

PLOS Science Wednesday: Hi Reddit, we're Igor, Steve and Gert and we sequenced fungus DNA and found banana crops are highly susceptible to the fungal pathogen and resistant to fungicides, creating unsustainable growing practices – Ask Us Anything!

PLOSScienceWednesday¹ and r/Science AMAs¹

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Abstract

Hi Reddit, We're Igor Grigoriev, Steve Goodwin and Gert HJ KEMA, and we recently published an article titled Combating a Global Threat to a Clonal Crop: Banana Black Sigatoka Pathogen *Pseudocercospora fijiensis* (Synonym *Mycosphaerella fijiensis*) Genomes Reveal Clues for Disease Control in PLOS Genetics. Gert HJ Kema, Professor of Tropical Phytopathology at Wageningen University, The Netherlands, researches fungal diseases in banana and wheat, with a focus on genetic diversity and mechanisms of pathogenicity of the causal agents. Igor Grigoriev, Head of Fungal Genomics program at the U.S. Department of Energy Joint Genome Institute and Adjunct Professor of Plant and Microbial Biology at University of California Berkeley, employs genomics tools to explore fungal diversity for energy and environment science and applications. Steve Goodwin, Research Plant Pathologist with the Agricultural Research Service of the U.S. Department of Agriculture and Adjunct Professor of Plant Pathology at Purdue University, uses genetics, genomics and bioinformatics approaches to analyze host-pathogen interactions between wheat and fungal pathogens and to utilize genetic diversity in hosts and pathogens. The PLOS Genetics article focused on determining the DNA sequence of the fungus and applies it by focusing on two major aspects of current banana production: overall susceptibility of the crop and reduced efficacy of disease control agents (fungicides). The overall susceptibility of the major export Cavendish banana varieties - that essentially form one huge monoculture around the globe - is the underlying problem of the unsustainable banana production. Hence, the only way to manage black Sigatoka is the use of fungicides. However, due to the high application frequencies (between 50-70 times per year) their efficacy continually decreases, which in turn requires more/different control strategies. Our paper unveils the unsustainable status quo by showing the need and possibility for developing new and better varieties with improved disease resistance. This helps growers in the developing world and meets consumer demands for a caring society. To learn more about the featured study, read Gert's PLOS Blogs post on Biologue. See for another effect of the global banana monoculture the PLOS Pathogens study Worse Comes to Worst: Bananas and Panama Disease—When Plant and Pathogen Clones Meet. Also, don't forget to follow us on Twitter: DOE Joint Genome Institute and USDA and Wageningen University. Visit us at www.panamadisease.org and/or subscribe to the newsletter. We'll be back at 1 pm EST (10 am PST, 5 pm UTC) to answer your questions, ask us anything!

[REDDIT](#)

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PLOSSCIENCEWEDNESDAY [R/SCIENCE](#)

Hi Reddit,

We're Igor Grigoriev, Steve Goodwin and Gert HJ KEMA, and we recently published an article titled [Combating a Global Threat to a Clonal Crop: Banana Black Sigatoka Pathogen *Pseudocercospora fijiensis* \(Synonym *Mycosphaerella fijiensis*\) Genomes Reveal Clues for Disease Control](#) in [PLOS Genetics](#).

[Gert HJ Kema](#), Professor of Tropical Phytopathology at Wageningen University, The Netherlands, researches fungal diseases in banana and wheat, with a focus on genetic diversity and mechanisms of pathogenicity of the causal agents.

[Igor Grigoriev](#), Head of Fungal Genomics program at the U.S. Department of Energy Joint Genome Institute and [Adjunct Professor of Plant and Microbial Biology](#) at University of California Berkeley, employs genomics tools to explore fungal diversity for energy and environment science and applications.

[Steve Goodwin](#), Research Plant Pathologist with the Agricultural Research Service of the U.S. Department of Agriculture and [Adjunct Professor of Plant Pathology](#) at Purdue University, uses genetics, genomics and bioinformatics approaches to analyze host-pathogen interactions between wheat and fungal pathogens and to utilize genetic diversity in hosts and pathogens.

The [PLOS Genetics article](#) focused on determining the DNA sequence of the fungus and applies it by focusing on two major aspects of current banana production: overall susceptibility of the crop and reduced efficacy of disease control agents (fungicides). The overall susceptibility of the major export Cavendish banana varieties - that essentially form one huge monoculture around the globe - is the underlying problem of the unsustainable banana production. Hence, the only way to manage black Sigatoka is the use of fungicides. However, due to the high application frequencies (between 50-70 times per year) their efficacy continually decreases, which in turn requires more/different control strategies. Our paper unveils the unsustainable status quo by showing the need and possibility for developing new and better varieties with improved disease resistance. This helps growers in the developing world and meets consumer demands for a caring society.

To learn more about the featured study, read Gert's PLOS Blogs post on [Biologue](#). See for another effect of the global banana monoculture the PLOS Pathogens study [Worse Comes to Worst: Bananas and Panama Disease—When Plant and Pathogen Clones Meet](#).

Also, don't forget to follow us on Twitter: [DOE Joint Genome Institute](#) and [USDA](#) and [Wageningen University](#).

Visit us at www.panamadisease.org and/or subscribe to the newsletter.

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Could the banana as we know it be extinct in our lifetime because of the fungus?

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[dfdx2](#)

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Gert - I don't think bananas will be extinct. Journalists like asking these questions, but the situation is of course very serious. Agronomically growing a suite of essentially identical clones around the world is asking for problems as banana history has shown already once before (Panama disease epidemic previous century). History repeats it self and hence we need to come up with solid strategic solutions. Prime target is to introduce genetic diversity - new varieties - to slow prevent and manage epidemics. This takes many yeas of R&D and meanwhile we need to implement other management options. 50-70 fungicide applications to manage black Sigatoka is very unsustainable.

Hey guys, thanks for your work. Is there any way we could safely and effectively build fungal resistance into Bananas, in some capacity using Gene Editing? And if so, is this being worked on currently in some capacity, or even on another crop to your knowledge? Thanks!

[stry8993](#)

Gert - For sure. Genetic modification, either through GM technologies or breeding is definitely possible. However, the facts are that the major genetic basic work on the plant side is still fairly limited. Not a single R gene has been mapped and for genome editing we have no clue yet on the targets. But, we'll get there, for sure.

How many different types of bananas have you tried? What's your favourite type and where did all this banana love in your life come from?

[ThePowerBees](#)

Gert - Many. Preferred are the local bananas in SE Asia. Got in touch with banana 12 yrs ago through the link with my R&D in wheat and a related fungus, *Zymoseptoria tritici*. Steve, Igor and me work on that pathogen already for decades. Hence, banana was a fantastic opportunity to use the gained know-how to boost R&D in banana. Much needed as it is generally considered an orphan crop, respite the fact that it is a staple for millions of people. It is a shame that R&D in banana is so limited.

How many different types of bananas have you tried? What's your favourite type and where did all this banana love in your life come from?

[ThePowerBees](#)

Steve - I've had a few and most are very good. Unfortunatly, I often tried them in other countries where I didn't know the cultivar name. If you go to Hawaii you can get several cultivars commonly, some of which taste much better than Cavendish in my opinion.

This sounds like a big deal for a lot of stakeholders. How well funded are you guys? Who contributes to the funding?

[pm-me-ur-window-view](#)

Gert - Frankly, we're always on the watch for new funding. There is never enough to meet our ambitions for safeguarding bananas. As mentioned earlier, banana funding is negligible compared to the major staple crops (wheat, rice, maize, potato and others). We have to come from far, but we're slowly getting there. More funds would help us to train many more students (capacity building is very important) and to come up with more innovative solutions and new varieties. Funding presently is mostly in public private partnerships, thus governments (Netherlands), companies (global, not the "big

guys" though), universities (Wageningen and others), institutions (JGI did a great job to support this work), private foundations/charity (Dioraphte in The Netherlands).

To prevent the loss of genetic variation people in South America have taken to cultivating many different kinds of corn. What chance is there that there is some long lost hybrid that may have more resistance in some remote tropical region?

[reb0014](#)

Gert - Possible. Requires old style explorations. Fact is that we are largely natural clones that may have developed thousands years ago in tropical forest. Both Gros Michel and Cavendish are no breeding products, but naturally formed triploids. We can repeat the process though and work from smart diploid breeding to new triploids

Does the customer buying these bananas consume spores of this fungus? If so, what effect does it have on their health?

[ferengiprophet](#)

Gert - Likely not. The fungus is a foliar pathogen that does not infect the fruit

How has global warming/climate change exacerbated the fungal issue with bananas? I have heard and read numerous pieces citing this, but no exact explanation as to why this encourages the various fungi's growth and resistances to fungicides (outside of overuse).

[TheCardiganKing](#)

Gert - Difficult to say. There are projections and yes, environmental changes will affect the distribution/epidemiology of fungi. No question. However, to precisely answer your question for banana pathogens is difficult, if not impossible, yet.

Can you figure out the genes for the now unavailable commercially and superior tasting Banana that preceded the current crops?

[picu](#)

Get- Yes, with sufficient budget we'll be able to target those genes

Interesting AMA.

The susceptibility of Bananas to fungus has been a known issue for a while, with bananas as cultivars lacking in genetic diversity and the Gros Michel effectively having been wiped out by Panama disease.

As I understand, the cavendish was initially thought to be fungus resistant, but this was quickly realized not to be the case once the crops were in place.

Given the sordid geopolitical history of Bananas and the economies which rely on them as a cash crop and staple, what are your thoughts and personal opinions on the political future of the Banana? Do you believe a hybrid/ genetically modified banana which can withstand the currently destructive fungi should be licensed and owned, or should the genes be "open sourced" to promote biodiversity and

economic freedom of growers?

Also- given that you all work for publicly funded institutions, what role and interest do chiquita and dole (who maintain a combined ownership of ~50% of the world's banana market) play in your research?

[know comment](#)

Gert - The miracle of Cavendish is that it is still resistant to the strains that caused the previous Panama disease epidemic (in Central/Latin America, the so-called Race 1 strains). This is absolutely unique. It is very susceptible to black Sigatoka though and now also to Tropical Race 4. Yes, we believe that GM/breeding is the way to go, and it's feasible. We choose a different strategy than the conventional breeding programs, which will likely deliver more alternatives and faster. Everything we do is public, even when co-funded by companies. Our philosophy is that technology should be freely available for countries that need banana as a staple. The companies you mention have a great interest in our R&D, they do not fund it.

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[know comment](#)

Steve - Cavendish actually was very resistant to Panama disease and it took quite a while before a new race evolved and became common enough to cause serious problems. I work for the U.S. Government so everything I do is public domain. If I found a real cure for black Sigatoka or Panama disease I would try to patent it if possible. The reason is that companies are the ones who can bring improved products to consumers and they will only do that if patent protection can provide a potential profit. If a new technology is not patented it is less likely to be used. I know this sounds counter-intuitive but that is the reality. However, this would not apply to small holders. In addition to the huge commercial banana production, bananas and plantains are staple food for billions around the world who cannot afford to apply fungicides. If we can find a way to help those growers then we would all be very happy.

How long can these fungi survive without banana-like plants?

If there are other, non-commercial, plants that these fungi can live on, could we breed a fungus-resistant version of that plant to create natural fungicides that can be used on banana plants?

If not, how easy is it to create clean areas of annually increasing size on plantations that keep out the fungus until it's eradicated?

[palordrolap](#)

Gert - Fusarium, decades. *P. fijiensis* not so long as it depends on the host for its survival. Your question refers mostly to Fusarium, right? Cleaning land from the persistent spores that survive for decades is not easy, but we're testing (biological) methods to do so. I'm sure that we will have many more tools to reduce Fusarium in soil over the next few years. We can use genes from other plants in disease control strategies. The paper gives one example: use a gene from tomato, or use it as a probe to find/clone/use the banana homologue

I went to Rwanda this past summer and the school I stayed at (Hope Haven Rwanda) is doing wonders for its community, including teaching the practice of composting. The locals have seen huge increases in their banana yields (and other crops they grow to live on).

Do certain farming practices or conditions help make the plants more resistant to the fungus?

[IdCallthePolice](#)

Gert - They grow different varieties, and the fungi we're talking about (TR4 Fusarium) are not (yet) there. They likely have black Sigatoka, but once you're out of a vast area production environment, these fungi, particularly the black Sigatoka fungus, do less damage. It all boils down to plant diversity. More variation slows down epidemics. Good news they've seen major gain in yield. Thanks for sharing!

Can biological fungicides succeed where chemical fungicides are failing?

[SoNowWhat](#)

Gert - Yes, they can, but they cannot replace them. At most they're part of the overall package

Do you think that the FHIA program is a good way to get a banana with commercial potential that resists Black Sigatoka, or do you think that genetic engineering would be a better way to combat it? Which approach is better in your opinion to combat diseases like Panama Disease, Black Sigatoka, and Bunchy Top Virus?

I know that both approaches have been attempted, but the genetically engineered ones have been bogged down for various reasons.

So you think that fungicide resistance will also become a problem for Yellow Sigatoka as well?

Thanks!

[pogrmman](#)

Gert - There is no exclusive strategy. We should do one as well as the other. GM is a great way to "repair" Cavendish deficiencies. Breeding is the way to go for the ultimately required diversity. I will not comment on individual breeding programs, but the facts are that thus far none has been successful in marketing viable replacements for Cavendish. Fungicide resistance is also an issue in Yellow Sigatoka. However, black Sigatoka is much more aggressive and has replaced YS populations in most countries.

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[pogrmman](#)

Steve - Yes, I think both approaches are needed. The FHIA program has produced bananas with increased resistance so we know it works. Genetic engineering will work in the future but getting around barriers to public acceptance will be the difficulty. For example, for Panama disease, there is a report that Host-Induced Gene Silencing can control the disease, although it has not been tested in the field to my knowledge. It also may be possible to use non-host resistance. One result from the black Sigatoka genome sequence is that it contained effectors (proteins that facilitate disease) that could interact with tomato resistance genes. Possibly genes from other edible crops that recognize the banana pathogen could be put into banana to increase its resistance.

Hello!

Has there been any reaction to your work from major agrochemical companies that have spent the last 60 years manufacturing and selling pesticides and fungicides (in ever-growing amounts) to banana cultivators?

Also, have any of your peers ever crossed paths with Jason Glaser? He was the producer/director of [Banaland: Blood, Bullets, and Poison](#). He has also been working with [La Isla Foundation](#) and great people in your neck of the woods to help find a solution to chronic kidney disease suffered by sugar cane workers in Central America, partially due to exposure to agrochemicals.

I'm sure he would be interested to hear of your work in the banana fields, as those workers and their children have also suffered from decades of poisoning from agrochemicals, which it sounds like your work could help significantly decrease.

Finally - do you think it would ever be feasible to grow bananas in non-equatorial regions in aquaponic or hot-house setups or something similar?

Thanks!

[LocalMexican](#)

Gert - Hi thanks. I have never met Jason Glaser. Would love to. We work with industrial partners to understand the global population structure. I'm sure there will be innovations to diversify the production environments. There is a lot to say about it, though. Leaving the current production areas will have a major impact on employments. Millions of people are involved in the banana chain. It is the most important export product of various countries, Ecuador, Philippines etc.

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Thanks!

[LocalMexican](#)

Steve - OK, that is several questions. We often have collaborators in industry to work on basic science, including on our genome paper. Industry sequenced the second genome. Agrochemical companies are definitely interested in the genome sequence, for example to help design compounds that could target the pathogen specifically with fewer negative environmental effects. Of course, our long-term goal would be to make chemicals unnecessary, but that is a long way off and many chemical companies also are into producing resistant plants. Hopefully we can work together to reduce the amount of chemicals applied.

I have not heard of Jason Glaser - maybe Gert knows of him.

You can grow bananas in greenhouses now - production out of tropical areas is possible but yields are probably too low to make them commercially viable. I have a dwarf banana I grow as a houseplant that has fruited several times so it is definitely possible to grow them outside of the tropics.

One thing that strikes me when looking at ancient agricultural practices are how diverse planting regimes used to be. Take the famous case of three sisters agriculture in the prehistoric United States. Maize would be planted with beans and squash. The maize would form a stalk for the beans to vine across. The squash would form a protective blanket across the soil to prevent both erosion and retain soil moisture. The beans, as nitrogen fixers, would reduce nutrient depletion if the soil. And eaten together, there was a complete protein. And the types of beans, maize, and squash had many, many varieties. These gardens appeared to the first Europeans as untamed swampland, but they did not require fallow cycles the way their farms did.

Contrast this with agriculture today: mono-cropping over large areas. Bananas are almost clones of each other grown in large fields; an ideal situation for a pathogen. The Irish potato famine was the result of a similar vulnerability.

So the question is, how much can we generalize from the banana risk to other crops? Above and beyond the particulars of this fungus, are we creating our own vulnerabilities with our current system of good production?

[Thalesian](#)

Gert - The short answer to your last question is, yes, at least in banana. See also the above discussions. Maintaining and deploying genetic diversity is crucial.

What is it about bananas that makes them so susceptible to fungus and unprotected by fungicide? I imagine it has something to do with it being a monoculture but many crops are monocultures.

[lejefferson](#)

Gert - Well, there are vast areas of crops, but mostly these are divided over a range of genetically different cultivars. This is where bananas are truly the exception. There it is mostly one and the same cultivar, thus genetically uniform. As these are natural clones, they have never been bred for such a vast acreage and that makes them prone to diseases

Is there a solution to the fungus problem or is a time machine the only thing that would fix it?

Is this a problem for both organic bananas and conventional bananas?

[Groverjay87](#)

Steve - It is a problem for both organic and conventional growers. Probably worse for organic growers since they have no available controls. There is no solution right now other than lots of sprays with fungicides, but even that is not sufficient as fungicide resistance evolves very rapidly. Unfortunately, a time machine wouldn't solve the problem - we would just get to see it happen again - although it would allow you to taste Gros Michel bananas again.

Is there a solution to the fungus problem or is a time machine the only thing that would fix it?

Is this a problem for both organic bananas and conventional bananas?

[Groverjay87](#)

Gert - organic and conventional bananas are both Cavendish. So they are both prone to the mentioned diseases. We can fix the fungal problems, see the above discussions.

I read a good start of your published article, and was curious as to how the black Sigatoka actually causes early ripening of the bananas. How then, do the other two similar pathogens differ to this?

[NiteStryker33](#)

Gert - Black Sigatoka is a foliar pathogen and once it is there it "manipulates" the physiology of the banana plant. Under stress most plants try to ripen quickly in order to shed their seeds. Bananas respond similarly, despite the absence of seeds in triploids, and switch on an early ripening machinery that affects overall quality and prevent export. Hence, huge indirect costs.

What are the prospects for developing fungicidal pathogens that could be used to attack the fungi threatening the banana?

[Lucretius](#)

Gert - Not very big, I'm afraid. Biocontrol will contribute to disease management though

What are the prospects for developing fungicidal pathogens that could be used to attack the fungi threatening the banana?

[Lucretius](#)

Steve - This is an interesting idea but I think the chances of something being developed are low. There certainly are fungi that are parasitic on other fungi but I don't know of any that attack the black Sigatoka pathogen.

Hey guys, thanks for your work, great article! Are these examples of the agricultural industry and consumer market selecting for a certain species variety (I also think of corn), and hence reducing genetic diversity and disease resistance, the norm or exception? What's the best way in your opinion for the industry to diversify these crops genetically while still making them marketable?

[El Hefe Ese](#)

Gert - In banana this is the norm. Retail, industry kind of "suffocate" the potential, already for years. We need to kind of circumvent, convince, break this armor. The best way forward is an innovative, professional, commercially driven and highly technologically driven breeding program meeting consumer preferences. Take consumers serious, they don't want to be told that they really need Cavendish.

Dumb question: how does sequencing DNA of fungus show you that bananas are susceptible to it?

[Shortl4ndo](#)

Dumb question

Igor - There are no dumb questions! Sequencing just by itself does not do it. We would like to understand what triggers it, how this happens, and how we potentially avoid it. With a genome in hands you can compare it to the genomes of other pathogens, find conserved genes and similarities to those already known genes, develop hypothesis and design experiment to study mechanism of action. We used the collection of ~700 annotated fungal genomes that we built at JGI Mycocosm (jgi.doe.gov/fungi), a web-based fungal genomics resource, which integrates fungal genomes with other omics data and provides interactive analytical tools to explore them.

Dumb question: how does sequencing DNA of fungus show you that bananas are susceptible to it?

[Shortl4ndo](#)

Steve - It doesn't, directly. Sequencing of the fungus identifies genes that are involved in infection and also those that are recognized by potential resistant plants. Having the sequence is only the beginning, just like having a road map can show you the way but doesn't get you there.

Beyond the need for increased general resistance in banana, is there work being done for specific effector-targeted immunity in banana? That is to say, are there specific plant-microbe interactions being studied for applications as strain-specific resistance genes, like there is for soybeans and *P. sojae*?

[FakDendor](#)

Steve - Yes, that came out of the sequencing project. There also is the possibility of using resistance genes from other hosts - one of the effectors from the banana pathogen is recognized by a tomato resistance gene.

Is there any long term alternative to the development of new varieties? If the diseases currently threatening the global supply of bananas are somehow eradicated, wouldnt it be just a matter of time until a similar diseases hits the cavendish?

[Svankensen](#)

Steve - Unfortunately, you are right that another disease is likely to show up, particularly with a long-lived, clonal crop. I think the only long-term solution will be genetic engineering of better resistance, but that will take time. Our sequencing the genome of the banana pathogen is only the first step in a long process.

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[Svankensen](#)

Gert - Yeah, what to say. There is always something, and unexpected things we're not prepared for can show up. Currently, the treats are these two fungi and, yes, we need to invest in strategic R&D to topple them down. Of course the beauty of breeding is versatility, we always can change focus, improve another character etc.

In your opinions, what are the critical skills right now in mycological genetics and genomics? The field is moving so fast and prices are dropping to the point that fungal genomes have become much more feasible even within the last few years. Looking forward, what tools and techniques should current graduate students be preparing for to enter the (academic or otherwise) job market?

[Microtiger](#)

skills

Igor: I suggest to look at molecular biology and bioinformatics. While genomics data become readily available from core lab facilities or commercial entities, bioinformatics skills remain critical for data analysis. In fact it requires more resources to assemble, annotate, and analyze genomics data computationally than sequence it. Frequently you are on your own facing tons of raw genomics data shipped to you. At JGI we perform these computational tasks for every genome we sequence (jgi.doe.gov/fungi) but you still need to understand how the data were processed, to which extent you can trust the data, and what else you can do with it

In your opinions, what are the critical skills right now in mycological genetics and genomics? The field is moving so fast and prices are dropping to the point that fungal genomes have become much more feasible even within the last few years. Looking forward, what tools and techniques should current graduate students be preparing for to enter the (academic or otherwise) job market?

[Microtiger](#)

Steve - This is easy - bioinformatics. As you noted, prices are low and dropping. The problem now is not in generating the sequences but in getting them analyzed. There are not enough people trained in bioinformatics and the demand far outstrips the supply. Grad students and postdocs who have training in bioinformatics are in high demand and can utilize the existing genomics resources to the fullest.

Why is bananas going extinct a bad thing health wise? Obviously anything going extinct is going to mess stuff up I was just wondering exactly how.

[dman3642](#)

Steve - Bananas are the number one fruit in the US - if they go extinct people will probably have worse diets. In many countries bananas and plantains are a staple food without which millions of people would starve. So it would be a really big problem if bananas are wiped out.

Thanks for your work! Have you examined the effect of sub-lethal doses of fungicides (due to, say, the degradation of a fungicide over time) on the pathogen and how it may positively effect its virulence?

[Kyle_r6](#)

Gert - There is a lot to say about sub-optimal doses of fungicides. Some claim that this improves control, others claim that it contributes to resistance development/selection. In principle, I tend to follow the recommendations of the industry to guarantee the lifetime of fungicides. We cannot spoil these worthwhile active ingredients. It has taken years of development to come up with these products. Without them we could presently not grow bananas. Whether we like it or not, these are the facts. So also from that perspective, more diversity in banana varieties is necessary to reduce the chemical load in banana production.

Thanks for your work! Have you examined the effect of sub-lethal doses of fungicides (due to, say, the degradation of a fungicide over time) on the pathogen and how it may positively effect its virulence?

[Kyle_r6](#)

Steve - This is an interesting question. In my lab we actually have looked at the effect of sublethal doses of fungicide in a different fungus (a wheat pathogen) and found that they increase the rate of loss of dispensable chromosomes. The stress caused by sublethal doses of fungicides could increase the mutation rate which certainly could affect virulence, but that has never been studied as far as I know.

Could genetically modifying bananas to be resistant to the fungus be a solution? Or using genetical engineering to breed a new cultivar?

[kemla](#)

Steve - Yes, definitely - come back in a few years.

Is it too late to reintroduce a somewhat natural genetic variation into bananas that would make them less susceptible to pathogens but also taste different or not be so full of sugar?

[midnightketoker](#)

Steve - This can be accomplished with breeding but it will be very slow.

Is it too late to reintroduce a somewhat natural genetic variation into bananas that would make them less susceptible to pathogens but also taste different or not be so full of sugar?

[midnightketoker](#)

Gert - No, see breeding posts above.

Is there some way to use the fungus (-gi?) for something?

It's a bit of a weird question.

[cloakedbolter](#)

gi?

Besides food (bread, cheese, mushrooms) and drinks (beer, wine, soda)? At JGI we explore fungi of importance for energy and environment science and applications. These include, for example, plant pathogens and symbionts (for plants to grow in sustainable fashion), plant biomass decomposers and sugar fermenters (to convert plant material into biofuels and other bioproducts) - <http://jgi.doe.gov/our-science/science-programs/fungal-genomics/genomic-encyclopedia-of-fungi/#feedstock>

How much the agronomic aspect influence the presence of the patogen? You think that will be possible to fix the problem (not eradication but control under level) without use of gene editing?

[Metaltest](#)

Steve - Agronomic practices certainly can have a big effect but are not sufficient to eradicate the problem completely once it is established. For example, in Australia the pathogen has been introduced a couple of times and as soon as it was noticed they immediately destroyed all bananas within a few miles of the outbreak and supposedly eradicated it. This may be possible but difficult if you don't catch it early. In Ecuador, they cut off infected leaves and put them on the ground with the upper surface down, since the spores are supposed to be produced only on the upper surface. This can slow it down but it is still very difficult to produce bananas. Agronomic effects are probably not large enough for effective disease management, unfortunately.

How much the agronomic aspect influence the presence of the patogen? You think that will be possible to fix the problem (not eradication but control under level) without use of gene editing?

[Metaltest](#)

Gert - I think so, see above posts. Gene editing is surely not the only option.

Isn't this what led to the extinction of the Bananas which the little banana candies are based on?

Care to touch on that subject briefly?

[ThatOtherGuy_CA](#)

Gert - Gros Michel was wiped out by Panama disease, another fungi, very serious.

How does genetic diversity play a role in a hypothetical near extinction event? I mean, for humans to survive we would need a large genetic pool. Is the same true for plants? Does it need to be larger/smaller for any reason?

I was thinking of this when they announced the "Ark" in Norway where seeds are stored.

Thank you for doing this AMA.

[Tobikaj](#)

Steve - I think there is no way to predict for certain regarding extinction events, but certainly higher genetic variation gives you more phenotypic variation and that should increase your chances of survival. The same rules of evolution that apply to humans also apply to plants. Asexually reproducing organisms with low genetic variability are usually much more vulnerable to extinction.

Please come to australia and help our Cavendish bananas. If you dont already know they have the soil born, Panama Tropical Race 4 (fusarium wilt)

Hopefully you guys can be of some help

[Auslsx](#)

Gert - Hi, there. There are excellent groups in banana R&D that support the Australian industry. They even managed - in a public private partnership - to eradicate black Sigatoka, miraculously.

Are there plans to reintroduce genetic diversity in banana crops (or better yet, is that even possible)?

[Jherden](#)

Steve - It is possible but difficult due to the way the industry is structured. Ability to be transported is almost as important as other factors.

Do you have any tips about growing apple trees in Virginia? We are having issues with what I believe are fungal infections in our fruit trees. I'm just trying to grow a few organic apples in my backyard. I have sprayed my trees with copper fungicide last week.

[ravenwarriorgoddess](#)

Steve - This is off topic, but probably you have apple scab, maybe also rust. Growing apples organically in the east is difficult.

Hey guys, thanks so much for doing this!

Given that fungi produce some of the most powerful anti-fungal compounds in nature - would it make sense to engineer/introduce a different species of endophytic fungi to protect the plant?

[jconn93](#)

endoph

Igor: Biocontrol is one of the directions pursued in Ag when variants of soil fungi promote plant growth or attack pathogenic fungi (e.g., http://genome.jgi.doe.gov/Mycoparasitic_fungi/). JGI has been a

pioneer in plant-fungal-microbe interactions (http://jgi.doe.gov/news_12_08_01/) to explore opportunities to both fend off pathogens and encourage symbiotic relationships (<http://bit.ly/JGIUMXMartin>) for nutrient exchange and defense.

What can a systems biologist do to help out? Is, for example, enough knowledge captured in machine readable pathway databases?

[egonw](#)

system

Igor: You are right, genomes are just a starting point and we are moving toward functional genomics to bridge the gap between the enormous number of sequenced genes and still relatively small number of genes with known function. JGI works with other DOE User Facilities like the Environmental Molecular Sciences Laboratory (<http://bit.ly/User-Facility-JGI>) to produce various omics types of data (genomics, transcriptomics, proteomics, epigenomics, metabolomics, etc) and analyze them. The recent "Facilities Integrating Collaborations for User Science" (FICUS) initiative was established for this purpose. (More: <http://bit.ly/JGI-FICUS>). FICUS is all about expanding the diversity of datasets and connecting systems; for example, we worked with Michelle O'Malley at UCSB on sourcing cellulolytic fungal enzymes from zoo animal feces capable of degrading biomass more efficiently for fuel, generating metabolomic datasets (<http://jgi.doe.gov/biofuel-tech-fungi-straight-from-the-farm/>).

How does sequencing a banana DNA allow you to know that banana's are susceptible to fungus and resistance to fungicide?

[fishlover](#)

Igor: see my answer above about fungal DNA, genome gives you pointers to genes, which you can study further, annotate, and modify if needed

With new genetic manipulation techniques is there anyway to insert resistance to fungal infection?

[Milestailsprowe](#)

Steve - We are working on that - come back in a few years!