Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.15, n.1, e5843, 2020
Recife, PE, UFRPE. www.agraria.pro.br
DOI:10.5039/agraria.v15i1a5843
Protocol 5843 - 28/06/2018 • Approved in 02/12/2019

Trichoderma spp. and its effects on seeds physiological quality and seedlings development of African mahogany

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ABSTRACT: *Trichoderma* is a beneficial fungus that can be used in both the control of phytopathogens and in promoting germination and plant growth. Thus, this study aimed to evaluate the effect of five *Trichoderma* isolates (T09, T12, T52, Tc and Tce) in seven different application modes on seeds and seedlings of the *Khaya ivorensis* A. Chev. (African mahogany). Fungi applications were tested by microbiolization of the seeds, in the pre-planting substrate, by monthly applications in the seedlings and in four combinations of these three treatments. Under laboratory conditions, the germination, germination speed index (GSI), and radicle and hypocotyl lengths were evaluated in seeds, treated and untreated, with *Trichoderma*. In the nursery, it was evaluated the height, root collar diameter, number of leaflets, root length, and the dry weight of root system and aerial part in seedlings with different forms of *Trichoderma* application. *Trichoderma* isolates did not influence germination percentage, GSI and radicle length. The fungus application methods in the *K. ivorensis* seedlings increased the height and leaflets number of the plants by at least one of the *Trichoderma* isolates tested in this study.

Key words: biological treatment; forest seeds; fungi; growth promotion; *Khaya ivorensis*

Trichoderma spp. e seus efeitos na qualidade fisiológica das sementes e no desenvolvimento de mudas de mogno africano

RESUMO: *Trichoderma* é um fungo benéfico que pode ser utilizado tanto no controle de fitopatógenos como na promoção da germinação e do crescimento de plantas. Assim, objetivou-se avaliar o efeito de cinco isolados de *Trichoderma* (T09, T12, T52, Tc e Tce), em sete modos de aplicação, sobre sementes e mudas de *Khaya ivorensis* A. Chev. (mogno africano). Foram testadas aplicações dos fungos via microbiolização das sementes, no substrato pré-plantio, em aplicações mensais nas mudas e, em quatro combinações desses três tratamentos. Em condições de laboratório foram avaliados a germinação, índice de velocidade de germinação (IVG) e, o comprimento da radícula e hipocótilo, em sementes tratadas e não tratadas com *Trichoderma*. Em viveiro, avaliou-se altura, diâmetro do coleto, número de folíolos, comprimento da raiz e, a massa seca da parte aérea e sistema radicular em mudas com as diferentes formas de aplicação de *Trichoderma*. Os isolados de *Trichoderma* não influenciaram a porcentagem de germinação, o IVG e o comprimento da radícula. Os modos de aplicação dos fungos avaliados nas mudas de *K. ivorensis* aumentaram a altura e o número de folíolos das plantas, por pelo menos um dos isolados de *Trichoderma* testado neste trabalho.

Palavras-chave: tratamento biológico; sementes florestais; fungos; promoção de crescimento; *Khaya ivorensis*

Introduction

One of the strong reasons for producing seedlings of forest species is obtaining wood with noble characteristics, and among these species, the African mahogany (*Khaya ivorensis* A. Chev) stands out.

African mahogany was introduced in Brazil aiming to replace the exploitation of Brazilian mahogany (*Swietenia macrophylla* King.), as it is resistant to the *Hypsiphyla grandella* Zeller (Lepidoptera: Pyralidae) (Gasparotto et al., 2001). Gil et al. (2017), when evaluating the economic viability of implanting this species in the municipality of Uruana-GO, showed that it would be an alternative for those who wished to invest in the forest market, even for small properties. However, the seedlings production of forest species brings with it a series of restrictions from sanitary origin, mainly in tropical regions.

In tropical forests, high humidity and temperature favor the pathogens development, thus making native species seeds vulnerable to attack by these organisms (Nascimento et al., 2006). Moreover, the large number of pathogens associated with seeds and, subsequently, to the resulting seedlings (Muniz et al., 2007), can cause deterioration of the seeds, and abnormalities and lesions in the seedlings (Piveta et al., 2010).

In this sense, seed treatment is a practice that must be performed while aiming at good quality seedlings. Among treatments that can be used on seeds and/or in production of seedlings, the *Trichoderma* fungus stands out among the filamentous ascomycetes due to its high adaptability to different environmental conditions and lifestyle variety, whether in the soil or growing saprofitically on wood, bark and many other substrates, in addition to interacting with animals and plants (Zeilinger et al., 2016)

Promoting plant growth by *Trichoderma* application was initially related to the control of harmful microorganisms present in the soil; however, in the phytopathogens absence, this action mechanism has been related to the production of hormones or growth factors, greater efficiency in the use of some nutrients and increased availability and absorption of nutrients by the plant (Lucon, 2009).

The advantages related to the use of *Trichoderma* make it one of the most commercialized fungi as a biopesticide, biofertilizer and soil inoculant, with an increasing number of new products regularly registered worldwide (Nachtigal, 2012). Therefore, the objective was to evaluate the effect of five isolates of *Trichoderma* spp. from the Amazon region, on both the germination and initial development of African mahogany seedlings (*K. ivorensis*).

Materials and Methods

For performing the tests, three isolates of *Trichoderma asperellum* (T09, T12 and T52) were used, hailing from rhizospheric soil of forest species in reforested areas and native forests, from the Urucu Base, Coari-AM, Brazil, and two isolates of *Trichoderma* spp. (Tc and Tce), from soils of agroforestry systems with Curauá (*Ananas erectifolius* L.B.Smith) and Cumaru (*Dipteryx odorata* (Aubl.) Willd.), from São Pedro Community, region of Eixo Forte, Santarém-PA, Brazil.

Prior to setting the tests up, different concentrations of *Trichoderma* isolates spores were tested in the African mahogany seeds treatment, and the concentration of 1.0×10^6 conidia mL^{-1} was selected.

For later use in the test assembly and in the subsequent stages of *Trichoderma* isolates application, all fungi were mass produced in parboiled rice grains and stored under refrigeration for application in the following treatments: a) Microbiolization of seeds; b) Application in substrate before planting; c) Monthly applications in substrate after planting; d) Microbiolization of seeds + Application in substrate before planting; e) Microbiolization of seeds + Biweekly applications in the substrate after planting; f) Application in substrate before planting + Monthly applications in substrate after planting and, g) Microbiolization of seeds + Application in substrate before planting + Monthly applications in substrate after planting.

For the microbiolization, seeds were immersed in suspensions of each one of the *Trichoderma* isolates, in the pre-established concentration, for 24 hours before the planting. Application in substrate consisted of the deposition of 10 g of rice colonized by the *Trichoderma* isolates, per kilo of substrate (forest topsoil), followed by its homogenization. Biweekly applications in substrate started at 15 days after planting, by putting 10 mL of the suspensions prepared with each *Trichoderma* isolate, in their respective treatments, at the same concentration used in the microbiolization of seeds. The four resulting treatments from the combinations between the three application modes were carried out following their own methodology. Control treatments consisted of the no application of *Trichoderma* isolates in seeds and seedling phase of the African mahogany. Prior to the sowing and throughout the evaluation period, the substrate was moistened daily, keeping it close to field capacity.

Effect of the *Trichoderma* isolates on germination and initial seedling development was evaluated under laboratory conditions, by depositing treated and untreated seeds with *Trichoderma* isolates in plastic trays containing sterile filter paper moistened with sterile water, volume equivalent to 2.5 times the dry paper weight, kept at room temperature and photoperiod of 12 hours, throughout the evaluation period. The experimental design was completely randomized, with five replicates containing 20 seeds per replicate.

The following parameters were evaluated: a) Germination Speed Index (GSI), by daily counting the germinated seeds number until stabilization, determined by the third stable count, and by GSI, calculated using the Maguire formula (1962); b) Germination, by counting the germinated seeds number, determining the percentage after stabilization, according to Brazil (2013) and, c) Radicle length, measurement aided by a digital caliper. Length of the hypocotyl was not measured because the seeds did not emit this structure during the evaluation period (18 days).

After finishing the laboratory test, seedlings resulting from microbiolized seeds and untreated with *Trichoderma* isolates were randomly transplanted to the experiment under nursery conditions.

Transplantation was carried out in polypropylene bags with a 2.25 kg capacity of substrate containing forest topsoil, with a seedling sowed per bag (25 x 14.5 cm), kept in a flower bed under full sun and the performed application methods of *Trichoderma* already described. The experimental design was completely randomized, with 10 replicates, having one seedling per replicate. Variables were measured biweekly during 150 days, with the first verification held at 15 days after transplantation. The experimental design was completely randomized, in a factorial scheme, 5x7+1 (five isolates of *Trichoderma* x seven application modes + one control), with 10 replicates, one seedling per replicate.

The following parameters were evaluated: a) Height of the plant, from its base to its last bifurcation, aided by a millimeter ruler; b) Root collar diameter, measured in the stem basal region, aided by a caliper; c) Number of leaflets, by counting all the seedlings leaves; d) Root length, at the test end (150 days), by measuring this structure with a millimeter ruler and, e) Dry weight of the root system and aerial part, obtained by weighing the plant material, dried in a forced circulation oven at 45 ºC for 40 hours (until constant weight).

Percentage data was transformed to arcsen√x/100. Means found in the test treatments under laboratory conditions were compared with Tukey test ($p \leq 0.05$). Comparisons between the means of treatment and control, in the test under nursery conditions, were performed with Dunnett test ($p \leq 0.05$), followed by comparison of treatments by Tukey test ($p \leq 0.05$), employing the statistical software Assistat Version 7.7 beta. When constructing the tables, untransformed data were used in order to better view the results.

Results

No significant difference was found for germination and the germination speed index of *K. ivorensis* seeds subjected to biological treatment. All *Trichoderma* isolates, except *Trichoderma* Tce, reduced the radicle size in relation to the control (Table 1).

Table 1. Mean values of germination, germination speed index (GSI) and radicle length in plants from seeds of mahogany **(***Khaya ivorensis*) treated and untreated with different *Trichoderma* isolates, at 18 days after setting the test up.

Treatments	Germination (%)	GSI	Radicle (mm)
Control	80.0 a	12.7 a	27.0 a
Trichoderma asperellum T09	91.0 a	11.6 a	15.5 bc
Trichoderma asperellum T12	91.0 a	12.6 a	16.7 bc
Trichoderma asperellum T52	83.0 a	10.9 a	12.5 c
Trichoderma sp. Tc	91.0 a	12.3 a	18.1 b
Trichoderma sp. Tce	91.0 a	13.2 a	27.1 a
CV (%)	13.9	16.0	11.2

Means followed by the same letter in the columns do not differ from each other by the Tukey test ($p > 0.05$).

In the nursery conditions test, only the data referring to height and number of leaflets of the seedlings differed from the control, by the Dunnett test (Table 2), with the seedlings height influenced by biological treatment, in all application modes except for monthly applications in substrate after planting.

Treatment of African mahogany seeds with *Trichoderma* isolates was effective only when isolates *Trichoderma* sp. Tce and *T. asperellum* T12 were used, increasing the seedlings height (18.5 cm) and their number of leaflets, respectively (Table 2), corresponding to an increase of 42% for height and 52% for the number of leaflets, in relation to the control.

Using fungi in substrate before planting had a positive effect in relation to the control, but only for *T. asperellum* T52 application (Table 2). This isolate increased the height of the mahogany seedlings by 15.5 cm. As for the biweekly applications of *Trichoderma* isolates in substrate after planting, no effect on any analyzed variable was verified (Table 2).

All combinations of fungus application modes provided an increase in the seedlings height by at least one of the *Trichoderma* isolates used, and in the triple combination of application modes (seed treatment + pre-planting application in substrate + biweekly applications post-planting), *T. asperellum* T09, *Trichoderma* sp. Tc and *Trichoderma* sp. Tce influenced positively this variable compared to the control (Table 2), with increases in seedling height of 20.2 cm; 16.1 cm and 16.8 cm, corresponding to the increments of 45.2%, 36% and 37.6%, respectively.

When comparing the treatments means by Tukey test, there was a significant difference for the application modes of factor for the variables height, and aerial part and the root system dry weight (Figures 1 and 2).

Applying fungi biweekly in substrate after planting brought the lowest seedlings height in relation to the combined use of application modes, except in the combination application in substrate before planting + biweekly applications in substrate after planting (Figure 1). Combination of seed treatment + application in substrate before planting increased the seedlings height by 9.2 cm, in relation to the isolated use of biweekly application in substrate after planting.

Aerial part dry weight of *K. ivorensis* seedlings was higher when the application modes of *Trichoderma* in seeds were used (Figure 2), as well as in all treatments involving the seeds treatment associated with other application modes (in combinations of seed treatment + application in substrate before planting; seed treatment + biweekly applications in substrate after planting and in the triple combination of seed treatment + application in substrate before planting + biweekly applications in substrate after planting). The application mode of seed treatment + application in substrate before planting increased the aerial part dry weight of the African mahogany seedlings by 2.9 g in relation to the isolated use of the biweekly application in substrate after planting.

Regarding root system dry weight of the African mahogany seedlings, there was a difference only between biweekly applications in substrate after planting and the combination

Table 2. Mean values of plant height, root collar diameter, number of leaflets, root length, and root and aerial part dry weight (DW) of mahogany seedlings (*Khaya ivorensis*) subjected to different application modes of five *Trichoderma* isolates, at 150 days after planting.

Treatments	Variables					
	Height (cm)	Root collar diameter (cm)	Number of leaflets	Root (cm)	DW aerial part (g)	DW root (g)
Control	44.7	4.4	25.0	19.4	5.5	1.5
T09: seeds treatment	58.4 ^{ns}	4.5 ^{ns}	29.0 ^{ns}	19.8 ^{ns}	6.4 ^{ns}	1.5 ^{ns}
T12: seeds treatment	57.8 ^{ns}	5.0 ^{ns}	38.0 *	18.8 ^{ns}	7.9 ^{ns}	1.7 ^{ns}
52: seeds treatment	53.3 ^{ns}	3.7 ^{ns}	26.0 ^{ns}	17.8 ^{ns}	3.9 ^{ns}	0.8 ^{ns}
Tc: seeds treatment	56.3 ^{ns}	4.3 ^{ns}	26.0 ^{ns}	18.5 ^{ns}	4.9 ^{ns}	1.3 ^{ns}
Tce: seeds treatment	63.3 **	4.8 ^{ns}	30.0 ^{ns}	19.8 ^{ns}	6.2 ^{ns}	1.4 ^{ns}
T09: application in substrate before planting	55.3 ^{ns}	3.9 ^{ns}	28.0 ^{ns}	16.8 ^{ns}	5.0 ^{ns}	1.0 ^{ns}
T12: application in substrate before planting	59.9 ^{ns}	4.7 ^{ns}	33.0 ^{ns}	19.6 ^{ns}	7.1 ^{ns}	1.7 ^{ns}
T52: application in substrate before planting	60.2 **	4.3 ^{ns}	34.0 ^{ns}	20.1 ^{ns}	5.8 ^{ns}	1.1 ^{ns}
Tc: application in substrate before planting	55.1 ^{ns}	4.4 ^{ns}	28.0 ^{ns}	19.0 ^{ns}	5.3 ^{ns}	1.1 ^{ns}
Tce: application in substrate before planting	56.7 ^{ns}	3.8 ^{ns}	28.0 ^{ns}	19.4 ^{ns}	5.3 ^{ns}	1.0 ^{ns}
T09: biweekly applications in substrate after planting	52.2 ^{ns}	4.2 ^{ns}	31.0 ^{ns}	17.6 ^{ns}	5.6 ^{ns}	1.1 ^{ns}
T12: biweekly applications in substrate after planting	49.1 ^{ns}	3.7 ^{ns}	23.0 ^{ns}	17.5 ^{ns}	4.0 ^{ns}	0.9 ^{ns}
T52: biweekly applications in substrate after planting	53.2 ^{ns}	4.1 ^{ns}	29.0 ^{ns}	20.3 ^{ns}	5.2 ^{ns}	1.2 ^{ns}
Tc: biweekly applications in substrate after planting	48.8 ^{ns}	5.2 ^{ns}	28.0 ^{ns}	17.5 ^{ns}	4.4 ^{ns}	1.0 ^{ns}
Tce: biweekly applications in substrate after planting	54.4 ^{ns}	3.9 ^{ns}	25.0 ^{ns}	17.4 ^{ns}	3.4 ^{ns}	0.7 ^{ns}
T09: ST + AS	61.5 **	4.3 ^{ns}	32.0 ^{ns}	18.7 ^{ns}	6.0 ^{ns}	1.3 ^{ns}
T12: ST + AS	59.2 ^{ns}	4.7 ^{ns}	28.0 ^{ns}	19.6 ^{ns}	6.6 ^{ns}	1.5 ^{ns}
T52: ST + AS	59.9 ^{ns}	4.4 ^{ns}	28.0 ^{ns}	19.7 ^{ns}	6.3 ^{ns}	1.3 ^{ns}
Tc: ST + AS	59.4 ^{ns}	4.9 ^{ns}	29.0 ^{ns}	19.8 ^{ns}	6.5 ^{ns}	1.1 ^{ns}
Tce: ST + AS	63.3 **	4.6 ^{ns}	32.0 ^{ns}	17.6 ^{ns}	6.3 ^{ns}	1.2 ^{ns}
T09: ST + BAS	56.3 ^{ns}	4.6 ^{ns}	28.0 ^{ns}	18.6 ^{ns}	6.1 ^{ns}	1.3 ^{ns}
T12: ST + BAS	56.2 ^{ns}	4.4 ^{ns}	30.0 ^{ns}	18.8 ^{ns}	6.5 ^{ns}	1.3 ^{ns}
T52: ST + BAS	65.0 **	5.0 ^{ns}	34.0 ^{ns}	20.0 ^{ns}	8.4 ^{ns}	1.7 ^{ns}
Tc: ST + BAS	63.3 ^{ns}	4.8 ^{ns}	35.0 *	18.6 ^{ns}	7.7 ^{ns}	1.3 ^{ns}
Tce: ST + BAS	60.0 ^{ns}	4.6 ^{ns}	35.0 ^{ns}	20.0 ^{ns}	8.2 ^{ns}	1.5 ^{ns}
T09: AS + BAS	65.2 **	4.2 ^{ns}	33.0 ^{ns}	20.2 ^{ns}	6.1 ^{ns}	1.3 ^{ns}
T12: AS + BAS	55.7 ^{ns}	4.6 ^{ns}	31.0 ^{ns}	19.5 ^{ns}	6.1 ^{ns}	1.4 ^{ns}
T52: AS + BAS	55.0 ^{ns}	4.1 ^{ns}	30.0 ^{ns}	18.0 ^{ns}	5.3 ^{ns}	1.2 ^{ns}
Tc: AS + BAS	53.9 ^{ns}	4.2 ^{ns}	26.0 ^{ns}	19.2 ^{ns}	5.3 ^{ns}	1.1 ^{ns}
Tce: AS + BAS	53.0 ^{ns}	3.7 ^{ns}	32.0 ^{ns}	18.3 ^{ns}	4.3 ^{ns}	0.9 ^{ns}
T09: ST + AS + BAS	64.9 **	4.5 ^{ns}	32.0 ^{ns}	18.7 ^{ns}	5.9 ^{ns}	1.2 ^{ns}
T12: ST + AS + BAS	54.3 ^{ns}	4.6 ^{ns}	31.0 ^{ns}	19.0 ^{ns}	5.7 ^{ns}	1.2 ^{ns}
T52: ST + AS + BAS	56.6 ^{ns}	4.2 ^{ns}	30.0 ^{ns}	18.5 ^{ns}	6.4 ^{ns}	1.2 ^{ns}
Tc: ST + AS + BAS	60.8 **	4.4 ^{ns}	30.0 ^{ns}	19.0 ^{ns}	5.8 ^{ns}	1.1 ^{ns}
Tce: ST + AS + BAS	61.5 **	4.0 ^{ns}	30.0 ^{ns}	17.8 ^{ns}	5.7 ^{ns}	0.9 ^{ns}

Note: ** significance: $p < 0.01$; * significance: $0.01 \leq p < 0.05$; ^{ns} non-significant, according to the Dunnett test. ST: seeds treatment; AS: application in substrate before planting; BAS: biweekly applications in substrate after planting.

application in substrate before planting + biweekly applications in substrate after planting (Figure 2).

Significant interaction of the application modes factors x *Trichoderma* isolates for the number of leaflets showed a significant difference only for the application in substrate before planting between the isolates of *Trichoderma* T12 and Tc with the isolate *T. asperellum* T52. The latter caused a greater number of leaflets when compared to T12 and Tc.

Discussion

Although biological treatment did not influence germination and GSI of African mahogany seeds, these results can be considered as positive, since using *Trichoderma* in these seeds did not cause any deleterious effect. According to Mastouri et al. (2010), *Trichoderma* spp. are fungi widely used in the seeds treatment that, in addition to controlling diseases, can promote plant growth and yield.

Results contrary to those found, regarding germination, were reported by Bernardes et al. (2011) when, evaluating the same *T. asperelllum* isolates used in this study (T09, T12 and T52), they observed an 18% reduction in the germination of *Dalbergia spruceana* (Amazon rosewood) in relation to the control, by treating the seeds with *T. asperellum* T09. In addition, Junges et al. (2016), when testing *Trichoderma* spp. at different times in the seedlings production process of native forest species, verified damage to the emergence of *Parapiptadenia rigida* (Angico) seedlings by the application of

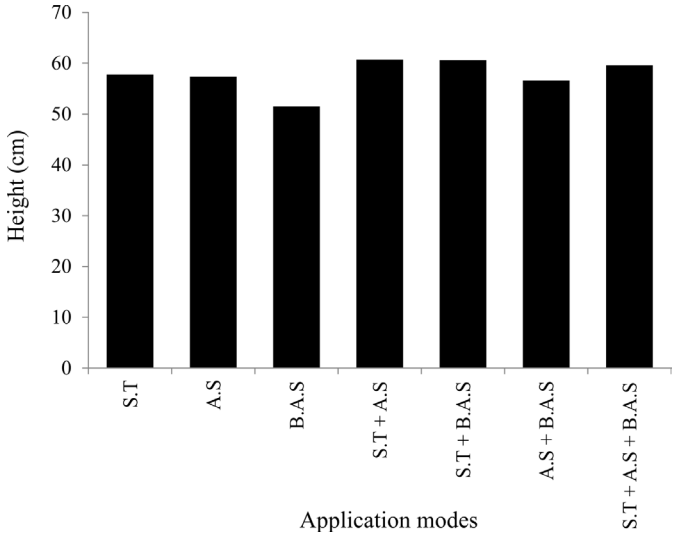

Figure 1. Mean height of seedlings of African mahogany (*Khaya ivorensis*) subjected to different application modes of *Trichoderma*, at 150 days after planting. Application modes of *Trichoderma*: S.T. - seed treatment; A.S. - application in substrate before planting; B.A.S. - biweekly applications in substrate after planting. Means followed by the same letters in the columns do not differ by Tukey test (p > 0.01).

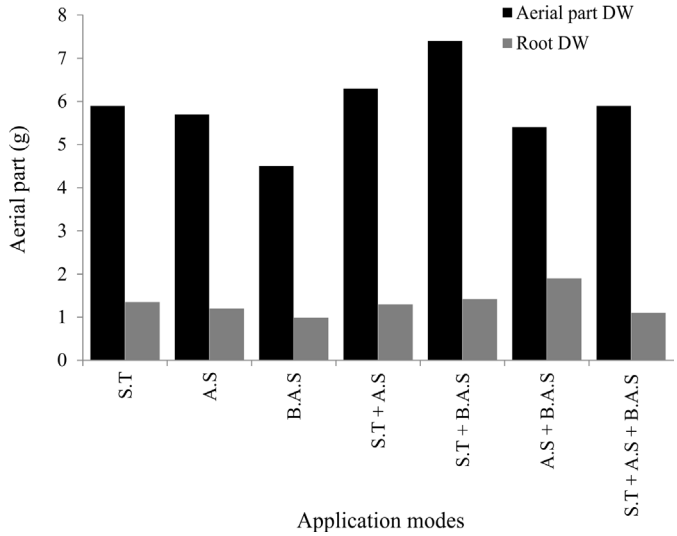

Figure 2. Dry weight of aerial part and root system of African mahogany (*Khaya ivorensis*) seedlings subjected to different applying modes of *Trichoderma*, at 150 days after planting. Application modes of *Trichoderma*: S.T. - seed treatment; A.S - application in substrate before planting; B.A.S - biweekly applications in substrate after planting. Means followed by the same letters in the columns do not differ by Tukey test (p > 0.01).

Trichoderma spp. via seed, reducing it by 35.9% in relation to untreated seeds.

However, positive results for *Trichoderma* use were found by Missio et al. (2016), when evaluating the factors storage time (0, 4, 8 and 12 months), seed protector (*Trichoderma* sp., chemical fungicide and control) and film (polymer and control) on the vigor and germination in seeds of *Jacaranda mimosifolia* D. Don (Jacaranda mimoso). They also observed that seeds treated with the fungus had greater vigor and germination than other treatments, concluding that *Trichoderma* sp. it is recommended for maintaining the vigor and germination of *J. mimosifolia* seeds, after 12 months of storage. Junges et al. (2016) verified that *Trichoderma* isolates colonized all seeds of *Pelthophorum dubium* (Spreng.) Taub. (Canafístula) and controlled the associated fungi, providing an increase in seedling emergence and in the number of leaves per seedling, showing use potential in the seeds treatment of this crop.

Corroborating the result found for GSI, Machado et al. (2015) found no significant difference for this variable in seeds of *Gochnatia polymorpha* (Less.) Cabr. (Cambará) treated with different *Trichoderma* isolates, on non-sterile substrate.

Contrary to what was observed for the effect of *Trichoderma* isolates on the root length of African mahogany seedlings, Bernardes et al. (2011) found positive results for this variable when evaluating the *T. asperellum* isolates T09, T12 and T52 in the seeds treatment of *Dalbergia spruceana* Benth. (Amazon rosewood), with a greater increase provided by *T. asperellum* T12, resulting in an increase of 1.81 cm in relation to the control. Machado et al. (2015) also found a significant difference for the seedlings of *G. polymorpha* (Cambará).

When evaluating the length of *J. mimosifolia* seedlings with biological, chemical and polymer treatment, Missio et al. (2016) observed that this variable decreased with increasing seed storage time in all treatments. However, seeds treated with *Trichoderma* showed less variation in length from the setting up right to the end of the study, at 12 months, with it being the only treatment that managed to generate seedlings of greater length.

Evaluating the antagonistic action of six biological products, including Trichodermil® and Trichodel®, Maciel et al. (2017) found that antagonistic agents acted by expanding the seedlings final quality variables in *Pinus taeda* L. and *Pinus elliottii* Engel., not significantly interfering with seedling emergence.

Different results from those found for the six analyzed variables in the *K. ivorensis* seedlings subjected to biological treatment, where an influence only on height and number of leaflets occured, were obtained by Azevedo et al. (2017), when evaluating the effect of vermicompost and/or *Trichoderma* isolates as growth promoters for *Jacaranda micrantha* Cham seedlings. (Caroba). The authors found that, in general, using *Trichoderma* provided better performance for all analyzed variables (height, root collar diameter, number of leaves, dry weight of aerial part and root system, Dickson index) and that joint using vermicompost and *Trichoderma* isolates represents an efficient tool for the seedlings production of *J. micrantha* in a nursery environment, promoting plant growth and anticipating the seedling commercialization.

Application of *Trichoderma* sp., according to Lazarotto et al. (2013), positively influenced the development of cedar seedlings (*Cedrela fissilis* Vell.), at 35 days after planting. Pereira (2017), verifying the growth-promoting effect of

Trichoderma asperellum in *P. taeda* seedlings, at 150 days after planting and Carvalho Filho et al. (2008), evaluating isolates of *Trichoderma* spp., found a significant difference for the height of hybrid G100 clones (*Eucalyptus grandis* Hill ex Maiden x *Eucalyptus urophylla* ST Blake) for the CEN 262 isolate (*Trichoderma harzianum*), an 43% increase in relation to the control.

Although *Trichoderma* isolates did not influence the root collar diameter of African mahogany seedlings, there are reports of the this fungus beneficial effect on this structure, as indicated by Amaral et al. (2017), when evaluating isolates of *T. asperellum* and *Trichoderma* virens on *J. micrantha* (Caroba). They observed a significant increase in the root collar diameter of the seedling at 90 days after planting.

The increase in the number of leaflets of African mahogany seedlings in plants treated with *Trichoderma* isolates in this study differed from that observed by Amaral et al. (2017) in *J. micrantha* plants at 90 days after sowing. These authors reported that inoculation of *Trichoderma* sp. did not increase this variable; however, Junges et al. (2016) pointed out that application of *Trichoderma* via seed produced greater leafing of the seedlings aerial part in *P. dubium* (Canafístula), differing among themselves with the later application of the biostimulator.

The increase in the number of leaflets in *K. ivorensis* seedlings provided by two treatments is a favorable result regarding its application, since according to Costa et al. (2012), leaves and leaflets contribute to a greater photosynthetic activity, supplying plants in terms of energy and contributing to their development.

The length of the root and dry weight of aerial part and root system of the African mahogany seedlings were not influenced by the *Trichoderma* isolates. Different results were found by Donoso et al. (2008) when evaluating a commercial product based on *T. harzianum* via fertigation, verifying a significant increase in the root system development of *Pinus radiata* D. Don seedlings, when associated with substrate based on organic compost. Souza et al. (2018) also found different results when analyzing the effect of *Trichoderma* spp. and liquid humus in the development of *Ficus carica* L. (Figueira) seedlings, observing that the treatments provided greater seedling development, causing greater root dry weight, with relative efficiency greater than 30% in relation to the control and that using *Trichoderma* spp. in substrate produced greater aerial part dry weight.

Evaluating *C. fissilis* (Cedro) seedlings subjected to treatment with *Trichoderma*, Junges et al. (2016) verified the action of treatments only on the aerial part length, where the later application produced seedlings with a larger aerial part. On the other hand, application via substrate was responsible for less developed seedlings; however, the treatments action was compensated by the root growth, since the total length did not differ between treatments.

According to Contreras-Cornejo et al. (2009), application of *Trichoderma* has been providing significant increases in the percentage and earliness of germination, dry weight and plant height, in addition to stimulating the lateral roots development in arabidopsis (*Arabidopsis thaliana* (L.) Heynh.).

The fact that most application modes of *Trichoderma* have increased the height of African mahogany seedlings for at least one of the fungus isolates, is a promising result, since if the objective is gain in height, the producers could use the best suited method to their conditions, with no losses in that variable. Amaral et al. (2017) also found significant gains in seedling biomass with the inoculation of *Trichoderma* in substrate. The promotion of plant growth by *Trichoderma* isolates may be associated with the production of hormones or other factors, and with the availability of nutrients in the substrate and their facilitated absorption (Lucon, 2009).

Conclusions

Trichoderma isolates did not influence the germination percentage and the germination speed index of the African mahogany (*K. ivorensis*) seeds. However, all the fungi isolates used, in at least one of the application modes, increased the height and/or the number of leaflets in *K. ivorensis* plants.

The application mode to seeds, by itself or in combination, proved to be the most promising way, standing out regarding the number of treatments that increased these two variables.

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