ENVIRONMENTAL SCIENCE JOURNAL FOR TEENS

JANUARY 2018

What makes some species successful invaders?

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Associate Editors:
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Abstract

Alien invaders are among us. It's true! Everyday, foreign plants and animals are turning up in new places. Some of these *non-native* species do extremely well and out-compete *native* species. They can cause environmental and economic harm. If they do so, we call them *"invasive species"*. Fortunately, not all non-native species are invasive. But what makes some species successful invaders and some not? Could beneficial partners be helping out? To find the answer, we studied some invasive *legumes* (plants in the bean and pea family) and their *rhizobial* partners. Rhizobia are beneficial *bacteria* located in legumes' roots (Figure 1). We found that invasive species can work with a broad variety of rhizobia under greenhouse conditions. However, native and invasive legumes in the wild hosted different types of rhizobia. To our surprise, invasive species had rhizobia similar to the ones in their native land. The question now becomes - where did they get these familiar rhizobia? Could it be a *co-invasion*?

Figure 1: Rhizobial bacteria infect legume roots and form nodules. We extracted and analysed the DNA of rhizobia collected from root nodules to identify the specific types of bacteria associated with each legume plant. (Image by *ninjatacoshell)*

Introduction

Humans often help plants, animals, and other life forms travel out of their native environment into new areas. These newcomers often encounter no natural predators, competitors or other restraints. They reproduce quickly, grow fast, and rapidly colonize their new habitat, and crowd out native plants and animals, causing harm to habitats and ecosystems. These harmful non-native species are called *invasive species*. Some invasive species spread pests and diseases, lowering *crop yields* (amount of grains, fruits, and vegetables produced). Others poison wildlife, reduce water quality, and cause soil erosion. In fact, invasive species are considered the second largest threat to *biodiversity* after habitat loss.

Then again, not all non-native species are invasive (i.e. cause harm). Indeed, some desired species fail to survive in a new environment. What makes certain species more invasive than others?

When scientists purposefully introduced non-native species into new areas, they discovered that one key to successful invasions is having *mutualistic* partners. Mutualism is a relationship where two different species "work together" and each benefits from the activity. Mutualistic interactions may increase the success of invasions by allowing partners to overcome environmental and biological barriers in a new area.

Here, we investigated the impact of mutualism and how mutualistic interactions form during the invasion process.

We hypothesized that successful invaders are *generalists,* meaning they can form interactions with a broad variety of mutualists, including unfamiliar partners available in a new area.

Methods

To test this hypothesis, we studied legumes and their mutualistic partners, rhizobia bacteria. Rhizobia infect legume roots and form *nodules* (swellings filled with bacteria). Rhizobia are *nitrogen-fixing bacteria*. Once they colonize root nodules, they convert nitrogen gas from the air (that is usually not accessible to plants) into nitrogen compounds that the host plant can use. This relationship benefits both organisms - legumes get nitrogen compounds that are crucial for their growth and the bacteria receive food (sugars) from the plant.

We studied three invasive and six native species of legumes and their rhizobial communities in the San Francisco Bay Area in California.

Field collections: We collected 20 to 60 individual plants per species. After unearthing and washing the roots, we cut off the nodules and grew rhizobium colonies from them. Then, we extracted and sequenced rhizobium *DNA* to identify specific types of rhizobia associated with native and invasive hosts. We identified 117 colonies of rhizobia, across both native and invasive legume species (Figure 2).

Greenhouse tests: Then, we tested the three invasive legumes for their ability to live with a variety of the rhizobia types we collected. We grew multiple individuals of each invasive legume species and introduced each individual to a different type of rhizobium. Thirty days later, we examined the roots and determined which types of rhizobia formed nodules.

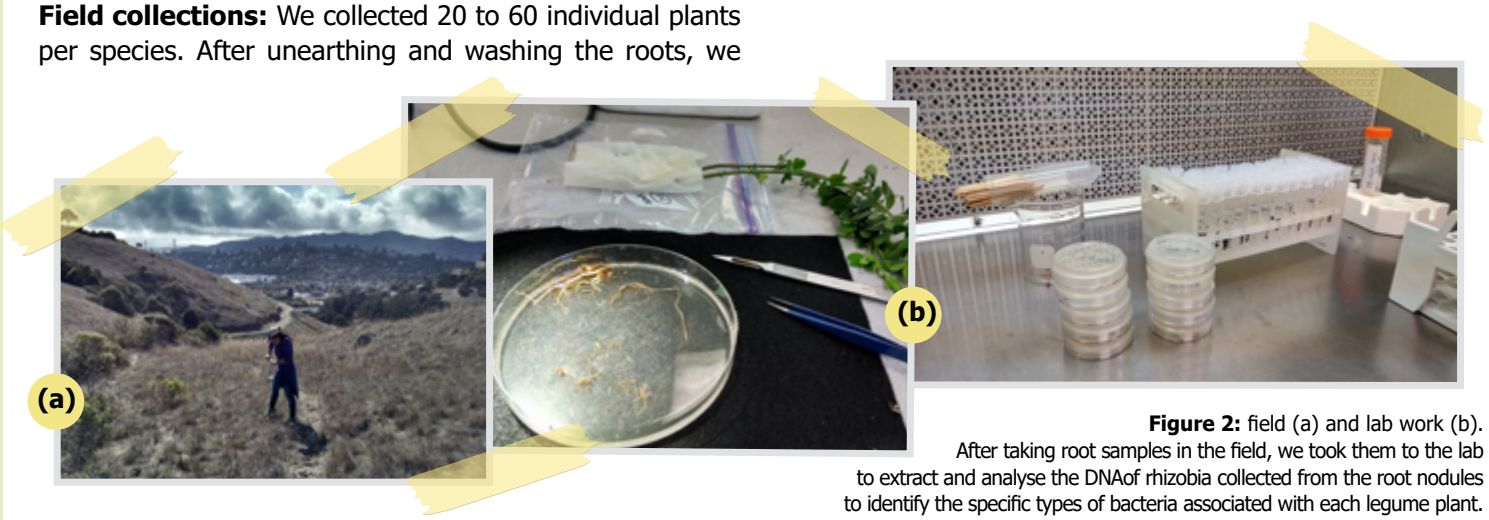

Figure 2: field (a) and lab work (b). After taking root samples in the field, we took them to the lab to extract and analyse the DNAof rhizobia collected from the root nodules to identify the specific types of bacteria associated with each legume plant.

Results

- We identified 19 genetically different rhizobium types in the field (Figure 3).
- Invasive and native species tend *not* to share rhizobium types: 10 types of rhizobia associated only with invasive hosts, 7 only with native hosts, and just 2 types lived with both invasive and native hosts.
- Invasive species associated with types of rhizobia similar to those in their native habitat.
- The rhizobium communities of most native legumes growing in the wild were quite similar (94% similar). The similarity of rhizobial communities of invasive legumes was slightly lower (81%). This indicates that invasive hosts don't rely on certain types, and can live with a broad variety of rhizobia.
- Under greenhouse conditions, all three invasive species were able to host a wide variety of rhizobia types. Whether the rhizobia came from a native or an invasive host made no difference to the invasive legumes.

Please, see Figure 3 on Page 3

Are the rhizobia communities of native and invasive species similar? Which type of host plants associate with a wider variety of bacteria? Native or invasive?

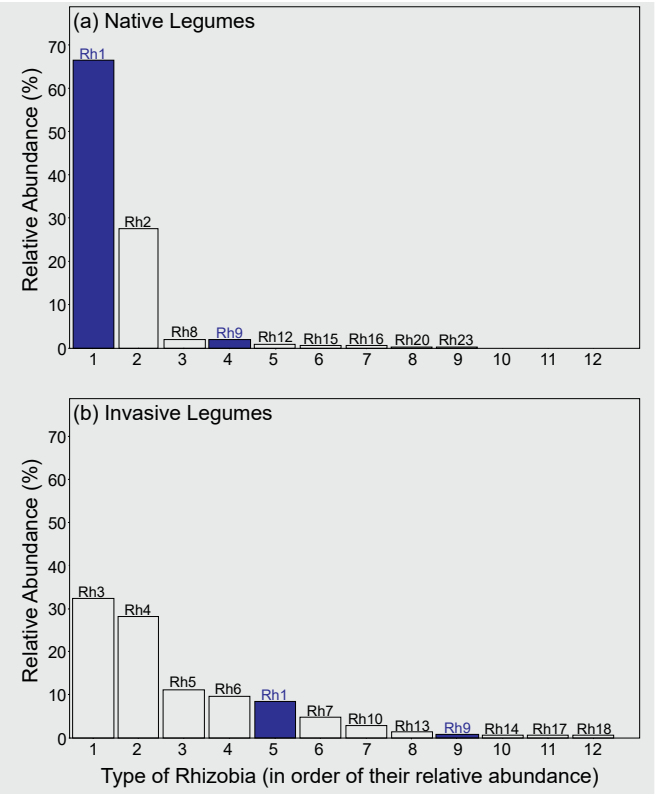

Figure 3:
Types of rhizobia we found in native (a) and invasive (b) legumes in the San Francisco Bay Area in California. Types are ordered according to how common they were (=relative abundance). Rhizobia types in blue are types that we found in both groups. All others were specific to either native or invasive legumes.

Discussion

The results from our greenhouse experiments clearly show that invasive legumes can live with a broad variety of rhizobia. This could definitely be a key factor making them successful invaders.

But to our surprise, invasive and native legumes growing in the wild do not share the same rhizobia. This result suggests that invasive hosts are not forming new interactions, even though they could. Rather, invaders tend to live with rhizobia similar to those they associate with in their native habitat.

This poses the question: how do they get rhizobia similar to those in their native habitat?

There are two possible scenarios:

- ***Cosmopolitan distribution:*** this hypothesis suggests "everything is everywhere", which means that these rhizobia were already present in the new area before the invasive legume arrived.
- ***Co-invasion:*** Rhizobia may arrive with their hosts, traveling in the roots of imported host plants, or with the soil on the introduced legume seeds. Legumes and rhizobia continue their mutualistic partnership and co-invade the area.

As we don't know what types of rhizobia were in the San Francisco Bay Area before the legume invasion, we can't determine exactly how the invasive legumes got their mutualistic bacteria when they first arrived.

However, removing these bacteria could prevent future biological invasions and restore invaded areas.

Conclusion

Invasive species represent a challenging problem. Government agencies and organizations work hard to prevent invasive species from spreading and to restore ecosystems affected by invasive species. However, they can't do it alone.

Here are a few things you can do to help:

- Know the native and invasive species in your area.
- Keep invasive species out of your yard.
- Contact officials when you notice new invasions.
- Spread the word. Educate yourself and others about the problem.
- Don't bring plants, animals, or soil between regions without first getting them inspected by officials.

Glossary of Key Terms

Bacteria – microscopic single-celled organisms that lack a nucleus.

Biodiversity – the variety of living organisms in an ecosystem. High biodiversity (many type of plants and animals) helps make an ecosystem more stable.

Cosmopolitan distribution – in biology this term means that a species occurs all around the world, or in most places in the world.

Co-invasion – two or more different species invading an area together.

Crop yield – amount of produce obtained from crop plants such as grains, fruits, or vegetables.

DNA (Deoxyribonucleic acid) – a material in the cells of all living things that carries the organism's genetic information.

Generalists – individuals that can do many kinds of tasks or interact successfully with many types of partners.

Invasive species – any kind of living organism that is not native to an ecosystem and causes harm. It can harm the environment, the economy, or even human health.

Legume – plants in the family that includes peas, beans, lentils, clover, soy, and acacia. Many legumes produce seeds in pea-like pods.

Native species – species that naturally occur in a particular area and that were not brought in by human activity.

Nitrogen fixation – a process by which nitrogen gas, which is abundant in the Earth's atmosphere is converted into forms of nitrogen that plants can use. Only bacteria can naturally fix nitrogen, but humans can use an industrial process to fix nitrogen.

Non-native species – a species that would not normally occur in a particular area, but was introduced to that area by human activity.

Mutualism/mutualistic – a long term relationship between organisms of different species in which each partner benefits from the activity of the other.

Rhizobia (rhizobium bacteria) – soil bacteria that fix nitrogen after becoming established inside root nodules of legumes. Rhizobia do not occur in legume seeds.

Root nodule – a swelling on the root of a legume plant, such as pea or clover, that contains rhizobia bacteria.

REFERENCES

La Pierre KJ, Simms EL, Tariq M, Zafar M, Porter SS (2017) *Invasive legumes can associate with many mutualists of native legumes, but usually do not.* Ecology and Evolution 7:8599–8611.
https://doi.org/10.1002/ece3.3310

Center for Invasive Species and Ecosystem Health: Invasive and Exotic Species of North America
https://www.invasive.org/

USDA: National Invasive Species Information Center
https://www.invasivespeciesinfo.gov/

Check your understanding

1 How does the mutualistic relationship between legumes and rhizobia benefit both organisms? Can you think of other mutualistic relationships?

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2 Why do invasive species cause problems?

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3 Can you hypothesize what might make a legume a good invader? What could make a legume a poor invader?

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4 What do you think: Could climate change be helping invasive species take over? If so, how?

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5 What are the invasive species in your area? Conduct research about the work done by government and organizations to prevent or remove them. How can you get involved?