical consideration of plant biodiversity effects driven by inter-genotypic interactions’, Grant-in-aid for Early-career Scientists, Grant ID:JP20K15880, Japan Society for the Promotion of Science (JSPS), Japan (a single lead applicant; direct cost 3,200,000 JPY + indirect cost 960,000 JPY = 35,049 EUR upon the currency rate of the starting date)
4. October 2017–March 2021. ‘Large-scale omics approach towards a pest control by mixed planting’, PRESTO project, Grant ID:JPMJPR17Q4, Japan Science and Technology Agency (JST) (a single lead applicant; direct cost 40,000,000 JPY + indirect cost 12,000,000 JPY = 391,418 EUR upon the currency rate of the starting date + group leader’s own salary) https://www.jst.go.jp/kisoken/presto/en/project/1112074/1112074_26.html
5. April 2016–September 2017. ‘Genome-wide association study and prediction of pest communities on natural accessions of the model plant species’, Research Fellowships for Postdoctoral Researcher, Grant ID:JP16J30005, Japan Society for the Promotion of Science (JSPS) (a single lead applicant; direct cost 2,700,000 JPY + indirect cost 810,000 JPY = 27,449 EUR upon the currency rate of the starting date + fellow’s own salary)
6. April 2015–March 2016. ‘A test of the mechanism maintaining plant defense polymorphism in a wild *Arabidopsis*’, Research Fellowships for PhD Students, Grant ID:JP15J00400, Japan Society for the Promotion of Science (JSPS) (a single lead applicant; direct cost 1,200,000 JPY + indirect cost 360,000 JPY = 12,101 EUR upon the currency rate of the starting date + fellow’s own salary)

Mentoring

1. Lukas Rohr (Master student at the University of Zurich; Role: supervisor)
2. Chongmeng Xu (PhD student at the University of Zurich, PhD defended on 17 April 2023; Role: co-supervisor as ‘Leitung der Dissertation’)
3. Elina Jansone (Undergraduate internship at the University of Zurich; Role: supervisor)
4. Kazuya Takeda (Research assistant at Ryukoku University; Role: daily supervisor as an employer)
5. Silvija Milosavljevic (Undergraduate at the University of Zurich; Role: co-supervisor)
6. Dimitri Anderfuhren (Undergraduate at the University of Zurich; Role co-supervisor)

Teaching experience

1. September 2021–March 2024. BIO373: Next Generation Sequencing for Evolutionary Functional Genomics, University of Zurich, Switzerland (Role: course management, co-instructor, and examiner;

- No. of participants = 15-20)
2. May 2022. BIO334: Practical Bioinformatics, University of Zurich, Switzerland (Role: temporal co-instructor during a sabbatical absence of PI; No. of participants = ca. 25)
 3. April 2019–May 2019. External Lecturer of Basic Genetics, Faculty of Agriculture, Ryukoku University, Japan (Role: 90-min. lectures × five times for a liberal art course in Japanese; No. of participants = ca. 50)
 4. July 2018–August 2018. International Biology Undergraduate Summer School (BUSS) 2018, University of Zurich, Switzerland (Role: supervision of undergraduate student’s fieldwork and presentation; No. of participants = 1)
 5. July 2017–August 2017. BIO378: Research Practical in Evolutionary Biology and Systematics, University of Zurich, Switzerland (Role: supervision of undergraduate student’s fieldwork, data analysis, and report writing; No. of participants = 1)
 6. September 2013–January 2015. External Teaching Assistant of Programming Practical, Faculty of Science and Technology, Ryukoku University, Japan (Role: teaching assistant of R language; No. of participants = 5-10)

Panels, boards, and reviewing activities

1. January 2019–Present. Editorial board member of the Society for the Study of Species Biology, Japan
2. April 2020–December 2021. Reviewing editor of *Journal of Evolutionary Biology*
3. December 2022. Organizing committee member of the 52nd symposium of the Study of Species Biology, Japan, <https://sites.google.com/view/sssb2020shiga>
4. November 2016. Organizing committee member of 5th Japan-Taiwan Ecology Workshop, Kyoto, Japan, <https://sites.google.com/site/jtecolw5th/>
5. Total 54 peer-review activities verified by the Web of Science, <https://www.webofscience.com/wos/author/rid/N-7939-2013>.

Active memberships in scientific societies

1. American Society of Naturalists (Permanent membership since October 2017)
2. Ecological Society of Japan (October 2011–Present)
3. Society for the Study of Species Biology (December 2010–Present)
4. European Society for Evolutionary Biology (April 2020–December 2024)
5. The Japanese Society of Plant Physiologists (January 2018–Present)

Organization of conferences

1. December 2019. **Sato Y**, Muranaka T. Cutting-edge technology of plant omics and phenotyping (in Japanese). The 51st Symposium of the Society for the Study of Species Biology, Miyazaki, Japan
2. March 2015. Sakata Y and **Sato Y**. Overview of evolutionary ecology of plant-herbivore interactions (in Japanese). Workshop 12: The 62nd Annual Meeting of the Ecological Society of Japan, Kagoshima, Japan

Prizes and awards

1. 2 February 2018. Inoue Research Award for Early-career Scientists, Inoue Foundation for Science, Japan
2. 3 December 2016. Kataoka Award for Early-career Researchers, The Society for the Study of Species Biology, Japan
3. 2 March 2016. Ikushi Prize for Outstanding PhD Students, Japan Society for the Promotion of Science (JSPS), Japan https://www.jsps.go.jp/english/e-ikushi-prize/awards_fy2015_01.html
4. April 2011–March 2015. Refund Exemption for Excellent Students, JASSO Scholarship, Japan

Career breaks

None

Personal skills

License

1. Swiss driver license
2. Japanese diver license

Computer languages

1. R (package developer level)
2. Python (basic level)
3. Bash (basic level)

Natural languages

1. English (proficient)
2. Japanese (native speaker)

References

1. Prof. Dr. Kentaro K. Shimizu

Position: Full Professor

Relationship: Postdoc advisor

Affiliation: Department of Evolutionary Biology and Environmental Studies (Institut für Evolutionsbiologie und Umweltwissenschaften), University of Zurich, Switzerland

Address: Winterthurerstrasse 190, 8057 Zurich, Switzerland

Phone: +41 44 635 6740

E-mail: kentaro.shimizu@uzh.ch

Website: https://www.ieu.uzh.ch/en/staff/member/shimizu_kentaro.html

Keywords: Evolutionary Genomics, Plant Mating System, Polyploidy

2. Prof. Dr. Atsushi J. Nagano

Position: Full professor

Relationship: Postdoc advisor

Affiliation: Faculty of Agriculture, Ryukoku University, Japan (adjunct with Project Professor at the Institute of Advanced Biosciences of Keio University, Japan)

Address: Yokotani 1-5, Seta Oe-cho, Otsu, Shiga 520-2194, Japan

Phone: +81 77 599 5656

E-mail: anagano@agr.ryukoku.ac.jp

Website: <https://researchmap.jp/anagano?lang=en>

Keywords: Bioinformatics, Transcriptomics, Plant Physiology

3. Prof. Dr. Hiroshi Kudoh

Position: Full professor

Relationship: PhD supervisor

Affiliation: Center for Ecological Research, Kyoto University, Japan

Address: 509-3, 2-chome, Hirano, Otsu, Shiga 520-2113, Japan

Phone: +81 77 549 8255

E-mail: kudoh@ecology.kyoto-u.ac.jp

Website: <https://www.ecology.kyoto-u.ac.jp/~kudoh/en/index.html>

Keywords: Molecular Ecology, Plant Ecology, Flowering Phenology

Achievements

[†]Equal contribution; *Correspondence

Peer-reviewed articles

1. Stockenhuber R, Akiyama R, Tissot N, Milosavljevic S, Yamazaki M, Wyler M, Arongaus AB, Podolec R, **Sato Y**, Widmer A, Ulm R*, Shimizu KK*. (2024) UV RESISTANCE LOCUS 8-mediated UV-B response is required alongside CRYPTOCHROME 1 for plant survival in sunlight under field conditions. *Plant and Cell Physiology* 65:35-48. <https://doi.org/10.1093/pcp/pcad113>
2. The Herbivory Variability Network. (2023) Plant size, latitude, and phylogeny explain variability in herbivory. *Science* 382:679-683. <https://doi.org/10.1126/science.adh8830> [a consortium paper including Y. Sato as one of 191 co-authors]
3. Xu C†, **Sato Y†***, Yamazaki M, Brassler M, Barbour MA, Bascompte J, Shimizu KK*. (2023) Genome-wide association study of aphid abundance highlights a locus affecting plant growth and flowering in *Arabidopsis thaliana*. *Royal Society Open Science* 10:230399. <https://doi.org/10.1098/rsos.230399>
4. **Sato Y***, Takahashi Y, Xu C, Shimizu KK*. (2023) Detecting frequency-dependent selection through the effects of genotype similarity on fitness components. *Evolution* 77:1145–1157. <https://doi.org/10.1093/evolut/qpaa028>
5. Shimizu-Inatsugi R*, Morishima A, Mourato B, Shimizu KK, **Sato Y**. (2023) Phenotypic variation of a new synthetic allotetraploid *Arabidopsis kamchatica* enhanced in natural environment. *Frontiers in Plant Science* 13:1058522 <https://doi.org/10.3389/fpls.2022.1058522>
6. Takimoto H†*, **Sato Y†**, Nagano AJ, Shimizu KK, Kanagawa A. (2021) Using a two-stage convolutional neural network to rapidly identify tiny herbivorous beetles in the field. *Ecological Informatics* 66:101466 <https://doi.org/10.1016/j.ecoinf.2021.101466>
7. **Sato Y**, Yamamoto E, Shimizu KK*, Nagano AJ*. (2021) Neighbor GWAS: incorporating neighbor genotypic identity into genome-wide association studies of field herbivory. *Heredity* 126(4):597–614. <https://doi.org/10.1038/s41437-020-00401-w>
8. **Sato Y†***, Takeda K†, Nagano AJ*. (2021) Neighbor QTL: an interval mapping method for quantitative trait loci underlying plant neighborhood effects. *G3; Genes/Genomes/Genetics* 11(2):jkab017. <https://doi.org/10.1093/g3journal/jkab017>
9. Shimizu-Inatsugi R*, Milosavljevic S, Shimizu KK, Schaepman-Strub G, Tanoi K, **Sato Y**. (2021) Metal accumulation and its effect on leaf herbivory in an allopolyploid species *Arabidopsis kamchatica* inherited from a diploid hyperaccumulator *A. halleri*. *Plant Species Biology* 36(2):208–217. <https://doi.org/10.1111/1442-1984.12304>
10. **Sato Y**, Tezuka A, Kashima M, Deguchi A, Shimizu-Inatsugi R, Yamazaki M, Shimizu KK*, Nagano AJ*. (2019) Transcriptional variation in glucosinolate biosynthetic genes and inducible responses to aphid herbivory on field-grown *Arabidopsis thaliana*. *Frontiers in Genetics* 10:787. <https://doi.org/10.3389/fgene.2019.00787>
11. **Sato Y**, Shimizu-Inatsugi R, Yamazaki M, Shimizu KK*, Nagano AJ*. (2019) Plant trichomes and a single gene *GLABRA1* contribute to insect community composition on field-grown *Arabidopsis thaliana*. *BMC Plant Biology* 19:163. <https://doi.org/10.1186/s12870-019-1705-2>
12. Nakadai R†*, Hashimoto K†, Iwasaki T, **Sato Y**. (2018) Geographical co-occurrence of butterfly species: the importance of niche filtering by host plant species. *Oecologia* 186(4):995–1005. <https://doi.org/10.1007/s00442-018-4062-1>
13. **Sato Y†***, Ito K†, Kudoh H. (2017) Optimal foraging by herbivores maintains polymorphism in defence in a natural plant population. *Functional Ecology* 31(12):2233-2243. <https://doi.org/10.1111/1365-2435.12937>
14. **Sato Y***, Kudoh H. (2017) Herbivore-mediated interaction promotes the maintenance of trichome dimorphism through negative frequency-dependent selection. *The American Naturalist* 190(3):E67-E77. <https://doi.org/10.1086/692603>
15. **Sato Y***, Kudoh H. (2017) Fine-scale frequency differentiation along a herbivory gradient in the trichome dimorphism of a wild *Arabidopsis*. *Ecology and Evolution* 7(7):2133-2141. <https://doi.org/10.1002/ece3.2830>
16. **Sato Y***, Kudoh H. (2016) Presence of substitute diets alters plant resistance to specialist and generalist herbivores: a meta-analysis. *Ecosphere* 7(11):e01446 <https://doi.org/10.1002/ecs2.1446>
17. **Sato Y***, Kudoh H. (2016) Associational effects against a leaf beetle mediate a minority advantage in defense and growth between hairy and glabrous plants. *Evolutionary Ecology* 30(1):137-154.

- <https://doi.org/10.1007/s10682-015-9809-0>
18. **Sato Y***, Sato S. (2015) Spring temperature predicts the long-term molting phenology of two cicadas, *Cryptotympana facialis* and *Graptopsaltria nigrofuscata* (Hemiptera: Cicadidae). *Annals of the Entomological Society of America* 108(4):494-500. <https://doi.org/10.1093/aesa/sav036>
 19. **Sato Y***, Kudoh H. (2015) Tests of associational defence provided by hairy plants for glabrous plants of *Arabidopsis halleri* subsp. *gemmifera* against insect herbivores. *Ecological Entomology* 40(3):269-279. <https://doi.org/10.1111/een.12179>
 20. **Sato Y**, Kudoh H*. (2014) Fine-scale genetic differentiation of a temperate herb: relevance of local environments and demographic change. *AoB PLANTS* 6:plu070. <https://doi.org/10.1093/aobpla/plu070>
 21. **Sato Y***, Kawagoe T, Sawada Y, Hirai MY, Kudoh H. (2014) Frequency-dependent herbivory by a leaf beetle, *Phaedon brassicae*, on hairy and glabrous plants of *Arabidopsis halleri* subsp. *gemmifera*. *Evolutionary Ecology* 28(3):545-559. <https://doi.org/10.1007/s10682-013-9686-3>
 22. **Sato Y***, Kudoh H. (2013) Relative strength of phenotypic selection on the height and number of flowering-stalks in the rosette annual *Cardamine hirsuta* (Brassicaceae). *Journal of Ecology and Environment* 36(3):151-158. <https://doi.org/10.5141/ecoenv.2013.151>
 23. **Sato Y***, Takakura KI, Nishida S, Nishida T. (2013) Dominant occurrence of cleistogamous flowers of *Lamium amplexicaule* in relation to the nearby presence of an alien congener *L. purpureum*. *ISRN Ecology* Article ID:476862. <http://dx.doi.org/10.1155/2013/476862>

Peer-reviewed monographs

1. **Sato Y***. (2018) Associational effects and the maintenance of polymorphism in plant defense against herbivores: review and evidence. *Plant Species Biology* 33(2):91-108. <https://doi.org/10.1111/1442-1984.12201>
2. Sakata Y*, **Sato Y**. (2017) Evolutionary ecology of plant defense: integrating different spatial scales within and among species (in Japanese). *Japanese Journal of Ecology* 67(3):287-306. https://doi.org/10.18960/seitai.67.3_287

Peer-reviewed conference proceedings

1. Kuzuhara H, Takimoto H, **Sato Y**, Kanagawa A. (2020) Insect pest detection and identification method based on deep learning for realizing a pest control system. *Proceedings of the Society of Instrument and Control Engineers (SICE) 2020 Annual Conference 2020*. pp. 709-714. <https://doi.org/10.23919/SICE48898.2020.9240458>

Contributions to books

1. **Sato Y**. (2024) Chapter 7: The maintenance of trichome dimorphism through associational effects: a case study of *Arabidopsis halleri* and a leaf beetle (in Japanese). In: Ecology of Plant Defense Against Herbivores (Y. Sakata and T. Tsunoda eds), *Species Biology Series*, Bun-ichi Sogo Shuppan, Tokyo, Japan. ISBN:978-4-8299-6211-4.
2. **Sato Y**, Muranaka T. (eds). (2023) Trans-Scale Biology of Plants: Integrating genomics, phenomics, and ecology to unveil biodiversity (in Japanese). *Species Biology Series*, Bun-ichi Sogo Shuppan, Tokyo, Japan. ISBN:978-4-8299-6210-7.

Patents and licenses

None

Computer programs

1. **Sato Y***, Yamamoto E, Shimizu KK, Nagano AJ. (2021) 'rNeighborGWAS'. R package available at the Comprehensive R Archive Network (CRAN), <https://cran.r-project.org/package=rNeighborGWAS>

2. **Sato Y***, Takeda K, Nagano AJ. (2021) ‘rNeighborQTL’. R package available at CRAN, <https://cran.r-project.org/package=rNeighborQTL>

And the other source codes for published research, personal utilities, and teaching materials are available at the GitHub repository, <https://github.com/yassato>

Conference contributions

1. **Sato Y**, Takahashi Y, Xu C, Shimizu KK. Detecting frequency-dependent selection through the effects of genotype similarity on fitness components. *biology²⁴: The largest conference of organismal biology in Switzerland*, ETH Zurich, Switzerland (19 January 2024, poster)
2. **Sato Y**, Shimizu-Inatsugi R, Takeda K, Nagano AJ, Shimizu KK. Genome-wide neighbor effects predict genotype pairs reducing herbivory in mixed planting. *Biodiversity Convention - From Science to Implementation*, Monte Verita, Ascona, Switzerland (27 June 2023, talk)
3. **Sato Y**, Shimizu-Inatsugi R, Takeda K, Nagano AJ, Shimizu KK. Keystone pairs of *Arabidopsis* accessions increase plant resistance to field herbivory. In Concurrent 15: *Arabidopsis* relatives from laboratories to natural fields (organized by Prof. K.K. Shimizu and H. Kudoh). *The 33rd International Conference on Arabidopsis Research (ICAR2023)*, Chiba, Japan (7 June 2023, talk)
4. **Sato Y**, Shimizu-Inatsugi R, Takeda K, Nagano AJ, Shimizu KK. Keystone genotype pairs increase plant resistance to herbivory. *Gordon Research Conference: Plant-Herbivore Interaction 2023*, Ventura, CA, USA (2 March 2023, poster)
5. **Sato Y**, Shimizu-Inatsugi R, Takeda K, Nagano AJ, Shimizu KK. Keystone genotype pairs increase population-level resistance to herbivory. *SwissPLANT 2023 Symposium*, Les Diablerets, Switzerland (23 January 2023, talk)
6. **Sato Y**, Shimizu-Inatsugi R, Nagano AJ, Shimizu KK. Neighbor GWAS: incorporating neighbor genotypic identity in genome-wide association study of field-grown *Arabidopsis thaliana*. ‘From place to space - Tracing the spatial dimension of plant sciences’ by *Plant Science Center Symposium 2022*, P30, ETH Zurich, Switzerland (7 December 2022, poster)
7. **Sato Y**, Takahashi Y, Xu C, Shimizu KK. Detecting frequency-dependent selection using a genetic marker regression of fitness components. In: S24 ‘Progress and Prospects in Adaptation Genomics’. *The 2022 Congress of the European Society for Evolutionary Biology*, Prague, Czech Republic (18 August 2022, reviewed talk)
8. **Sato Y**, Nagano AJ, Shimizu KK. Genomics of within-species mixed planting against insect herbivores. In: MON3-b ‘From the species to the individual: investigating plant diversity on the scale that matters most’ (organized by Drs. P. Villa and M.C. Schuman). *World Biodiversity Forum 2022*, Davos, Switzerland. (29 June 2022, reviewed talk) <https://www.worldbiodiversityforum.org/>
9. Kuzuhara H, Takimoto H, **Sato Y**, Kanagawa A. Insect pest detection and identification method based on deep learning for realizing a pest control system. *The Society of Instrument and Control Engineers (SICE) Annual Conference 2020*. Chiang Mai, Thailand [changed into an online meeting due to COVID-19] (25 September 2020, talk)
10. **Sato Y**. Using personal legacy data to reveal the molting phenology of Japanese cicadas. In: S19 ‘Ongoing Cicada Research in East Asia’ (organized by Prof. J. Yikweon), *The 8th EAFES International Congress*, Nagoya, Japan (April 2018, invited talk)

And the other 7 English posters and 35 contributions in Japanese (4 invited talks, 10 talks and 21 posters)

Outreach activities

1. Teaching assistant for making a botanical specimen at Japanese School in Zurich (Japanische Schule in Zuerich), Uster, Switzerland. (1 July 2023, in Japanese)
2. **Sato Y**, Sato S. (2016) 12-years cicada monitoring. *Proceedings of the Natural History Museum Mt. Fujiwara* 38:1–5 (in Japanese)
-> Plain-text Japanese summary of Sato and Sato (2015) *Annals of the Entomological Society of America* 108(4):494–500.

Preprint

1. **Sato Y***, Shimizu-Inatsugi R, Takeda K, Schmid B, Nagano AJ*, Shimizu KK*. (2023) Genome-wide neighbor effects predict genotype pairs that reduce herbivory in mixed planting. *bioRxiv* <https://doi.org/10.1101/2023.05.19.541411>