# Fusarium wilt incidence and common bean yield according to the preceding crop and the soil tillage system

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Abstract – The objective of this work was to evaluate the effects of preceding crops and tillage systems on the incidence of Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*) and common bean (*Phaseolus vulgaris*) yield. The cultivar BRS Valente was cultivated under center-pivot irrigation in the winter seasons of 2003, 2004 and 2005, after several preceding crops established in the summer seasons. Preceding crops included the legumes *Cajanus cajan* (pigeon pea), *Stylosanthes guianensis*, and *Crotalaria spectabilis*; the grasses *Pennisetum glaucum* (millet), *Sorghum bicolor* (forage sorghum), *Panicum maximum*, and *Urochloa brizantha*; and a consortium of maize (*Zea mays*) and *U. brizantha* (Santa Fé system). Experiments followed a strip-plot design, with four replicates. Fusarium wilt incidence was higher in the no-tillage system. Higher disease incidences corresponded to lower bean yields in 2003 and 2004. Previous summer cropping with *U. brizantha*, *U. brizantha* + maize consortium, and millet showed the lowest disease incidence. Therefore, the choice of preceding crops must be taken into account for managing Fusarium wilt on irrigated common bean crops in the Brazilian Cerrado.

Index terms: *Fusarium oxysporum*, *Phaseolus vulgaris*, crop-livestock integration, crop rotation, no-tillage, soilborne pathogen.

## Incidência da murcha-de-fusário e produção do feijoeiro de acordo com cultivos prévios e sistemas de preparo do solo

Resumo – O objetivo deste trabalho foi avaliar os efeitos de cultivos prévios e sistemas de preparo do solo sobre a incidência de murcha-de-fusário (*Fusarium oxysporum* f. sp. *phaseoli*) e a produtividade do feijoeiro-comum (*Phaseolus vulgaris*). A cultivar BRS Valente foi cultivada sob irrigação por pivô central nos invernos de 2003, 2004 e 2005, após diversos cultivos prévios estabelecidos no verão. Os cultivos prévios incluíram as leguminosas *Cajanus cajan* (guandu), *Stylosanthes guianensis* e *Crotalaria spectabilis*; as gramíneas *Pennisetum glaucum* (milheto), *Sorghum bicolor* (sorgo-forrageiro), *Panicum maximum* e *Urochloa brizantha*; além de um consórcio entre milho (*Zea mays*) e *U. brizantha* (sistema Santa Fé). Os experimentos seguiram o delineamento em faixas, com quatro repetições. A incidência da murcha-de-fusário foi maior no sistema plantio direto. As maiores incidências da doença corresponderam ao menor rendimento do feijão-comum em 2003 e 2004. Cultivos de verão prévios com *U. brizantha*, *U. brizantha* consorciada com milho, e milheto apresentaram as menores incidências da doença. Portanto, a escolha desses cultivos prévios deve ser considerada para o manejo da murcha-de-fusário, em cultivos irrigados de feijão-comum no Cerrado brasileiro.

Termos para indexação: *Fusarium oxysporum*, *Phaseolus vulgaris*, integração lavoura-pecuária, rotação de culturas, plantio direto, patógenos habitantes do solo.

## Introduction

Brazilian domestic bean production is about 4.0 million tonnes, and about 15% is produced during the irrigated winter crop in the Cerrado region (Companhia Nacional de Abastecimento, 2012).

Fusarium wilt in common bean (*Phaseolus vulgaris* L.), caused by *Fusarium oxysporum* (Schlecht.) f. sp. *phaseoli* Kendrick & Snyder, is prevalent on most bean producing areas in Brazil. Losses due to the disease have been gradually rising in central Brazil, mainly under central pivot irrigation, due to intensive production practices, such as successive plantings in the same area (Rava et al., 1996; Paula Junior et al., 2004).

*Fusarium oxysporum* is considered a soil inhabitant, most likely introduced in bean fields by infected seed or use of contaminated farm implements. The primary symptom is characterized by discolouration of the vascular tissue. Above-ground symptoms include loss of turgour and leaf chlorosis, starting from the lower leaves, sometimes followed by leaf abscission and plant death. It may be manifested on only one side of the host plant (Schwartz et al., 2005). Infection may occur even at the seedling stage, impairing development and resulting in stunted plants. Measures for Fusarium wilt control include genetic resistance and adoption of integrated disease management actions, such as crop rotation and use of healthy seed. Although host resistance is an efficient option for the control of Fusarium wilt, many growers still favour somewhat susceptible cultivars, due to their desirable agronomic characteristics and consumers' preference.

Tillage systems and the use of cover and rotational crops are known to affect soilborne pathogen populations and soilborne diseases (Abawi & Widmer, 2000). No-till (NT) practices are presently widely adopted for several grain crops in Brazil (Freitas et al., 2002) and, although bean yields are usually higher than the average national mean in the NT system, Paula Junior et al. (2004) claimed that, after an increase in the initial years of NT adoption, yields gradually decrease, partially due to the increase in the severity of soilborne diseases. One of the problems associated with the NT system is soil compaction, which may aggravate *Fusarium* diseases (Miller & Burke, 1985). Bean growers have been adopting the NT cropping system since the early 1990s, also because it reduces production costs substantially. Nevertheless, no research on the effects of this practice on common bean Fusarium wilt has been published, even though recent results with beans and soybeans have shown reduction of some soil fungi in the NT, as compared to the conventional cropping (CC) system (Freitas et al., 2002; Napoleão et al., 2005).

Successful NT systems must provide adequate biomass for soil cover. For the irrigated common bean in the winter, crops for biomass should be planted in the late summer or autumn, as maize, wheat, millet, soybean, foraging legumes, oats and sorghum. Moreover, an integrated crop-livestock system for cattle pasture and grain production, based on rotations of legume grains with tropical forage grasses, such as *Urochloa* spp, has been proposed (Kluthcouski et al., 2000). Despite some evidence of reduced soil inoculum and increased yields in the NT system using *Urochloa* spp. as cover crop (Costa & Rava, 2003), extended studies (lasting longer than one year) on the effect of these practices on wilt in common bean have not been published.

The objective of this work was to evaluate the effects of preceding crops and tillage systems on the incidence of Fusarium wilt and common bean yield.

## Materials and Methods

Experiments were carried out in three consecutive winter growing seasons (2002/2003, 2003/2004 and 2004/2005), in a Rhodic Haplustox (58% clay, 13% silt, and 29% sand), in an experimental field at Embrapa Arroz e Feijão, Santo Antônio de Goiás, GO, Brazil (16°29'18"S, 49°17'56"W, 823 m altitude). The experimental area had been cultivated for six years in the no-tillage (NT) system, and it was reported to be naturally-infested with *Fusarium oxysporum* f. sp. *phaseoli*. In the previous growing season (2001/2002), it was cropped with common bean 'Pérola', moderately resistant to *Fusarium* (Salas et al., 2001).

The following legume and grass species were planted in November/December of 2002, 2003 and 2004, as preceding summer crops: pigeon pea [*Cajanus cajan* (L.) Millisp]; stylo [*Stylosanthes guianensis* (Aublet) Sw. var. *vulgaris*, cv. Mineirão]; crotalaria (*Crotalaria spectabilis* Roth.); millet [*Pennisetum glaucum* (L.) R. Br, cv. BN-2]; forage sorghum [*Sorghum bicolor* (L.) Moench, cv. BR 304]; *Panicum maximum* Jacq cv. Mombaça; brachiaria [*Urochloa brizantha* (Hochst ex A. Rich.) Stapf, cv. Marandu]; and a consortium between maize (*Zea mays* L.) and *U. brizantha* (Santa Fé system). After grain harvest of sorghum and maize, 130–150 days after planting (DAP), all biomass was processed in a rolling stalk chopper (Triton, Joaçaba, SC, Brazil) for better distribution in soil surface (NT), or for soil incorporation (CC) of organic residues. Strips (20x4 m) of each summer crop were then divided into two sub-strips of 10x4 m for planting beans in the NT or CC systems. In the conventional cropping system protocol, heavy tillage precedes seeding, whereas in the no-tillage system, common bean is sown directly into previous crop debris.

Common bean 'BRS Valente' was mechanically sown at 3 cm depth, 60 days after biomass was triturated, at the beginning of each winter season (June/July of each year). This black grain cultivar has an undetermined growth habit (type II) and is susceptible to Fusarium wilt. Rows were planted 0.45 m apart, with 18 plants per meter. Fertilization followed standard protocols for the Brazilian central region (Silva & Del Peloso, 2006), with N-P-K plus Zn at planting, and extra N at 20 and 40 DAP. Weeds were controlled in the pre-plant period with 5.0 L ha$^{-1}$ glyphosate (Monsanto, São Paulo, SP, Brazil), and with 0.25 L ha$^{-1}$ fomesafen (Syngenta, Santo Amaro, SP, Brazil) and 1.25 L ha$^{-1}$ fluazifop-P-butil (Syngenta, Santo Amaro, SP, Brazil) at 30 DAP. Irrigation was done by a central pivot system, when water potentials at 0.15 m were at the -0.03 and -0.04 MPa interval.

The experiment followed an 8x2 strip-plot design with four replicates. Cropping system corresponded to the whole-plot factor, and summer crop species to the subplots. Experimental units consisted of 10x4 m strips, with eight rows per treatment and an average of 1,440 bean plants.

Soil samples were collected from every experimental unit, at the 0.05–0.10 m soil depth with an Uhland soil sampler (Uhland, 1950), and dry mass was determined after drying at 105$^{o}$C for 24 hours (Blake & Hartge, 1986). Soil bulk density was determined as dry mass per cylinder volume (98.17 cm$^3$). Common bean grain yield was estimated by harvesting the six central meters of the two central lines of each experimental unit (2.7 m$^2$), to avoid interplot interference. Grain humidity was adjusted to 11% prior to weighing.

Percentage of wilting plants was estimated at 90 DAP, based on a sample of 50 plants per experimental unit. Plants were examined for typical *Fusarium* wilting symptoms. Confirmation of preliminary diagnosis for *F. oxysporum* was done by plate isolations of random symptomatic plants, with aid of microscopic observations. Disease, pathogen and agronomic variables were subjected to correlation analysis, ANOVA and mean separation according to Tukey´s multiple range test, using the Sisvar software. The square root transformation was used for some variables, prior to ANOVA.

## Results and Discussion

Positive correlations were found between disease incidence and soil bulk density in 2004 and 2005 (Table 1). Disease incidence was also negatively correlated with yield in 2003 and 2004.

The amount of dry mass produced in the summer correlated negatively with wilt incidence in bean crop in the 2004 winter (Table 1). In 2005, a negative correlation was also found between Fusarium wilt and dry mass of summer crops. According to this data set, it was not possible to determine whether this correlation indicates a primary effect of dry mass on Fusarium wilt incidence per se, or whether this effect is confounded by the composition of the summer crop residue; therefore, these questions remain to be studied.

Wilt incidence correlated negatively with grain yield and soil compaction. The effects of wilt on yield are widely known, and the association of soil compaction with wilt has also been reported (Miller & Burke, 1985).

In 2003, summer crops significantly affected bean yield (Table 2). Concerning yield in 2004, a significant interaction between cropping system and summer crops was found, with no differences among summer crops in the NT system. In 2005, no significant differences were detected in grain yield. Moreover, grain yield was higher in the conventional system compared with NT (Table 3).

**Table 1.** Pearson´s correlation coefficients between summer crop dry mass and incidence of Fusarium wilt, grain yield, and soil bulk density in three consecutive planting seasons.

| Variable | 2003 | | | 2004 | | | 2005 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fusarium wilt incidence | Grain yield | Soil bulk density | Fusarium wilt incidence | Grain yield | Soil bulk density | Fusarium wilt incidence | Grain yield | Soil bulk density |
| Summer crop dry mass | -0.1199[ns] | 0.2094[ns] | 0.0770[ns] | -0.4121* | 0.3230* | -0.1242[ns] | -0.0903[ns] | -0.0711[ns] | -0.0597[ns] |
| Fusarium wilt incidence | | -0.2766* | 0.0286[ns] | | -0.3295* | 0.2604* | | -0.0488[ns] | 0.2775* |
| Grain yield | | | -0.1713[ns] | | | -0.0353[ns] | | | -0.0955[ns] |

[ns]Non significant. *Significant at 5% probability.

Incidence of Fusarium wilt was significantly affected by planting system and summer crops ($p \leq 0.05$), and no interaction was detected between these factors. In the first season (2003), no significant differences for

**Table 2.** Grain yield of common bean 'BRS Valente' planted in succession to summer crops under no-till cropping system (NT) or conventional cropping system (CC)[1].

| Summer crop | Grain yield (kg ha^{-1}) | | | |
|---|---|---|---|---|
| | 2003 | 2004 | | 2005 |
| | | NT | CC | |
| Crotalaria | 2,724bc | 1,716[ns] | 2,003ab | 2,321[ns] |
| Pigeon pea | 2,007ab | 1,391 | 1,888a | 2,540 |
| *Stylosanthes* | 2,024ab | 1,361 | 2,141ab | 2,473 |
| *Urochloa* | 2,221abc | 1,368 | 2,868b | 2,100 |
| *Urochloa* + Maize | 2,514bc | 1,638 | 2,156ab | 2,251 |
| Millet | 3,152c | 1,821 | 2,551ab | 2,549 |
| *Panicum maximum* | 2,610bc | 1,251 | 2,836b | 2,516 |
| Forage sorghum | 1,509a | 1,576 | 1,756a | 2,186 |
| CV (%) | 26.7 | 21.7 | | 17.1 |

[1]Means followed by equal letters, in the columns, do not differ by Tukey's multiple range test, at 5% probability. [ns]Non significant.

**Table 3.** Soil bulk density and grain yield in the two cropping systems.

| Cropping system | Soil bulk density (g cm^{-3}) | | | Common bean grain yield (kg ha^{-1}) | | |
|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 |
| No-till | 1.49* | 1.40[ns] | 1.30* | 2,001* | 1,515* | 1,885* |
| Conventional | 1.38 | 1.36 | 1.18 | 2,690 | 2,275 | 2,849 |
| CV (%) | 1.29 | 6.93 | 4.95 | 10.9 | 30.5 | 9.88 |

*Significant interactions between cropping systems and preceding crops, at 5% probability. [ns]Non significant.
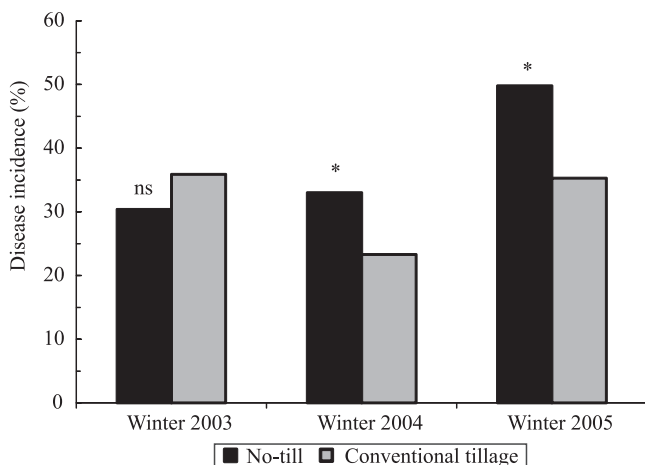


**Figure 1.** Incidence of Fusarium wilt on 'BRS Valente' common bean rotated with grasses or legumes, in no till or conventional cropping systems, during the winters of 2003, 2004 and 2005. [ns]Nonsignificant.*Significant at 5% probability.

the disease incidence were apparent between planting systems, but in 2004 and 2005 seasons, Fusarium wilt incidence was higher in the NT system (Figure 1).

Among summer crops, the highest disease incidence was observed after sorghum and the lowest after millet in 2003 (Figure 2 A). In 2004, the highest disease incidence was again observed after sorghum, and the lowest after millet or brachiaria and *Panicum* in 2004 (Figure 2 B). In 2005, the highest wilt incidence was reported after crotalaria, and other legumes and sorghum, and the lowest after millet or brachiaria (Figure 2 C).
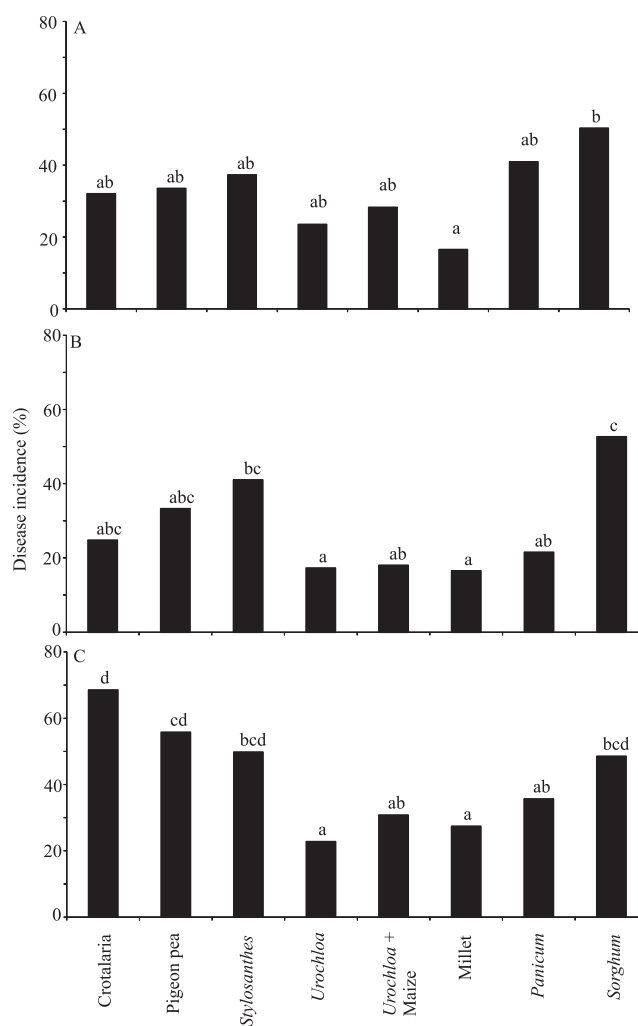


**Figure 2.** Incidence of Fusarium wilt on 'BRS Valente' common bean rotated with grasses or legumes: A, winter 2003; B, winter 2004; and C, winter 2005. Average means of the cropping systems. Means followed by equal letters do not differ, by Tukey's test, at 5% probability.

Fusarium wilt in beans was more favoured in the NT than in the CC system, whether previous summer crops were grasses or legumes. Previously, in the same experimental area, Toledo-Souza et al. (2008) reported that soilborne *Fusarium* populations were generally larger in NT than in the CC treatments, except for planting after *Urochloa* in 2003 and 2005. Steinkellner & Langer (2004) also found that conservation practices such as no-tillage resulted in increased incidence of soilborne fusaria, which emphasizes the importance of disease management practices to prevent the buildup of soilborne plant pathogen populations. Zambolim et al. (2000) hypothesized that the survival of some pathogens in the NT system could be explained by the greater availability of plant residues, which could in consequence be used as substrate for the saprophytic phase. However, other authors (Stone et al., 2004) argued that conservational tillage systems contribute to the development of suppressive microflora against soilborne pathogens. Although neither hypothesis has been examined in detail here, the genus *Fusarium* is generally regarded as a soil inhabitant and, conceivably, could benefit from the nonincorporated dry mass available to soil inhabitants in the NT system.

Disease incidence seems to have increased on the third year, both in no-till and conventional systems, in five out of six rotations (no-till and conventional) with crotalaria, pigeon pea and stylosanthes (Figure 3). In one instance (rotation with stylosanthes in the conventional system), disease levels did not increase, but remained above all grass rotation crops (except for sorghum). In the longer term comparison, after three years of disease assessment, the increase in disease incidence in the NT system was particularly evident after crotalaria and pigeon pea planting. Except for forage sorghum, lowest incidences of Fusarium wilt were constantly found after grass summer crops, specially millet and *U. ruziziensis* (Figure 2). Such results endorse Toledo-Souza et al. (2008), who found that legume crop residue increased soil populations of other bean pathogens, such as *Rhizoctonia solani* Kühn. As observed in 2005, legume summer crops should be avoided on rotations with center-pivot irrigated crops of common beans in the Cerrado region, either in the NT or CC systems.

Dhingra & Coelho Neto (1999) worked with potted individual plants and verified that the legumes *Dolichos lablab*, *Phaseolus lunatus*, *Mucuna aterrima*,

*Canavalia ensiforme* and *Vigna ungulata* were all by *Fusarium oxysporum* host, and noted that they would aid in the persistence of the pathogen in soil and in the incidence of bean Fusarium wilt. They also noted that roots of pigeon pea and crotalaria were colonized by *Fusarium oxysporum*, and that sorghum, rice and maize were poor hosts of the pathogen. Our results, in 2005 season, support the legume x grass contrast, except for sorghum, which allowed high-disease levels from the first to the last planting season (Figure 2).
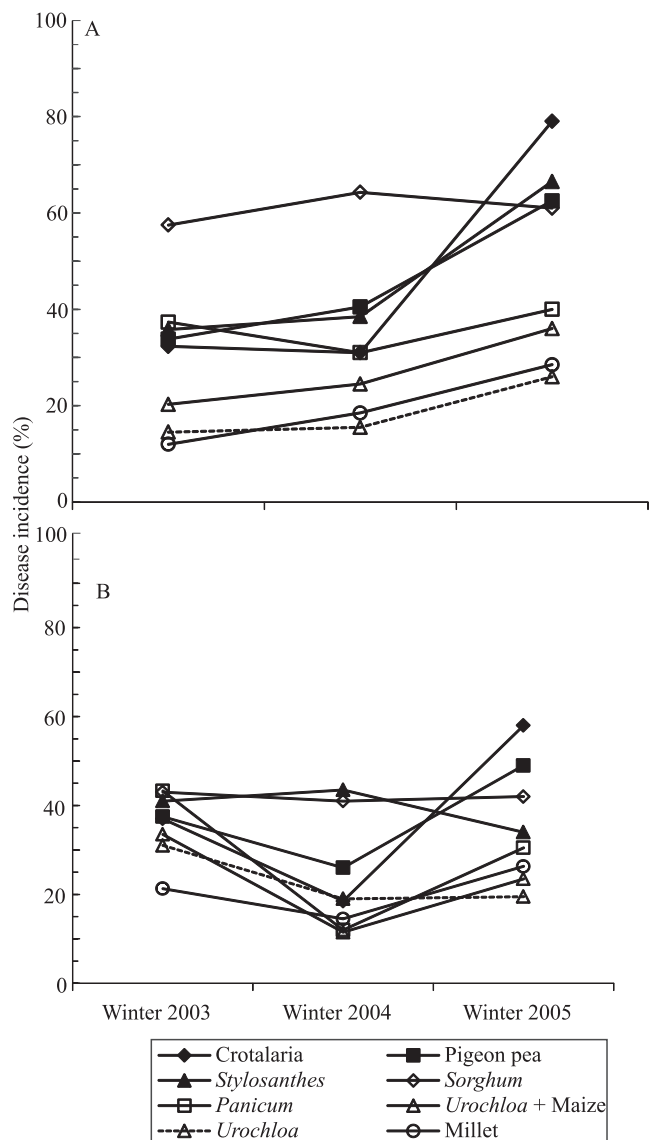


**Figure 3.** Dynamics of the incidence of Fusarium wilt on common bean 'BRS Valente' rotated with grasses or legumes, in the no-till (A) or conventional (B) cropping systems, during the winters of 2003, 2004 and 2005.

From the practical point of view, millet, *U. brizantha*, *U. brizantha* + maize, and *P. maximum* can be recommended as summer crops in rotation with bean, especially in conventional cropping, for the management of Fusarium wilt.

All summer crops here tested are adopted in tropical regions as forage crops, except for millet. Species of *Urochloa* sp. cropped alone or simultaneously with maize have been promoted in Brazil, due to several benefits in crop-livestock systems, or as a source of straw in NT systems (Landers, 2007). According to our results, such systems also support additional advantages in the management of soilborne diseases, as a sustainable agriculture measure, along the lines reviewed by Abawi & Widmer (2000).

Finally, we report the increased Fusarium wilt incidence observed on common beans cropped under no-tillage. Toledo-Souza et al. (2008) showed a consistent rise in soilborne populations of *Fusarium* spp. throughout three growing seasons in the NT system, especially after crotalaria and pigeon pea planting. In the current study, *Fusarium oxysporum* was probably also benefited from the adoption of the NT system. Thereby, the choice of preceding crops should be taken into account for the management of the irrigated bean winter crops in the Brazilian Cerrado and other similar tropical ecosystems.

## Conclusions

1. Millet, *Panicum maximum*, *Urochloa brizantha* and a consortium of maize with *U. brizantha* are the best rotations for Fusarium wilt management on common bean crops.

2. Fusarium wilt incidence increases on no-tillage systems, in comparison with conventional tillage, regardless of crop sequences.

3. Rotations affect the disease incidence and common bean yield, where *Fusarium* wilt is favored in crop sequences with forage sorghum, pigeon pea, crotalaria and stylo.

## Acknowledgements

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