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UNIVERSITÉ CÔTE D'AZUR Agriculture: both a contributor and victim of climate change



CMrs

science for people, life & earth

RÉPUBLIQUE FRANÇAISE

Growing human population: → higher demand for food

14

12

10

2

^oopulation (billions)



Cereal production and demand



@†

oa

The Lancet. 2020

Likely peak at 9.73 billion people (8.8-10.9 uncertainty interval) around 2064

Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study

Stein Emil Vollset, Emily Goren, Chun-Wei Yuan, Jackie Cao, Amanda E Smith, Thomas Hsiao, Catherine Bisignano, Gulrez S Azhar, Emma Castro, Julian Chalek, Andrew J Dolgert, Tahvi Frank, Kai Fukutaki, Simon I Hay, Rafael Lozano, Ali H Mokdad, Vishnu Nandakumar, Maxwell Pierce, Martin Pletcher, Toshana Robalik, Krista M Steuben, Han Yong Wunrow, Bianca S Zlavog, Christopher J L Murray



An increase of 25-70% above current production levels will be necessary

Agriculture in 2050: Recalibrating Targets for Sustainable Intensification

MITCHELL C. HUNTER, RICHARD G. SMITH, MEAGAN E. SCHIPANSKI, LESLEY W. ATWOOD, AND DAVID A. MORTENSEN



CMS

How to reconcile higher production with climate change mitigation?

More land conversion \rightarrow CO₂ (+ risk of exposition to new pests and parasites from the wild)

 \rightarrow Need to produce more using less land (improve yield / surface)... but how ?

Using more fertilizer $\rightarrow N_2 0 = \text{greenhouse gas}$

Improve plant resistance to abiotic stress:

- Drought
- Floodings



64) Zotta Mota A.P., Nicolini Oliveira T., Cleo Vinson C., Rhys Williams T.C., Mota do Carmo Costa M., Guerra Araujo A.C., <u>Danchin E.G.J.</u>, Grossi-De-Sa M.F., Messenberg Guimaraes P., Miranda Brasileiro A.C. **Contrasting effects of wild Arachis dehydrin under abiotic and biotic stresses.** Frontiers In Plant Science 2019 (View Online)

73) Vinson CC, Zotta Mota AP, Porto BN, Oliveira TN, Sampaio I, Lacerda AL, <u>Danchin EGJ</u>, Guimaraes PM, Williams TCR, Brasileiro ACM. Characterization of raffinose metabolism genes uncovers a wild Arachis galactinol synthase conferring tolerance to abiotic stresses. Scientific Reports. 2020 (View online).











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Pests, pathogens and parasites destroy 20 -30% Wheat of the world agricultural production



Rice

Maize

Potato







Despite considerable efforts to control them ... including pesticides, many of which being harmful for environment and biodiversity

+ Climate change exacerbates the problem

- Reduce efficiency of some pesticides
- Break some resistance genes in plants
- Favorable to proliferation and expansion of pests and parasites...



RÉPUBLIQUE

Soybean The global burden of pathogens and pests on major food crops

Serge Savary¹, Laetitia Willocquet¹, Sarah Jane Pethybridge¹, Paul Esker³, Neil McRoberts⁴ and Andy Nelson⁵*

Nature Ecology & Evolution, 2017



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Nature-inspired solution?



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What species do in nature through time and when environment change? → They evolve and adapt!

How?

- ightarrow Mutations in their DNA (genomes) provide variability in their forms and fitness (phenotypes)
- → The diversity of forms is submitted to the filter of selection (environment) and only the fittest forms pass the filter... the fittest forms transmit their mutations to the next generation, and so on ...



Environmental changes \rightarrow new filter for selection

Problem: pests and parasites tend to evolve faster than their host because

- Shorter generation time
- Higher offspring / generation
- Bigger population size
- → Higher variability and adaptability



Ability to manipulate and degrade plants evolved multiple times independently





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Our questions and how we study them



nature

• How has this ability to manipulate plants emerged during evolution

- → Decode the genomes of agricultural pests and compare them to those of other species
 - \circ \rightarrow unlock the secrets of their adaptation to plant parasitism

Nematology: terra incognita no more NEWS AND VIEWS

James P McCarter

biotechnology The genome sequence of the plant-parasitic roundworm Meloidogyne incognita opens new avenues to boosting food production.

ARTICLES

909 Genome sequence of the metazoan plant-parasitic nematode *Meloidogyne* incognita

P Abad, J Gouzy, J-M Aury, P Castagnone-Sereno, E G J Danchin, E Deleury, L Perfus-Barbeoch, V Anthouard, F Artiguenave, V C Blok, M-C Caillaud, P M Coutinho, C Dasilva, F De Luca, F Deau, M Esquibet, T Flutre, J V Goldstone, N Hamamouch, T Hewezi, O Jaillon, C Jubin, P Leonetti, M Magliano, T R Maier, G V Markov, P McVeigh, G Pesole, J Poulain, M Robinson-Rechavi, E Sallet, B Ségurens, D Steinbach, T Tytgat, E Ugarte, C van Ghelder, P Veronico, T J Baum, M Blaxter, T Bleve-Zacheo, E L Davis, J J Ewbank, B Favery, E Grenier, B Henrissat, J T Jones, V Laudet, A G Maule, H Quesneville, M-N Rosso, T Schiex, G Smant, J Weissenbach & P Wincker () see also p 882

Multiple lateral gene transfers and duplications have promoted plant parasitism ability in nematodes

Etienne G. J. Danchin^{a,1}, Marie-Noëlle Rosso^a, Paulo Vieira^a, Janice de Almeida-Engler^a, Pedro M. Coutinho^b, Bernard Henrissat^b, and Pierre Abad^a



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CINIS

OPEN OACCESS Freely available online

PLOS PATHOGENS

science for people, life & eart

Identification of Novel Target Genes for Safer and More Specific Control of Root-Knot Nematodes from a Pan-Genome Mining

Etienne G. J. Danchin^{1,2,3*}, Marie-Jeanne Arguel^{1,2,3*}, Amandine Campan-Fournier^{1,2,3*}, Laetitia Perfus-Barbeoch^{1,2,3}, Marc Magliano^{1,2,3}, Marie-Noëlle Rosso^{1,2,3}, Martine Da Rocha^{1,2,3}, Corinne Da Silva⁴, Nicolas Nottet^{1,2,3}, Karine Labadie⁴, Julie Guy⁴, François Artiguenave⁴, Pierre Abad^{1,2,3}



Our questions and how we study them





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How pests and parasites adapt to environmental changes including control methods

- → Compare the genomes of different populations of a same species in different environment
 - \rightarrow identify genomic variations associated to their adaptations

Population genomics supports clonal reproduction and multiple independent gains and losses of parasitic abilities in the most devastating nematode pest

Georgios D. Koutsovoulos, Eder Marques, Marie-Jeanne Arguel, Laurent Duret, Andressa C. Z. Machado, Regina M. D. G. Carneiro, Djampa K. Kozlowski, Marc Bailly-Bechet, Philippe Castagnone-Sereno, Erika V. S. Albuquerque, Etienne G. J. Danchin 🗙, ... See fewer authors

First published: 19 October 2019 | https://doi.org/10.1111/eva.12881 | Citations: 11



Movements of transposable elements contribute to the genomic plasticity and species diversification in an asexually reproducing nematode pest

Djampa K. L. Kozlowski, Rahim Hassanaly-Goulamhoussen, Martine Da Rocha, Georgios D. Koutsovoulos, Marc Bailly-Bechet, Etienne G. J. Danchin 🔀

First published: 05 May 2021 | https://doi.org/10.1111/eva.13246

Take home messages

- Pests and pathogens cause 20-30% loss on worldwide production (despite current extensive control methods)
- We must reduce these losses using more environment-friendly & sustainable methods
- We study species natural evolution to inspire new methods to better combat them.







Ongoing and future directions



- Incorporate AI to accelerate these analyses and be ready for many new genomes to come
- Extend these analyses to other pests and parasites to identify convergent evolution and thus crucial central genes for plant parasitism

... and keep in mind that after harvest

- > 30% of the global food production is lost and wasted
- 14% between harvest and market
- I7% at market and consumer level



Food and Agriculture Organization of the United Nations





Acknowledgments







