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# PROMOTING BENEFICIAL MICROORGANISMS

## TECHNICAL GUIDANCE DOCUMENT



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### INTRODUCTION

Beneficial soil microorganisms such as bacteria, fungi, and algae are found in high numbers in native soils and play an essential role in the functioning of natural plant communities. A teaspoon of productive soil generally contains between 100 million and 1 billion bacteria, the most common soil microorganism (NRCS 2012).

Bacteria ecosystem services including nutrient cycling, development of soil structure, disease suppression, improvement of infiltration and water retention. There are four general categories of bacteria. Nitrogen fixing bacteria develop a symbiotic relationship with legumes. The bacteria develop nitrogen fixing nodules on root hairs. The bacteria benefit the host plant by supplying nitrogen in exchange for carbohydrates. Nitrifying bacteria convert ammonium into a form of nitrogen (nitrite) that can be used by vegetation. Denitrifying bacteria convert nitrate into the gasses nitrous oxide or Nitrogen, this can have a water quality benefit in aquatic systems with high nitrate levels. Actinomycetes are effective at decomposing organic materials and are the source of the “earthy” smell of soil.



Upland seeding with inoculated legume seed.

The succession of bacteria and soil structure are linked to plant succession as a restoration site develops. On exposed soil photosynthetic bacteria develop first and fix atmospheric nitrogen and carbon and produce organic matter. They also immobilize nitrogen and other nutrients that initiate the nitrogen cycle in the soil and the growth of early successional plant species. As the vegetation community changes additional types of organic matter enter the system, providing new food sources for bacteria. As the plant community develops, different types of organic matter enter the soil and change the type of food available to bacteria. In turn, different types of bacteria develop that aid the development of soil structure, further promoting plant succession at the restoration site (NRCS Soil Quality Website 2012).

Nitrogen fixing bacteria (Rhizobia) is one type of bacteria that is often incorporated as part of restoration efforts as most prairie legumes have associated rhizobial bacteria that aid their growth and ability to fix nitrogen. Nitrogen is a limiting nutrient in many natural prairie environment legumes and rhizobia can help support the entire community. Not all restoration sites contain rhizobia suitable for use with legumes and inoculation with appropriate rhizobia is often necessary to aid the growth of legumes and to support other

plants. Rhizobia specific for most of the native legumes planted in Minnesota have been developed at the University of Minnesota. Without rhizobial bacteria inoculation

Fungi are microscopic organisms that grow between soils particles as long strands called hyphae. Fungi play an important role in soil and plant community health by performing important services including decomposition and nutrient cycling, as well as disease suppression, development of soil structure, increase soil infiltration and water retention.

Soil fungi are grouped into three categories. Decomposers convert organic matter into fungal biomass, carbon dioxide and organic acids that can be used by plants. *Pathogens* colonize roots of plants and can cause damage or kill plants, however, nematode-trapping fungi that parasitize disease-causing nematodes, and fungi that feed on insects may be useful as biocontrol agents. *Mutualists* (mycorrhizal fungi) colonize plant roots establish a symbiotic relationship with plants and benefit in the relationship by receiving 3-20% of the carbon produced by plants. Plants benefit by receiving increased nutrients and water transport, increased tolerance to heavy metals, and increased disease resistance. Mycorrhizae also improve soil structure and increase cycling of organic matter. *Ectomycorrhizae* grow on the surface layers of the roots and are commonly associated with trees, while *endomycorrhizae* grow within root cells and are commonly associated with grasses, row crops, vegetables, and shrubs ((NRCS Soil Quality Website2012).



Soil fungi play an essential role in ensuring ecosystem health and resiliency.

Mycorrhizae are associated with most plant genus. Some upland prairie plants that rely on mycorrhizae include warm season grasses such as big bluestem and Indian grass and forbs such as gray-headed coneflower, purple prairie clover, and round-headed bush clover (Miller 1997). They appear to be beneficial in prairie restorations on severely disturbed or nutrient poor soils. Seedlings of bur oak grow much quicker when mycorrhizae are incorporated into their root systems.

Mycorrhizae fungi Mycorrhiza can be lost from farming/tilling, soil removal, toxin/chemicals and inundating or over-irrigating upland soils. In determining if mycorrhizal fungi are needed for a site soil tests can be sent to lab for testing. If a site has been under row crop agriculture or otherwise disturbed the addition of mycorrhizae will likely be beneficial.

Algae can cover the soil surface in areas where plant cover is limited due to harsh conditions or disturbance. Algae often form symbiotic relationships with fungi, plants and animals. Ecosystem services provided by algae include soil stabilization and carbon, water and nitrogen cycling. Algae are not actively added to restoration sites but can often colonize sites during the restoration process.

## APPLICATION

**Mycorrhizal Inoculation** - Mycorrhizae fungi are very host specific and reliable sources of mycorrhizae are still being developed for use in restoration. Most efforts have focused on mass-producing mycorrhizal plant species in greenhouses with a native soil inoculum. In some cases soil or downed wood (for forested communities) can be collected from a donor site and be spread at a restoration site. Mycorrhizal fungi are most commonly incorporated by the inoculation of potted plants or by spreading soil, seed or pellets that have been inoculated in trenches or by broadcasting over the restoration site. When handling and broadcasting mycorrhizae fungi it is important to wear a dust mask. Broadcasting of inoculants should be conducted after seeding is complete and evenly over the site. Light raking or harrowing will help cover and protect the inoculant.

In addition to the use of nitrogen fixing bacteria and mycorrhizae fungi, certain steps can be taken during the restoration process to promote microorganisms. For example, site preparation methods can have a big influence on the health of microorganism communities. Tilling and chemical application can decrease bacteria and fungi populations. As a result, there are often benefits to not tilling sites that have intact soil structure. Fields that have been in agricultural production may benefit from the planting of cover crops to allow a season or longer for soil structure and associated microorganisms to re-develop prior to seeding permanent seed mixes. Areas of restoration sites that have intact components such as remnant vegetation can be important to protect during the restoration process, as these areas can act as sources for beneficial bacteria as other components of a restoration develop. Inundation can decrease populations of microorganisms so it is important to avoid inundating upland intact upland soils.



Native clovers are legumes that benefit from bacterial inoculation

**Bacterial Inoculation** - Inoculum is typically mixed directly with legume seeds prior to seeding. During inoculation seed, inoculants and a sticker that binds microorganisms to the seed are mixed until the seeds are uniformly covered. Inoculation is available from vendors for a number of genus used in restoration. It is important to mix inoculum with seed shortly before seeding and to protect inoculated seed from drying. There have also been efforts to mix inoculum into the cover crop that will be used for a project as a means to increase the amount of inoculum in the soil of the restoration site. It is important to check with vendor providing seed mixes to ensure that appropriate bacterial inoculum is included with legumes.

## OTHER CONSIDERATIONS

Repeated tilling or chemical use can decrease microorganism populations. Temporary cover crops can be used to allow time for microorganism populations to increase prior to seeding permanent seed mixes. The use of inoculum can give a competitive advantage to native species, decreasing maintenance needs.

## COSTS

The use of temporary cover crops tends to be \$20-50 per acre installed. Bacterial inoculum costs around \$1.00 to \$2.00 per genus requiring inoculation in a mix. Mycorrhizal inoculum costs from \$30-\$60 per acre.

## ADDITIONAL REFERENCES

The Tallgrass Restoration Handbook for Prairies, Savannas, and Woodlands, Packard, S., Mutel, C.F.

Use of mycorrhizal inoculum as a soil amendment during prairie restoration. Tallaksen, [www.hort.agri.umn.edu/h5015/rrrmain.htm](http://www.hort.agri.umn.edu/h5015/rrrmain.htm).