Soil bacteria - help or hindrance for moving plants?

Abstract

Some plant species tend to spread easily across continents and to islands, either because people bring them deliberately or because the plants’ seeds hitchhike attached to human travelers and their stuff. We wanted to find out why some plant species spread more easily than others. Once a plant is introduced (on purpose or accidentally) to a new area, what allows it to establish and spread? To answer these questions, we studied the spread of legumes, a family of plants that includes peas and beans (Fig.1), as well as the mutualistic bacteria that live amongst some of their roots. Although these bacteria help some legumes grow in their native ranges, we found that the species of legumes that form mutualistic relationships with soil bacteria are less likely to colonize new areas than species of legumes without mutualistic bacteria.

Introduction

Plant and animal species in a given place evolve to live in a balanced way together – each species has enemies and competitors that keep population sizes from exploding out of control. But humans help many plant and animal species move around the world, by bringing them on purpose (like by planting Australian trees in California to try to grow lumber for tall wooden ships’ masts) or by accident (like by having a grass seed stuck in your socks when you fly from one continent to another). Sometimes plant species outside their native range can take over because they don’t have natural enemies to keep them in check. This can allow these plants to grow rampanty, blocking light from other plants and changing the habitat for animals that live there. Understanding how and why certain plant species invade new areas while others don’t is essential for conservation and land management. When a plant species relocates, it doesn’t just leave its enemies behind, it also leaves its friends: like the pollinators which help it reproduce, or the mutualistic bacteria around its roots that help it get nutrients from the soil.

We wanted to find out:
- Which factors help a non-native plant species establish in a new area?
- And how much do a plant’s ‘friends’ matter in helping invasive species spread?
Methods

To answer these questions, we studied a family of plants known as legumes (which includes clover, soybeans, and beans). Legumes are special because many of its species form a mutualistic relationship with bacteria called rhizobia. These live in nodules (small swellings) on their roots and help them convert nitrogen in the air into a form which the plant can use for food (Fig. 2). Because this specialized mutualistic relationship evolved a long time (roughly 55 million years) ago, most legumes grow poorly without rhizobia. But some legume species never evolved a mutualistic relationship with rhizobia (or lost it) and so can grow without their help.

Legumes are not born with rhizobia. Instead, they have to form the mutualistic relationship with soil bacteria that are available wherever their seeds land. Therefore, we hypothesized that legumes that rely on rhizobia might have a harder time getting established in a non-native location if their mutualistic bacterial partner wasn’t found there. To test this hypothesis, we compared the spread of legume species that were reliant on rhizobia to those that were not.

We closely examined several characteristics of 3,530 different species of legumes: the native and non-native ranges, whether they were trees or shrubs; whether they had human uses or not, and whether they needed rhizobia to grow or not. Then we used statistical analysis to see which factors corresponded most with a particular species’ ability to have a large non-native range.

Results

Our main findings (Fig. 3) were:

- Of all the legume species we studied, about one fifth (22%) have established outside their native range.
- Legume species that need rhizobia to grow are about half as likely to occur in a non-native range than legumes that don’t need rhizobia.
- Even if legumes with rhizobia do establish in a non-native range, they’re less likely to have established in several different non-native areas than legumes that do not need rhizobia.
- Legume species that humans use (for food, timber, or other uses) were much more likely to establish in non-native areas than legume species that humans don’t use, regardless of whether they were mutualistic with rhizobia or not.

Why do you think legumes that don’t need rhizobia show higher means in both graphs?

Dots show averages and lines extending out vertically from the dots are error bars which show the range of uncertainty in the estimates of the average.
Discussion

Our results show that mutualistic relationships with rhizobia really matter when it comes to the ability of legumes to colonize and establish in new areas around the world. In fact, partnerships with mutualistic rhizobia hindered the ability of legumes to spread to new areas, across multiple continents and islands. What does this mean for conservation and management? First, if we don't want more legumes to spread to non-native areas, we need to pay attention to the spread and distribution of rhizobia. Currently, scientists don’t fully know all the different types of soil bacteria and where they occur in the world, including rhizobia. It is hard to monitor bacteria directly, so we don’t know how much humans are themselves spreading rhizobia around. We think that scientists who work on invasive species should start researching more about the spread of mutualistic bacterial partners of plants, since intentional or accidental introductions of bacteria like rhizobia could allow invasive legumes to flourish in non-native areas.

Conclusion

Invasive species that establish and take over in new areas can compromise natural biodiversity. But there’s a lot we can do to help preserve the diversity of plants and animals that are native to where we live, even if invasive species are also present. You can plant native species in your garden and encourage your school and city to use native species in their landscaping. If you find out which native birds or insects in your area are being outcompeted by invasive species, you can plant the native flowers and plants they need for food.

Glossary of Key Terms

- **Bacteria** – microscopic single-celled organisms.
- **Biodiversity** – the variety of organisms that live in any given region. There is high biodiversity when there are many different types of plant and animal species in a region.
- **Competitor** – the species or organisms that struggle for the same resources within an environment.
- **Error bar** – a line through a point on a graph that represents the statistical uncertainty of the value of that point.
- **Hypothesize** – to scientifically predict, based on observation or previous knowledge.
- **Invasive species** – a non-native species that causes ecological or economic harm in its new environment.
- **Mutualism/mutualistic** – the way two organisms of different species exist in a relationship in which each individual benefits from the activity of the other. In our case, some legumes form a mutualistic relationship with rhizobia bacteria in the soil. Rhizobia help the legumes get nutrients and the legumes share food with the rhizobia.
- **Legumes** – a family of plants which include peas, beans, lentils, clover, soy, and acacia. Many legumes produce seeds in pea-like pods.
- **Leaf litter** – the decaying leaves of plants.
- **Non-native species** – a species that would not normally occur in a particular ecosystem. Human activities sometimes result in the introduction of non-native species.
- **Range** – the distribution of a species within a geographical area.
- **Rhizobia** – a type of soil bacteria which form mutualistic relationships with some legumes. Rhizobia live in nodules on the roots of legume plants. While inside the nodule, rhizobia convert nitrogen in the air to a form that the plants can use for food.
- **Species** – a group of similar organisms that are able to breed with each other.
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REFERENCES

https://www.nature.com/articles/ncomms14790

Pacific Northwest Research Station: “What is an invasive species?”
https://www.fs.fed.us/pnw/invasives/

New Mexico State University: “Nitrogen Fixation by Legumes.”
http://aces.nmsu.edu/pubs/_a/A129/

Check your understanding

1. Why are invasive species a problem?

2. What are some factors that determine whether a species exists outside of its native range?

3. Why do legumes that are *not* in living a mutualistic relationship with rhizobia invade new areas more often than legumes that are?

4. To prevent the spread of more legume species, why should scientists focus on learning more about rhizobia?