

## Introduction

Myconate contains the biologically active isoflavone formononetin which is a natural signaling compound. The formononetin in Myconate is well documented for its ability to stimulate the colonization of mycorrhizal fungi, it has been shown to increase the rate and extent of VAM (Vesicular-Arbuscular Mycorrhizal) fungal colonization. Spore germination, growth direction and rate of VAM are all affected. Most soils have an ample supply of mycorrhizae and Myconate facilitates their germination and draws these beneficial organisms to the crops roots effectively and rapidly.

When applying Myconate to encourage root colonization by natural or applied mycorrhizal fungi inoculants, it is important to consider what effect any planned fungicide treatments may have on this goal. Mycorrhizal fungi can be quite sensitive to certain fungicides, but by no means all of them. Moreover, sensitivity can be influenced by the method of application of the fungicide. Some fungicides may actually stimulate mycorrhizal fungi, while others may be detrimental.

The available literature in this field and has been compiled and the following lists of fungicides for which published data exists regarding their effect on mycorrhizal fungi. The detailed data tables and references are provided later in this document. Furthermore, based on field tests, there are some general rules regarding fungicide use in this context. These rules are presented here:

### General Rules Regarding Use of Fungicides with Mycorrhizal Fungi Inoculants:

1. Typically, **foliar application of nonsystemic fungicides** (applied at label rates) has very little impact on mycorrhizal fungi, which reside on the roots. Even though some fungicide material may reach the soil, the amount reaching the actual root zone is usually too low to have any significant, long-term effect on mycorrhizal fungi.
2. **Soil drench applications of nonsystemic fungicides** (applied at label rates) can be detrimental to mycorrhizal fungi particularly if applied before root colonization takes place. This method places the greatest fungicidal load at the root zone and is therefore the method most likely to cause harm to mycorrhizal fungi. Because of this, it is important to avoid using soil drench fungicides too close to

inoculation time. Once spores have thoroughly colonized the roots, mycorrhizal fungi tend to be less sensitive to detrimental, **nonsystemic** fungicides applied by soil drench because:

- a. fungicide levels will be high in the soil, but tend to be considerably lower inside root tissue.
  - b. high levels of fungicides in soil can kill off fungal tissue in the soil, but not fungal tissue embedded inside the root.
  - c. when fungicide levels in soil diminish from leaching or gradual degradation, fungal tissue inside the root will grow a new absorbing network out into the soil to restore the mycorrhizal effect.
3. Foliar or soil applications of **systemic fungicides** can lead to accumulation of fungicide in the root tissue having a negative impact on mycorrhizal fungi. In general, roots of treated plants are not susceptible to colonization by mycorrhizal fungi for up to 3 weeks after systemic fungicide treatment.
  4. In general, **fungicidal seed treatment** effects on mycorrhizal colonization are minor and inconsistent across species. Even though some fungicides have been shown to have deleterious effects when applied as a soil drench, it appears that the low rates needed for seed treatment dissipate sufficiently to allow for root colonization during early growth.

### Summary of Fungicide Use with Mycorrhizal Fungi:

1. **Foliar nonsystemic** fungicides typically can be used at any time.
2. Avoid using **soil drench** fungicides too close to the time of inoculation, that is, two weeks before inoculation (longer if systemic) and four weeks after inoculation.
3. **Seed treatment** fungicides are generally safe due to the low rates used and rapid dissipation in the soil and roots.
4. **No fungicides eradicate either target fungi or mycorrhizae**; they only decrease development for a

**Always read and follow label instructions before using this product.**

Myconate<sup>®</sup> are a registered trademarks of Plant Health Care, Inc., US Patents 5,002,603 - 5,085,682 - 5,691,275 - 5,981,775. Other patents pending.

# Effects of Fungicides on Mycorrhizal Fungi and Root Colonization

short time after application. The duration of this effect depends on the length of time for which the chemical persists in the environment.

## REVIEW OF PUBLISHED DATA ON SPECIFIC FUNGICIDAL EFFECTS ON MYCORRHIZAL FUNGI AND ROOT COLONIZATION:

The compiled list, from published data, the following lists of fungicidal effects on mycorrhizal fungi.

1. In this data summary, seed treatments are considered separately from all other applications, and effects on vesicular arbuscular mycorrhizae (VAM) and ectomycorrhizae are also listed separately.
2. The data is tabulated alphabetically by fungicidal a.i.
3. The reported effects are classified as either positive (P), no effect (O) or negative (N) and in each case a number signifying the reference is provided as a superscript to the letter. The complete list of references is provided at the foot of each Table.

**TABLE 1: Reported Effects of Seed Treatment Fungicides on Vesicular Arbuscular Mycorrhizae and Root Colonization:**

FUNGICIDE A.I.	EFFECT	COMMENTS
Azoxystrobin [strobilurin]	O <sup>x</sup>	In corn, soybeans and wheat
Carbendazim [benzimidazole]	N <sup>3</sup>	In peanuts
Captan [phthalimide]	O <sup>1</sup>	In zucchini and corn captan reduced root colonization [albeit inconsistently] but did not do so at all in tomato.
Emisan [MEMC mercuric]	N <sup>3</sup>	In peanuts
Fludioxonil [phenylpyrrole]	P <sup>2</sup> /P <sup>4</sup>	In soybeans
Fludioxonil + Mefenoxam	N <sup>2</sup> /P <sup>4</sup>	In soybeans
Copper oxychloride	P <sup>3</sup>	In peanuts
Mancozeb [dithiocarbamate]	N <sup>3</sup>	In peanuts
Mefenoxam [acylalanine]	O <sup>1</sup> /N <sup>2</sup> /O <sup>4</sup>	in soybeans only
Metalaxyl [acylalanine]	O <sup>x</sup>	In corn, soybeans and wheat
Tebuconazole [triazole] +Metalaxyl	O <sup>1</sup>	In corn, tomato, zucchini and muskmelon
Thiram [dithiocarbamate]	O <sup>1</sup> /N <sup>3</sup>	O in corn and muskmelon, N in peanuts
Ziram [dithiocarbamate]	N <sup>3</sup>	In peanuts

### TABLE 1: Commentary:

From this table it is clear that most of the modern, widely used seed treatment fungicides are safe for VAM fungi, having zero or even positive effects on mycorrhizal colonization.

The exceptions, those reported as having negative effects, tend to be older fungicides, most of which are not in common use for seed treatments today, having been replaced by the more modern fungicides. Mancozeb, thiram and ziram are all dithiocarbamates so, as a group, these appear to be deleterious to mycorrhizal fungi, at least when tested in peanuts but thiram was not deleterious in corn or muskmelon. Emisan (a mercuric treatment) and carbendazim [a benzimidazole] were both negative for mycorrhizal fungi but again, have only been tested in peanuts. Copper, however appeared to provide a stimulus to mycorrhizae in peanuts. Captan (a phthalimide) reduced root colonization inconsistently in corn and zucchini but not in tomato.

Neutral or positive effects have generally been recorded for azoxystrobin [strobilurin], fludioxonil [phenylpyrrole], mefenoxam and metalaxyl [acylalanines], tebuconazole [triazole] and thiram (in corn) and these materials are in very common use in seed treatments in major crops today. Negative mycorrhizal responses to mefenoxam in soybeans have been reported but not in other crops. This is consistent with some mixed reports for metalaxyl on mycorrhizal fungi so some crop, or mycorrhizal species, effects may be in play here.

TABLE 2: Reported Effects of Fungicides on Vesicular Arbuscular Mycorrhizae and Root Colonization [applied other than as seed treatments]:

Common Name	Trade Name	Endo Mycorrhizae Recommendation
Azoxystrobin	Heritage, Quadris	OK
Azoxystrobin + Propiconazole	Quilt	Avoid use
Banrot	Banrot	N.A.
Benodamil	Bayleton	Avoid use
Boscalid, 3-pyridinecarboxamide,2-chloro- N-(4'-chloro(1,1'-biphenyl)	Endura	OK
Caplan	Caplan, Orthocide	Avoid use
Carboxin + Thiram	Vitavax	OK
Chloroneb	Terraneb SP, Terremec SP+B14	No effect at low rate, tends to suppress at high rate
Chlorothalonil	Bravo Plus, Chloroflo, Chlortosip, Chloronil,	OK
Copper Hydroxide	kocide	OK
Cyproconazole	Sentinel	OK
Difenoconazole + Metalaxyl	Dividend	OK
Difenoconazole + Fludioxonil + Mefenoxam + Thiamethoxam	Acceleron®	OK
Dithiocarbamates	Ferbam	Minimal effect at low to moderate rates, possible suppression at high rates
Ethylenebisdithiocarbamate ion (EBDC) i(C4H6N2S4I	Powerline MZ	OK
Etridiazole	Koban	Insufficient data
Fenamiosulf	Lesan	Insufficient data
Fenarimol	Rubigan	Avoid use
Fludioxonil, 70- N-[3-(1-methylethoxy) ! phenvll-2-(trifluoromethyl)	Maxim 4F, Maxim MZ	OK
Folpet	Phaltan	Avoid use
Folpet	Cleary's 3336, Fungo, Systec 1998, SenatorWSB	OK
Fosetyi-AL	Alliette, Prodigy, Alliette Signature	OK
Ipconazole	Rancona	OK
Iprodione	Rovral, Chipco 26019	OK
Mancozeb (EBDC)	Manzate, Manzate flowable, Fore, Nubark MZ,	OK
Maneb (EBDC)	Maneb. Mancozeb	OK
Metalaxyl-Ridomil	Apron / <i>Subdue Maxx</i>	OK
Myclobutanil	Eagle, Rally, Systhane	OK
Olpisan	Olisan	Insufficient data
Penflufen + Prothioconazole	Titan Emesto / Emesto Silver	OK
Pentachloronitrobenzene	Blocker	Avoid use
Propamocarb	Banol, Previcur, Proplant	OK
Propiconazole	Stratego, Banner MAXX, Dorado, Tilt	Avoid use
Pyraclostrobin	Headline	OK
Quintozene	PCNB Terrachlor, Turfcide	No effect at low rate, tends to suppress at high rate
Tebuconazole	Folicur®, Folicur 3.6	OK
Tebuconazole + Metalaxyl	Raxil xt	No negative effects when used as a seed treatment. Avoid drench applica-
Tebuconazole + Thiram	Raxil Thiram	OK
Thiamethoxam + Mefenoxam + Fludioxonil	Cruiser Maxx	OK
Thiazole	Benomyl, Benlate, Tersan 1991	Avoid use
Thiophanate-methyl/ Etridiazole	Banrot	Insufficient data
Thiram	Thiram, Tersan 75	OK
Triadimefon	Bayleton	Avoid use
Zinc ethelene bisdithiocarbamate	Dithane	OK
Zinc white	Zinc oxide	N.A.
Ziram	Ziram	N.A.

General Observations: Most foliar sprays of any fungicide (except systemics such as Bayleton) have little effect on Mycorrhizal Fungi.

## Effects of Fungicides on Mycorrhizal Fungi and Root Colonization

The Table above can best be summarized by listing the fungicide classes that have provided a neutral or positive result compared with those with negative reports. These divisions can be further divided into those with multiple or single results. Such a summary follows:

**TABLE 2: Breakdown of Reports by Fungicide Classes and Number of Reports:**

Fungicide Classes	No. of compounds in given class with:				
	Multiple Reports			Single Reports	
	Neutral/ Positive	Even	Negative	Neutral/ Positive	Negative
acyclalanines	1				
aromatic hydrocarbons	1		2		2
benzimidazoles	2		1		
carbamates/ dithiocarbamates	4			1	
carboxamides/ dicarbox- amides	2		2	1	
chloronitriles	1		1		
copper compounds			1		
fenaminosulf				1	
hydroxyanilides				1	
imidazoles			1		
morpholines		1		1	
oxine benzoate				1	
phenylpyrroles				1	
phosphonates	1				
Phosphoro thiolates				1	
phthalimides			2	1	
piperazines	1				
pyrimidines / OH pyrimidines	1			1	
pyridines				1	
strobilurins	1				
sulfamides		1			
sulfur compounds	1				
thiadiazoles			1		
thiazoles			1		1
thiophanates	1				
triazoles			2	3	1