THE EFFECT OF *Bacillus subtilis* AND *Rhizobium* INOCULATION OF DRY BEAN SEED ON ROOT ROT SEVERITY AND YIELD IN MINNESOTA

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Dry bean root rot in Minnesota is caused primarily by *F. solani* f. sp. *phaseoli* in a complex with *R. solani* and *F. oxysporum*. Seed treatment with *Bacillus subtilis* reduces disease severity (DS) but *Rhizobium* inoculation can result in significantly reduced root rot and increased yield. The objectives of this study were 1) to determine the effect of *Bacillus subtilis* on the incidence and severity of bean root rot, 2) to compare a conventional and granular formulation of *Bacillus subtilis*, and 3) to determine effectiveness of root-rot control with co-inoculations of *Bacillus subtilis* (MBI600 or GBO3) and *Rhizobium tropici* UMR 1899 and *Rhizobium leguminosarum* RCR3622 (HiStick). Two experiments were conducted in Verndale, MN in a sandy loam (USDA classification). In the first experiment the seed treatments had no effect on plant emergence. However, seed treated with either *B. subtilis* MBI600 or GBO3 and *Rhizobium* UMR 1899 reduced bean root rot and increased yield, when compared to untreated plants (Table 1). All treatments that included *B. subtilis* or *Rhizobium* outyielded the standard seed treatment (Captan+Lorsban+ Streptomycin) (SST) by approximately 120 to 400 kg ha^{-1}. Co-inoculation with *B. subtilis* MBI600 and *Rhizobium* UMR1899+RCR3622 reduced DS and enhanced yield (1,904 kg ha^{-1}) relative to the untreated control (1,498 kg ha^{-1}) and SST (1,415 kg ha^{-1}) treatments (Table 1).

In the second experiment no differences were detected in plant emergence. Disease severity decreased with all treatments and the lowest DS was obtained with *Bacillus subtilis* MBI600 applied to the seed plus a granular application of *Rhizobium* UMN 1899 (DS 3.1) (Table 2). The use of a granular formulation with *Rhizobium* UMR 1899 applied to the soil as well as the peat formulation was efficient in significantly increased yield (2,302 kg ha^{-1}) relative to the untreated control (1,812 kg ha^{-1}). In contrast the granular formulation of *Bacillus subtilis* MBI600 was not as efficient as the seed application (Table 2). In most of the treatments the response to inoculation with *Rhizobium* UMR 1899 improved yield probably due to a combination of factors, improved nitrogen fixation and decrease of disease severity. When *Bacillus subtilis* MBI600 alone was applied to seed (2,167 Kg/ha) or combined with a granular treatment of *Rhizobium* UMR 1899 (2,019 Kg/ha) yields were increased, compared to the untreated (1,812 Kg/ha). Seed inoculation of *Rhizobium* had an effect on dry bean, reducing DS, increasing root dry weight and improving yield. Seed inoculation with *Rhizobium* alone increased dry bean yield (2,040 kg ha^{-1}). Inoculation of dry beans with a co-formulation of *Bacillus subtilis* and *Rhizobium* in a peat carrier can alleviate the effects of bean root rot.

Table 1. Effect of dry bean seed inoculation with *Rhizobium* and *Bacillus subtilis* on disease severity, root and plant dry weight and yield in Verndale, MN in 2001

Treatment	Disease severity 1-9	Root dry weight (g)	Plant dry weight (g)	Yield Kg/ha
Rhizobium tropici 1899 + *Rhizobium* RCR3622 + *Bacillus subtilis* MBI600 (seed)	4.2 b	1.98 a	7.32 ab	1,904 a
Rhizobium tropici 1899 + *Rhizobium* RCR3622	4.1 b	1.70 ab	9.00 a	1,806 ab
Bacillus subtilis GBO3 (seed)	3.7 b	1.76 ab	8.70 a	1,782 ab
Rhizobium 3622 (seed)+*B. subtilis* GBO3 (seed)	4.1 b	1.83 a	7.21 ab	1,779 ab
Bacillus GBO3 (seed)	4.3 b	1.81 a	8.94 a	1,763 a
Rhizobium 3622 (seed)	3.6 b	2.10 a	8.78 a	1,630 abc
Bacillus MBI600 (seed)	4.2 b	1.36 ab	7.09 ab	1,626 abc
Untreated Seed	6.3 a	0.89 b	6.00 b	1,498 bc
Captan+Streptomycin+Lorsban	5.8 a	1.78 a	7.00 ab	1,415 c

[1]Different letters within a column are significant different by LSD 5%

Table 2. Effect of dry bean inoculation with *Rhizobium* and *Bacillus subtilis* on disease severity, plant and root dry weight and yield in Verndale, MN in 2001

Treatment	Disease severity 1-9	Root dry weight (g)	Plant dry weight (g)	Yield Kg/ha
Rhizobium tropici 1899 (granular-soil)	4.6 ab[1]	0.94 ab	7.4 ab	2,302 a
Bacillus subtilis MBI600 (seed)	4.8 ab	0.92 ab	6.8 ab	2,167 ab
Captan+Streptomycin + *Rhizobium* 1899 (granular)	4.3 b	0.8 b	7.4 ab	2,066 ab
Rhizobium 1899 (seed)	4.3 b	0.8 b	6.8 ab	2,040 ab
Rhizobium 1899 (granular) + *Bacillus* MBI600 (seed)	3.1 c	0.8 b	6.9 ab	2,019 ab
Rhizobium 1899 (seed) + *B. subtilis* MBI600 (seed)	4.8 ab	0.9 b	7.0 b	1,985 ab
Captan+Streptomycin + MBI600 (granular) + *Rhizobium* 1899 (granular)	5.0 ab	0.75 b	5.9 ab	1,956 ab
Captan + Streptomycin	4.6 ab	0.96 ab	8.0 ab	1,907 ab
Captan+Step +*B. subtilis* MBI600 (granular)	4.5 b	1.32 a	8.6 a	1,904 ab
Rhizobium UMR1899 (granular) + *B. subtilis* MBI600 (granular)	4.2 b	1.09 ab	7.8 ab	1,883 ab
Untreated Seed	5.8 a	0.89 b	5.6 b	1,812 b
B. subtilis MBI600 (granular)	4.8 ab	0.82 b	6.8 b	1,746 b

[1]Different letters within a column are significant different by LSD 5%