COMMERCIAL MICROBIAL INOCULANTS AND
INOCULATED TRANSPLANTS FOR RECLAMATION1

TIM WOOD2

Abstract.—Inoculation of seed and containerized plants with mycorrhizal fungi and nitrogen-fixing bacteria can enhance the establishment of grasses, forbs, shrubs, and trees on reclaimed lands. At present a variety of microbial inoculants and inoculated transplants are commercially available and should be considered for use by reclamation specialists. Guidelines for determining the need for inoculants, for specifying strains to be used, and for ordering and applying inoculants and inoculated transplants are discussed.

INTRODUCTION

Mycorrhizal fungi and symbiotic nitrogen-fixing bacteria should be considered by reclamation specialists as tools for improving plant establishment and speeding the recovery of disturbed lands. Four groups of these microorganisms are of particular importance. These are: (1) vesicular-arbuscular (VA) mycorrhizal fungi which associate with most grasses, forbs, and broadleaved trees and shrubs (Powell and Bagyaraj, 1984); (2) ectomycorrhizal fungi which associate with many woody plants including oaks, willows, pines, firs, and spruces (Marks and Kozlowski, 1973); (3) bacteria in the genus Rhizobium which fix nitrogen in association with most legumes (Burton, 1980); and (4) actinomycetes (filamentous bacteria) in the genus Frankia which fix nitrogen with a variety of woody dicots including species in the genera Alnus, Cercocarpus, Purshia, Cowania, and Ceanothus (Kerkman et al., 1984). Mycorrhizal fungi generally benefit plants through improved uptake of phosphorus, trace metals, and other sparingly soluble nutrients. Nitrogen-fixing bacteria convert atmospheric dinitrogen to ammonium-nitrogen, a form that plants can readily use. Both classes of organisms typically improve plant growth and survival, particularly on relatively sterile, infertile soils. As such, these microbes hold considerable potential for use as inoculants to improve the establishment of vegetation on reclaimed lands.

At present, a variety of microbial inoculants and inoculated plant materials are commercially available for use in reclamation. This paper discusses guidelines for determining the need for inoculation, for specifying the microbial strains to be used, and for purchasing and applying microbial inoculants and inoculated transplants.

DETERMINING THE NEED FOR INOCULATION

While many studies have shown that inoculations with mycorrhizal fungi and nitrogen-fixing bacteria can enhance the establishment of plants on disturbed lands (Daft and Hacskaylo, 1977; Berry and Marx, 1978; Lambert and Cole, 1980; Call and McKell, 1984), it is not safe to assume that inoculations will prove cost effective in all instances. On-site test plots, comparing the growth and establishment of inoculated and non-inoculated plants, offer a direct approach to analyzing the need for inoculation, and it is recommended that such tests be run whenever feasible. When trials are not feasible, the reclamation specialist can consider several rules of thumb in judging the potential need for inoculation.

1 Paper presented at the National Meeting of the American Society for Surface Mining and Reclamation. [Denver, Colorado, October 8-10, 1985]
2 Tim Wood, Senior Scientist, NPI, Salt Lake City, Utah.

Proceedings America Society of Mining and Reclamation, 1985 pp 314-321
DOI: 10.21000/JASMR85010314
https://doi.org/10.21000/JASMR85010314
(2) If plants such as conifers or alders, with fairly specific inoculant requirements, are
introduced onto sites where they have not grown before, they are likely to benefit from inoculation
(Nikola, 1980). Again, natural populations of the
required symbionts will probably be low.

(3) Inoculation typically proves most cost
effective when conditions for plant growth are
suboptimal-to-marginal, and when the principal
limitations on plant growth are soil infertility
and perhaps drought. If site conditions are so
severe (e.g. extremes in soil fertility, moisture
availability, salinity, and metal toxicities) that
plants cannot survive regardless of their
mycorrhizal or nodulation status, then inoculation
isn't going to help. Similarly if conditions are
extremely favorable for plant establishment,
performance may be little enhanced by inoculation.
(Note, however, that inoculation can generally
improve the establishment of transplants when other
conditions for plant growth are favorable. During
the establishment period root systems of container-
ized plants are confined to fairly small soil
volumes and are thus subject to moisture and
nutrient stress. Inoculations with mycorrhizal
fungi, in particular, can aid plants in more fully
tapping that restricted soil volume for nutrients
and water (c.f. Menge et al., 1978).)

(4) Plant species differ in their dependency
on mycorrhizal fungi. Some plants including many
grasses and annual forbs have finely divided root
systems and have lesser requirements for inocula-
tion than do plants with thicker roots and few
root hairs (Baylis, 1974). Other plants are non-
mycorrhizal and don't require or form the association
(Gerdemann, 1968). Similarly, only a
limited number of plants form Symbiotic nitrogen-
fixing associations. Specific information on the
mycorrhizal dependency and nodulation status of
given plants can be obtained from local special-
ists and inoculum producers.

STRAIN SPECIFICITY

Considerable variation in effectiveness (plant
growth promoting ability) exists between strains of
mycorrhizal fungi and nitrogen-fixing bacteria.
Estimates suggest that for a given plant host in
a given soil, the most effective strains should be
2-3 times more active in promoting plant growth
than the average strain (Abbott and Robson, 1977;
Wood and Dalling, in press). Given this
variability, considerable attention should be paid
to selection of elite bacteria and fungi, best
adapted for specific hosts and site conditions.

Rhizobium bacteria are host specific and have
been divided into a number of cross-inoculation
groups, i.e. groups of plants that are nodulated
by a common strain (Burton, 1980). Six Rhizobium
species have been named in conjunction with these
groups. Four of importance to reclamation are
Rhizobium mellioli for Medicago (alfalfa) and
Mellotus species, R. trifoli for Trifolium
(clover) spp., R. leguminosarum for Vicis (vetch)
and Lathyrus (pea) spp., and R. lupinum for Lupinus
(lupine) spp. Other cross inoculation groups
exist, and complete lists of host-Rhizobium com-
patibilities can be obtained from inoculum suppliers
(Burton and Martinez, 1980).

Rhizobium strains also differ in site prefer-
ences, i.e. in tolerances for extremes in soil pH,
soil moisture, and soil temperature, and in sus-
ceptibilities to biotic stresses including com-
petitors, predators, and parasites (Lowendorf,
1980). Again, information on the adaptations of
specific strains can be obtained through inoculum
suppliers and local specialists.

Frankia strains show a degree of host specifi-
city. Two cross inoculation groups have been
broader defined but no species names have been
assigned (Baker et al., 1981). Little is known
about the ecological specificity of Frankia strains.

VA mycorrhizal fungi show little if any host
specificity. Under proper conditions, most strains
can colonize most plants. Some site specificity
though has been shown. Some species (e.g. Glomus
mossasa) tend to prefer soils with near neutral
soil pH's, while others (e.g. Acaulospora lagei)
prefer more acid conditions (Young et al., 1985).
Some isolates appear more tolerant of high phos-
phorus soils than do others (Hayman et al., 1976).
There is undoubtedly additional variation between
strains for tolerances to extremes in soil moisture
and soil temperature although these have not been
well documented. Again, it would be prudent to
contact inoculum producers and local specialists
for advice on site-specific strain selection.

Ectomycorrhizal fungi and their hosts show
varying degrees of microbe-host specificity.
Many pines and firs, for example, can be colonized
by a wide range of ectomycorrhizal fungi (Molina
and Trappe, 1982) while plants such as alders and
poplars tend to be more selective (Molina, 1981).
Differences in tolerances for specific soil condi-
tions (e.g. organic matter content) have been
demonstrated between some fungi, but there are few
such studies, and generalizations cannot be made
at this time. Again, it would be worthwhile con-
tacting inoculum producers and local specialists
for advice on site-specific strain selection.

For situations in which little is known con-
cerning strain specificity, on-site test plots
comparing the performance of several inoculant
strains should be considered as a means of obtain-
ing specific information.

COMMERCIAL AVAILABILITY OF INOCULANTS AND
INOCULATED TRANSPLANTS AND GUIDELINES
FOR ORDERING MATERIALS

Table 1 summarizes information on the avail-
ability of microbial inoculants. Names of pro-
ducers/distributors, and their product lines are
given for the various groups of nitrogen-fixing
bacteria and mycorrhizal fungi.

While many of the Rhizobium inoculants commonly
used in agriculture can be purchased off of the
Most distributors of native and rangeland seeds will precoat legume seed with appropriate Rhizobium strains upon request. Precoating is not a standard practice in the Intermountain West, and reclamation specialists should specify pre inoculation if it is desired. Lead times of 3-4 weeks may be required for precoating.

Frankia inoculants are available on a limited basis from two companies, Rhizotec in Canada and NPI in Salt Lake City, UT. All Frankia inoculants must be custom ordered several months in advance, as these organisms grow slowly. Strains suitable for use with Alnus spp. are the most available and easy to use. Production and use of inoculants for P. tinctorius, C. laccata, and H. sp. A dozen other fungal strains are in various stages of research and development. The company expects to be in full-scale commercial production of ectomycorrhizal inoculum by 1987.

Vegetative ectomycorrhizal inoculum is available in limited quantities from Sylvan Spawn Laboratory, Inc. in Kittanning, PA. Sylvan Spawn will produce commercial batches, in multiples of 90 liters, on an advanced order basis. Two to three months of lead time are required. At present the company produces inoculum of Pisolithus tinctorius, Laccaria laccata, and H. sp. A dozen other fungal strains are in various stages of research and development. The company expects to be in full-scale commercial production of ectomycorrhizal inoculum by 1987.

Two companies, Mycor Tec in Greenville, CA and International Forest Seed Co. in Odenville, AL, sell spores of Pisolithus tinctorius, an ectomycorrhizal fungus that has benefited the establishment of pines on disturbed lands in the Southeast.

SUMMARY

Microbial inoculants, containing mycorrhizal fungi and nitrogen-fixing bacteria, are commercially available for use in reclamation. Inoculation should be considered, especially when reclamation plans involve severely disturbed soils and/or microbially dependent plant species. In purchasing inoculants, reclamation specialists should consider three points: (1) Strains of mycorrhizal fungi and nitrogen-fixing bacteria show varying degrees of host and site specificity and efforts should be made to select the most effective strains for a particular project; (2) Most microbial inoculants and inoculated transplants must be custom ordered with lead times varying from 3-4 weeks to 12-18 months; (3) Application of many microbial inoculants is not a routine undertaking, and reclamation specialists should not only consult with inoculum suppliers and other experts in developing their reclamation strategy, but also consider the use of experimental plantings as a means for determining inoculation needs, identifying superior strains, and developing efficient inoculation techniques.

APPLICATION

Microbial inoculants are most efficiently applied to reclaimed soils in direct conjunction with plant materials. Rhizobium inoculants should be included in seeds prior to sowing. Frankia, VA mycorrhizal, and ectomycorrhizal inoculants should be applied to seedlings in nurseries, and the preinoculated plants, with their microbial associations established, should then be transplanted into the field. Broadcast dispersal of inoculants directly onto reclaimed soils is an inefficient means of application and should be avoided. If inoculants have to be applied directly to field soils, they should be placed directly beneath seed or transplant by hand or with a fertilizer drill. Reclamation specialists can consult with inoculum suppliers or other specialists concerning proposed application techniques. Again, because microbial inoculations are not routine in many instances, experimental test plots can be helpful in establishing effective application methods.
Table 1. Sources of microbial inoculants and inoculated transplants. Some materials are available on a regular commercial basis (+) while others must be custom ordered (custom).

<table>
<thead>
<tr>
<th>Producer/Distributor</th>
<th>Bulk Inoculum</th>
<th>Inoculated Seed/Plants</th>
<th>Starter Cultures</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHIZOBIUM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitragin Sales Corp., Milwaukee, WI</td>
<td>+/Custom</td>
<td>+</td>
<td>CUSTOM</td>
</tr>
<tr>
<td>Kalo Industries, Kansas City, MO</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Urbana Laboratories, Urbana, IL</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Local Seed Companies</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>NPI, Salt Lake City, UT</td>
<td>CUSTOM</td>
<td>Custom</td>
<td>+</td>
</tr>
<tr>
<td>Local Universities</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>FRANKIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPI, Salt Lake City, UT</td>
<td>CUSTOM</td>
<td>Custom</td>
<td>+</td>
</tr>
<tr>
<td>Rhizotec Laboratories, Canada</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Local Universities</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>VA MYCORRHIZAL FUNGI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPI, Salt Lake City, UT</td>
<td>+/Custom</td>
<td>Custom</td>
<td>+</td>
</tr>
<tr>
<td>Local Universities</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>ECTOMYCORRHIZAL FUNGI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sylvan Spawn Laboratory,</td>
<td>CUSTOM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worthington, PA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mycor Tec, Greenville, CA</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>International Forest Seed Co., Odenville, AL</td>
<td>+</td>
<td>CUSTOM</td>
<td></td>
</tr>
<tr>
<td>Select Nurseries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPI, Salt Lake City, UT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Universities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. Forest Service</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LITERATURE CITED


References


