Review Article

Fungi associated with major agricultural and forage crops in integrated systems of tropical regions

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ABSTRACT

Integrated production systems were developed to preserve productive resources and maintain the profitability of agribusiness. However, the use of seeds of low physiological and sanitary quality and the implantation of agricultural and forage crops in production fields of low sanitary quality may favor the dissemination and proliferation of phytopathogens such as fungi. Therefore, using the scientific literature, this work aimed to identify the fungi associated with the main agricultural and forage crops that cause damage to the integrated production systems of tropical regions and their control measures. This work was based on a literature review in the Scielo, Scopus and Google Scholar databases, with data obtained between 1999 and 2019. The keywords employed were "fungus", "tropical grass"; "agricultural crops"; "ICL"; and "ICLF" and their respective terms in Portuguese, under different combinations. For the inclusion criteria, publications (papers, books, theses, dissertations, and scientific communiqués) from 1999 to 2019 which fit the study aim were selected, both in the Portuguese and English languages. The publications that did not meet the criteria of this study and were repeated in databases were considered as exclusion criteria. The main fungi associated with forage and agricultural crops and soils of integrated systems of tropical regions are *Bipolaris* sp., *Curvularia* sp., *Exserohilum* syn. *Helminthosporium* sp., *Phoma* sp., *Fusarium* sp., *Macrophomina* sp., *Pythium* sp., *Rhizoctonia* sp. and *Sclerotium* sp. The main methods of fungal control are the use of quality seeds, crop rotation, resistant cultivars, and chemical seed treatment.

Keywords: Crop rotation, fungicides, resistant cultivars, sustainable agriculture, tropical grass

1. INTRODUCTION

Agribusiness is worldwide in importance, providing **essential** nutrients and contributing significantly to the world economy. Due to the widespread essentiality of agribusiness, there is a need to keep the systems that compose it increasingly productive while preserving the land and reducing the need to open new areas. In order to achieve this purpose, sustainable cultivation models have been created and perfected, such as Integrated Crop-Livestock (ICLS) and Crop-Livestock-Forest (ICLF) systems. These systems aim at the maximum use of the land without degradation, improvement in the physical-chemical quality of the soil, in the zootechnical indexes of the animal component and income diversification [1, 2, 3, 4, 5, 6, 7].

Both of the above-mentioned integrated systems (ICLS and ICLF), if poorly managed, might suffer from pest and disease attacks. In addition, the implantation of low sanitary quality crops in production fields, culminating in the use of seeds with low physiological and sanitary quality may favor the dissemination and proliferation of pests and phytopathogens in productive areas, reducing the yield of agricultural and forage crops and, consequently, affecting animal performance [8, 9, 10].

Among the phytopathogens that can affect productive areas, fungi and nematodes are the ones that cause most concern as they can decimate crops when in high incidence, being difficult to eradicate from the production system [10].

In order to adopt fungal control measures, aiming at the maximum yield of integrated systems in tropical regions, it is necessary to know the fungal incidence in the production fields of the main crops used in these systems, considering that the cultivation of forages belonging to the genera *Brachiaria* syn. *Urochloa* and *Panicum,* as well as agricultural crops such as soybean, maize, sorghum, and millet, are predominant in integrated production systems [11, 12, 13, 14, 15, 16, 17, 18].

Based on this, this study aimed to identify the fungi associated with the main agricultural and forage crops that damage the integrated production systems of tropical regions, as well as their control measures.

2. METHODOLOGY

This work was based on a literature review in the Scielo, Scopus and Google Scholar databases, with data between 1999 and 2019.

The keywords employed were “fungus”, “tropical grass”; “agricultural crops”; “ICLS”; and “ICLF”; and their respective terms in Portuguese “fungos”, “capins tropicais”; “culturas agrícolas”; “iLP”; and “iLPF”, under different combinations.

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For inclusion criteria, publications (papers, books, theses, dissertations, and scientific communiqués) from 1999 to 2019 which fit the study aim were selected, both in the Portuguese and English languages. Publications prior to 1999 that did not meet the criteria of this study (analyzed by titles and abstract) and were repeated in the databases were considered as exclusion criteria.

After reading the titles of articles and other publications, we selected 88 publications that met the initially proposed criteria, which were read in full.

3. RESULTS AND DISCUSSION

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Fungi are phytopathogenic agents at higher rates of association with seeds, presenting longevity in the productive system through the production of resistance structures [19, 20]. They are among the main causes of diseases in forage plants, causing losses in the yield and quality of the green mass produced, besides reducing the quality (germination and vigor) of the seeds [8, 9, 21, 22, 23, 24, 25, 26].

Among the fungi present in soils used in integrated systems, and the fungi associated with *Brachiaria* syn. *Urochloa* sp., *Panicum* sp. and main agricultural crops, there are phytopathogenic taxa belonging to the genera *Bipolaris* sp., *Curvularia* sp., *Exserohilum* syn. *Helminthosporium* sp., *Phoma* sp., *Fusarium* sp., *Macrophomina* sp., *Pythium* sp., *Rhizoctonia* sp., and *Sclerotium* sp.. There are also secondary fungi such as *Alternaria* sp., *Aspergillus* sp., *Cladosporium* sp., *Epicoccum* sp., *Nigrospora* sp., *Penicillium* sp., and *Trichoderma* sp. [8, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36].

Bipolaris sp.

Bipolarys sp. is a pathogenic fungus with a 100% seed transmission rate to the seedlings. It is the main fungus that attacks *Panicum* sp., causing leaf spot disease. However, this fungus can be associated with the integument and interior of the seeds and with crop residues of susceptible crops, such as tropical grasses, maize, wheat, rice, and coffee. In addition, it is favored by temperatures between 22 and 30 °C [24, 25, 37, 38, 39, 40, 41, 42, 43, 44, 45].

The disease and its symptoms are similar in susceptible cultures, being manifested as brown spots and coalescence of the lesions in episodes of severe infestation. These symptoms can be observed 50 days after the sowing of susceptible crops in infected areas and/or using contaminated seeds [37, 38, 46]. In addition to the symptoms of contamination by phytopathogens in tropical plants, it causes disturbances in animals and humans, such as allergies, pulmonary and cutaneous infections [47].

Listing as alternatives to control the disease, the use of resistant cultivars and fungicides is commonly employed. The application of pyraclostrobin associated with epoxyconazole or tebuconazole alone has been promising for the reduction of the disease intensity in *P. maximum* seed production fields, increasing the speed of germination. In addition, cultural control, such as crop rotation, is an effective measure for disease control, since it reduces the initial inoculum [37, 38, 48].

Furthermore, the fungal control can be performed by means of seed treatment with fungicides, aiming to reduce the incidence of fungi in the seeds and in the soil, especially in the initial stages of development of the susceptible plants, besides avoiding the introduction or re-inoculation of phytopathogens [49, 50].

***Curvularia* sp.**

Curvularia sp. is a pathogenic fungus found in several regions of the world that has an important incidence in forage plants of the *P. maximum* species, causing the leaf spot disease [24, 25, 51]. Furthermore, it can cause rotting, reduction of germination up to seed unfeasibility (associating to the integument and endosperm), and death of seedlings in susceptible species, such as tropical grasses and maize**. It has an absent sexual reproduction**, reproducing asexually by ascomycetes [28, 37, 39, 52, 53, 54, 55].

In addition to the diseases that it causes in susceptible plants, the fungus can cause allergic conditions, endocarditis, pheochycosis, mycetoma, onychomycosis, keratitis, brain abscesses, urinary and pulmonary infections, and infectious wounds in animals and humans [56, 57, 58, 59, 60, 61].

For the *Curvularia* sp. control it is possible to employ a seed treatment with the thiram or thiram-associated carboxin fungicides, which also have efficiency in the control of other fungi, such as *Alternaria* sp., *Gerlachia* sp. and *Dreschlera* sp.; as well as the fungicides fludioxonil combined with metalaxyl-M, colorless fludioxonil comminuted with metalaxyl-M, and thiram alone, which also have fungus control efficiency on *Penicillium* sp., *Alternaria* sp., *Drechslera* sp., and so forth. In addition, the association of thiram and thiabendazole fungicides in seed treatment may promote a greater emergence of seedlings [28, 62, 63].

***Exserohilum* syn. *Helminthosporium* sp.**

Such as the fungus *Curvularia* sp., the fungus *Exserohilum* sp. syn. *Helminthosporium* sp. causes rotting, seed unfeasibility and death of seedlings, as well as leaf and stem spot diseases. The manifested symptoms are necrotic and elliptic lesions with intense sporulation of the pathogen [9, 37, 64].

It survives in crop remains (saprophytic form) and in the soil, forming resistance structures and associating to seeds (integument and endosperm) and hosts, such as tropical grasses, sorghum and maize (causing helminthosporiosis). In addition, the fungus is favored by temperatures between 18 and 27 °C and high moisture. The main control method is through genetic resistance and crop rotation with resistant cultures [39, 41, 42, 43, 44, 64].

***Phoma* sp.**

The pathogenic fungus *Phoma* sp. affects several crops from many continents, such as soybean and coffee. In the European region, the main etiological agent in soybean is *Phoma pinodella* (=*Phoma sojicola*). The causal agent in Brazil is the fungus *Phyllosticta sojicola* [35, 65, 66, 67].

Furthermore, this fungus also focuses on forages of the genus *P. maximum.* The symptoms depend on the severity of the incidence, beginning four or five days after the inoculation, causing leaf spot with elongated, necrotic and irregular characteristics, rotting, seed unfeasibility and death of seedlings. By possessing fast and aggressive growth, it can even kill infected seeds before germination [25, 37, 51, 68]. The fungus belongs to the group of mitosporic fungi and is a Coelomycete, presenting cylindrical, hyaline and small non-septate conidia [69].

An efficient alternative to control this fungus is the treatment of seeds with thiram fungicides, thiram associated to carboxin, fludioxonil combined with metalaxyl-M, colorless fludioxonil comminuted with metalaxyl-M, and thiram alone [28, 62, 63].

***Fusarium* sp.**

Fungi of the genus *Fusarium* sp. cause damage to agricultural production systems composed of several agricultural crops, tropical grasses, and animals. This occurs due to the incidence of fusariosis and production of mycotoxin. The symptom of fusariosis in plants is dependent on the phytopathogen species and on the interspecific relation between host-phytopathogen. Mycotoxins can cause symptoms such as false heat, abortion, stillbirths, infertility, problems in the digestive system, bleeding, anemia due to the destruction of the bone marrow, vomiting, necrosis of the epidermis and death of the animals [70, 71, 72].

The *F. solani* species causes red root rot in the soybean crop, a symptom of which is the rotting of the root system; *F. moniliforme* causes the fusarium rot disease in crops of cotton, rice, maize, sorghum, and tropical grasses, in addition to the potential for intoxication of animals due to the production of mycotoxins (zearalenone, fumonisins, and vomitoxins or deoxynivalenol). *F. graminearum, F. equiseti,* and *F. tricintum* also produce mycotoxins in maize, sorghum, soybean, wheat, and oat crops, as well as *F. pallidoroseum,* which can break the stem and lead to the tipping of the cotton, beans and soybean plants [70, 73].

Furthermore, tropical grass seeds susceptible to phytopathogens may increase the inoculum potential in the area and act as a reservoir for future dissemination in crops that will succeed in the area, such as pine, cotton, wheat, rice, bean, soybean, maize, sugarcane, and so forth. The incidence level can be influenced by ideal climatic conditions of high temperature and soil moisture [24, 25, 34].

An effective measure for the control of these phytopathogens is the chemical treatment of seeds with fungicides. Among the available options in the commercialization, as previously mentioned for the control of *Curvularia* sp. and *Phoma* sp, the use of thiram or carboxin associated with thiram is highlighted, besides the fungicides fludioxonil combined with metalaxyl-M, colorless fludioxonil comminuted with metalaxyl-M, and thiram alone. **Furthermore, i**In the absence of resistant cultivars, well-drained and fertilized soils and healthy and certified seeds can be employed [28, 34, 62, 63].

***Macrophomina* sp.**

The genus *Macrophomina* sp. inhabits the soils and manages to multiply in vegetal remains by means of its propagation structures produced by the mycelium (microsclerocios). These structures are resistant to adverse conditions for long periods in the soil. The ideal conditions for phytopathogens to develop are high temperatures and moisture. Moreover, after the insertion into the production area, it attacks roots, stems, leaves, and fruits of susceptible crops, such as sunflower, cotton, sorghum, maize, soybean, and bean, among others. The main species, *M. phaseolina,* triggers symptoms corresponding to grayish lesions that may evolve to rot and tissue destruction. On the other hand, this tissue disruption causes chlorosis, wilt, drought, and death of susceptible plants [34, 74].

The broad spectrum of susceptible species and the absence of resistant cultivars hinder the control through crop rotation, although the performing of this practice with forage grasses is recommended. Also, it is always recommended to use healthy and certified seeds [34].

Moreover, i It is observed that soybean plants produce the phytoalexin gliceolin when infected by *M. phaseolina,* a compound that has the potential to restrict the development of the mentioned fungus through the rapid biosynthesis of glycerol by the plant during fungal infection. This feature may promote genetic improvement programs in the search for resistant plants to *M. phaseolina*. As a palliative measure to reduce the incidence of these phytopathogens, it is possible to use cultivars with higher tolerance to drought and/or high temperatures [75, 76].

***Pythium* sp.**

This pathogen is an inhabitant of the soil which can infect seeds and seedlings. It can be associated with plant remains (saprophytes) or susceptible plants, such as soybean, sorghum, cotton, bean, maize, wheat and tropical grasses. The fungus presents resistance structures (oospores) that allow its survival in adverse conditions [73, 77].

The most frequent species are *P. graminicola* and *P. debaryanum*, but**. In addition,** *P. ultimum* causes the most impact. The symptoms related to the attack of this genus correspond to chlorosis, growth reduction and drying of the leaves; in ideal conditions of development (high moisture and mild temperature), the lesions develop rapidly causing wilt, root rot and tipping of the plant [73, 77].

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Furthermore, it also causes economic losses to the agricultural production system since it contributes to the onset of sudden death (root rot and plant tipping) of the Marandu grass (*B.* syn. *Urochloa brizantha* cv. Marandu), along with *Rhizoctonia* sp., *Fusarium* sp. and water stress [37, 78].

***Rhizoctonia* sp.**

The fungus Rhizoctonia is a saprophytic fungus, being able to exert parasitism on several crops and animals. It presents a high gene flow, genetic diversity, sexual reproduction and dispersion of clones with high adaptability, as well as producing resistance structures (sclerotia) which remain in the soil for long periods [73, 79, 80].

The *R. solani* species can cause leaf burning, collection rot and death in tropical grasses, soybean and maize; in soybean, it causes plant tipping and root rot, which may reduce the vigor and germination rate of the seeds, as well as toxins that inhibit plant growth. In cotton, the fungus causes the tipping of the plants [73, 79, 80, 81].

The methods that have effectiveness in controlling the fungi living in the soil, such as *Pythium* sp. and *Rhizoctonia* sp., are based on the chemical treatment of seeds, rotation of crops with resistant species (grasses) and elimination of crop residues. With regard to the biological control, isolates of the fungus *Trichoderma* spp. have effectiveness in the control of *R. solani* [34, 82, 83].

***Sclerotium* sp.**

The main species, *Sclerotium rolfsii*, lives in the soil and affects crops of soybean, bean, potato, and tomato, among others. It causes the rotting of roots and colon, wilt and tipping of infected plants. The symptoms are manifested in the region of the lap of the plant and correspond to dark spots that originate the cortical rot. This rot can be identified by the formation of a white mycelium and brown-colored resistance structures (sclerocytes). The destruction of tissues occurs under these structures and, with that, wilt, drought and death of the plants. The ideal development conditions occur in regions of tropical climate, with temperatures within 25 and 35 °C and soil moisture in 70% of the field capacity [34, 73, 84].

As a control method, the need to use healthy and certified seeds, the elimination of crop residues and crop rotation with maize and cotton (resistant plants) are highlighted, as well as the efficiency of the fungicide tebuconazole in the colony growth and in the germination of sclerotia of *S. rolfsi* with regard to the chemical control [34, 85, 86].

In general, for the fungal control, it is always necessary to employ seeds with high physiological and sanitary quality, as well as crop rotation, resistant cultivars and chemical treatment of seeds with fungicides. Seed treatment has a low cost and can improve seed germination and seedling development. However, for effective seed treatment and fungal control, effective fungicides are necessary [34, 49, 87, 88].

4. CONCLUSION

The main fungi associated with forage and agricultural crops and soils of integrated systems in tropical regions are *Bipolaris* sp., *Curvularia* sp., *Exserohilum* syn. *Helminthosporium* sp., *Phoma* sp., *Fusarium* sp., *Macrophomina* sp., *Pythium* sp., *Rhizoctonia* sp. and *Sclerotium* sp.

The main methods of fungal control involve the employment of high-quality seeds, crop rotation, resistant cultivars and chemical seed treatment.

COMPETING INTERESTS

We declare that no competing interests exist.

REFERENCES

1. Almeida RG, Ramos AKB, Zimmer AH, Machado LAZ, Kichel NA, Gontijo Neto MM et al. Performance of tropical forages in crop-livestock and crop-livestock-forest integration systems. In: Cordeiro LAM, Vilela L, Kluthcouski J, Marchão RL, editors. Crop-livestock-forest integration: the producer asks, Embrapa responds. 1st ed. Brasília: Embrapa; 2015. Portuguese.

2. Balbino LC, Cordeiro LAM, Porfírio-da-Silva V, Moraes A, Gladys BM, Alvarenga RC et al. Technological evolution and productive arrangements of crop-livestock-forestry integration systems in Brazil. Pesquisa Agropecuária Brasileira, 2011;46(10):1-12. Portuguese DOI: 10.1590/S0100-204X2011001000001

3. Costa JL, Rava CA. Influence of *Brachiaria* in the management of bean diseases with soil origin. In: Kluthcouski J, Stone LF, Aidar H, editors. Crop-livestock integration: 1st ed. Santo Antônio de Goiás: Embrapa; 2003. Portuguese.

4. Leonel FP. Crop-livestock integration: production and forages quality. In: Zervoudakis JT, Cabral LS. Nutrition and production of beef cattle. 1st ed. Cuiabá: UFMT; 2011. Portuguese.

5. Macedo MCM. Crop and livestock integration: the state of the art and the near future. Revista Brasileira de Zootecnia. 2009;38(spe):133-146. Portuguese. DOI: 10.1590/S1516-35982009001300015

6. Mello, LMM. Crop-livestock integration in no-till system. In: Brazilian Congress of Soil Science. Annals. Viçosa: Brazilian Society of Soil Science; 2003. Portuguese.

7. Vilela L, Martha Junior GB, Macedo MCM, Marchão RL, Guimarães Júnior R, Pulrolnik K et al. Integrated crop-livestock systems in the Cerrado region. Pesquisa Agropecuária. 2011;46:1127-1138. Portuguese. DOI: 10.1590/S0100-204X2011001000003

8. Vechiato MH, Aparecido CC. Fungi in forage grasses seeds: phytosanitary restriction and detection methods. São Paulo: Biological Institute of São Paulo; 2008. Portuguese.

9. Vechiato MH, Aparecido CC, Fernandes CD. CD. Frequency of fungi in batches of commercialized *Brachiaria* and *Panicum* seeds. Campo Grande: Embrapa; 2010. Portuguese

10. Fernandes CD. The sanity of forage seeds and their impact on crop-livestock-forestry integration systems. In: Brazilian Congress of Seeds, 18. The seed in agricultural productivity and conservation of genetic resources: abstracts. Florianópolis: Brazilian Association of Seed Technology; 2013. Portuguese.

11. Embrapa Sede. Technologic solutions: *Brachiaria brizantha* cv. Marandu. Acessed 12 Mar 2019. Available: https://www.embrapa.br/busca-de-solucoes-tecnologicas/-/produto-servico/863/brachiaria-brizanthacv-marandu.

12. Semeata. *Brachiaria ruziziensis*. Acessed 02 Mar 2019. Available: http://www.semeata.com.br/?sessao=produto&folder=1&ver&id=7.

13. Pedreira CGS, Moura JC, Silva SC, Faria VP. In: Pastures and the environment. 23° Symposium on Pasture Management. Annals. Piracicaba: 23° Symposium on Pasture Management; 2006: 165-185. Portuguese

14. Embrapa Sede. Technologic solutions: *Panicum maximum* cv. Mombaça. Acessed 13 Mar 2019. Available: https://www.embrapa.br/busca-de-solucoes-tecnologicas/-/produto-servico/882/panicum-maximumcv-mombaca.

15. Embrapa Sede. Technologic solutions: *Panicum maximum* cv. Tanzânia-1. Acessed 13 Mar 2019. Available: https://www.embrapa.br/busca-de-solucoes-tecnologicas/-/produto-servico/885/panicum-maximumcv-tanzania-1.

16. Alvarenga RC, Gontijo Neto MM, Ramalho JH, Garcia JC, Viana MCM, Castro AADN. Crop-Livestock Integration System: the model implemented in Embrapa Milho e Sorgo. Sete Lagoas: Embrapa; 2007. Portuguese

17. Alvarenga RC, Rodrigues JAS, Santos FC, Gontijo Neto MM, Viana MCM. Sorghum cultivation in integrated crop-livestock or crop-livestock-forestry systems. Sete Lagoas: Embrapa; 2011.

18. Rodrigues JAS, Cruz JC. Growing millet. Sete Lagoas: Embrapa; 2009. Portuguese.

19. Ministério da Agricultura, Pecuária e Abastecimento. Rules for seed analysis. Brasília: MAPA/ACS; 2009. Portuguese

20. Kruppa PC, Russomano OMR. Fungi in medicinal, aromatic and condimentary plants - soil and seed. 2009. Portuguese. Acessed 14 Jun 2019. Avaliable: http://www.infobibos.com/Artigos/2009_1/Fungos/index.htm>. Acesso em 14 de junho 2019.

21. Lucca-Filho OA, Porto MDM, Maia MS. Fungi in Ryegrass-annual seeds (*Lolium multiflorum* Lam.) e and its effects on the establishment of the pasture. Revista Brasileira de Sementes. 1999;21(2):142-147. Portuguese. DOI: 10.17801/0101-3122/rbs.v21n2p142-147

22. Schafer M, Kotanen PM. The influence of soil moisture on losses of buried seeds to fungi. Acta Oecologica. 2003;24(5-6):255-263. DOI: 10.1016/j.actao.2003.09.001

23. Mertz LM, Henning FA, Maia MS, Meneghello GE, Henriques A, Madail R. Physiological and sanitary quality of cawpea seeds processed in gravity table. Revista Brasileira de Sementes. 2007;29(3):1-7. Portuguese. DOI: 10.1590/S0101-31222007000300001

24. Marchi CE, Fernandes CD, Bueno ML, Batista MV, Fabris LR. Fungi associated to comercial seed of braquiária grass. Arquivos do Instituto Biológico. 2010;*77*(1):65-73. Portuguese.

25. Mallmann G, Verzignassi JR, Fernandes CD, Santos JM, Vechiato MH, Inácio CA et al. Fungi and nematodes associated with tropical forage seeds. Summa Phytopathologica. 2013;39(3):201-203. Portuguese. DOI: 10.1590/S0100-54052013000300010

26. Marcos MF, Jank L, Fernandes CD, Verzignassi, JR, Mallmann G, Queiroz CA et al. Reaction to Bipolaris maydis, the causal agent of leaf spot, in apomictic hybrids of *Panicum maximum*. Summa Phytopathologica. 2015;41(3):197-201. Portuguese. DOI: 10.1590/0100-5405/2078

27. Vechiato MH. Sanity of grass forages seeds. In: Brazilian Symposium on Seed Pathology, 8. Annals. Londrina: Abrates; 2004. Portuguese.

28 Lasca CC, Vechiato MH, Kohara EY. Control of *Brachiaria* spp. seed-borne fungi: effectiviness of fungicide and influence of the storage period of treated sedds on the action of these products. Arquivos do Instituto Biológico. 2004;71(4):465-472. Portuguese.

29. Fernandes CD, Marchi CE, Jerba VF, Borges MF. Pathogens associated with tropical forage seeds and control strategies. In: Zambolim L. Seeds, sanitary quality. Viçosa: Federal University of Viçosa; 2005. Portuguese.

30. Marchi CE, Fernandes CD, Jerba VF, Trentin RA, Bueno ML, Guimarães LR et al. Tropical forage seeds: associated pathogens and control strategies. In: Brazilian Symposium on Seed Pathology, 10. Annals. Londrina: Abrates; 2006. Portuguese.

31. Marchi CE, Fernandes CD, Borges CT, Santos JM, Jerbal VF, Trentin RA et al. Phytopathogenic nematofauna of commercial seeds of tropical forages. Pesquisa Agropecuária Brasileira. 2007;42(5):655-660. Portuguese. DOI: 10.1590/S0100-204X2007000500007

32. Witt FAP, Oliveira FF, Takeshita V, Ribeiro LFC. Quality of health seeds the Urochloa and Panicum sold in matogrossense north. Enciclopédia Biosfera. 2015;11(21):1636-1645. Portuguese.

33. Silva AEL, Reis EM, Tonin RFB, Danelli ALD, Avozani A. Identification and quantification of fungi associated with seeds of ryegrass (*Lolium multiflorum* Lam.). Summa Phytopathologica. 2014;40(2):156-162. Portuguese. DOI: 10.1590/0100-5405/1935

34. Athayde Sobrinho C, Belmino CS. Feijão-Caupi: Fungi. Acessed 14 Jun 2019. Available: https://www.agencia.cnptia.embrapa.br/gestor/feijaocaupi/arvore/CONTAG01_59_510200683537.html.

35. Vieira Junior JR, Fernandes CDF, Silva DSG, Santana L, Minosso S, Almeida U et al. Isolated fungi from *Brachiaria* sp. associated with sintoms type “brachiaria disease”. In: Brazilian Congress of Phytopathology, 44. Annals. Brasília: Tropical Plant Pathology; 2011. Portuguese

36. Embrapa Soja. Soybean production technologies – Central Region of Brazil 2009. 1st ed. Londrina: Embrapa; 2008. Portuguese.

37. Marchi CE, Fernandes CD, Verzignassi JR. Diseases in forage plants. Campo Grande: Embrapa; 2011. Portuguese.

38. Costa RV, Silva DD, Cota LV. Corn bipolares leaf spot. Sete Lagoas: Embrapa; 2014.

39. Santos GR, Tschoeke PH, Silva LG, Silveira MCAC, Reis HB, Brito DR et al. Sanitary analysis, transmission and pathogenicity of fungi associated with forage plant seeds in tropical regions of Brazil. Journal of Seed Science. 2014;36(1):54-62. DOI: 10.1590/S2317-15372014000100007

40. Tavanti TR, Takada J, Ribeiro LFC, Moraes SRG, Pedreira BC. Occurrence of *Bipolaris maydis* leaf spot on tanzania guineagrass in the north region of the Mato Grosso state. Revista de Ciências Agroambientais. 2016;14(1):82-85. Portuguese. DOI:

41. Amorim L, Rezende JAM, Bergamin-Filho A, editors. Phytopathology manual. 4th ed. Piracicaba: Agronômica Ceres; 2011. Portuguese.

42. Bueno CJ, Ambrósio MCQ, Souza NL. Production and evalution of survival of resistance structures of soilborne phytopathogenic fungi. Summa Phytopathologica. 2007;33(1):47-55, 2007. Portuguese. DOI: 10.1590/S0100-54052007000100007

43. Danelli AD, Viana E, Fiallos FG. Pathogenic fungi found in wheat seeds and medium early maturity, produced in three parts of Rio Grande do Sul, Brazil. Scientia Agropecuaria. 2012;3(1):67-74. Portuguese.

44. Quadros DG, Andrade AP, Oliveira GC, Oliveira EP, Moscon ES. Components of seed production of two cultivars of *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf haverst by manual or mechanical sweeping. Semina Ciências Agrárias. 2012;33(5):2019-2028. Portuguese. DOI: 10.5433/1679-0359.2012v33n5p2019

45. Caligiorne RB, Resende MA, Melillo PHC, Peluso CP, Carmo FHS, Azevedo V. In vitro susceptibility of chromoblastomycosis and phaeohyphomycosis agents to antifungal drugs. Medical Mycology. 1999;37(6): 405-409. DOI: 10.1111/j.1365-280X.1999.00245.x

46. Michalski V, Charchar Jd'A, Anjos JRN, Fernandes FD, Silva MS, Silva WAM. Transmission of seeds fungi to *Panicum maximum* seedlings. In: Faleiro FG, Andrade SEM. Meeting of young talents from Embrapa Cerrados abstracts presented, 3. Planaltina: Embrapa; 2007. Portuguese.

47. Fryen A, Mayser P, Glanz H, Füssle R, Breithaupt H, Hoog GS. Allergic fungal sinusitis caused by *Bipolaris (Drecheslera) hawaiiensis.* Eur. Arch. Otorhinolaryngol. 1999;256(7):330-334.

48. Faria AYK, Albuquerque MCF, Neto DC. Physiological quality of cottnseeds submitted to chemical and biological treatments. Revista Brasileira de Sementes. 2003;25(1):121-127. Portuguese. DOI: 10.1590/S0101-31222003000100019

49. Carvalho NM, Nakagawa J. Seeds: science, technology and production. 4th ed. Jaboticabal: FUNEP; 2000. Portuguese.

50. Guerra JI, Costa MLN. Evaluation of diseases management in *Brachiaria brizantha* cv BRS Piatã. In: Meeting of Teaching, Research and Extension - Scientific Education: Scientific Innovations and Regional Development, 3. Annals. Dourados: UEMS; 2012. Portuguese.

51. Mentem JOM, Ishizuka MS. Health of tropical forage seeds - Upgrade course of tropical forage seeds production: relevant aspects to seed production. Presidente Prudente: AEAPP/FATL; 2015. Portuguese.

52. Guimarães GI, Lima MLP. General and morphological aspects of the fungus *Curvularia* sp. General and morphological aspects of *Curvularia* sp. Acessed 12 Mar 2019. Available: https://fitopatologia1.blogspot.com/2010/10/aspectos-gerais-e-morfologicos-do-fungo_7393.html

53. Yago JI, Roh JH, Bae S, Yoon YN, Kim HJ, Nam MH. The effect of seed-borne mycoflora from sorghum and foxtail millet seeds on germination and disease transmission. Mycobiology. 2011;39(3):206-218. DOI: 10.5941/MYCO.2011.39.3.206

54. Revankar SG. Dematiaceous fungi. Mycoses. 2007;50(2):91-101. Portuguese.

55. Ferrreira LS. Characterization of isolates of *Curvularia* spp corn endophytic by morphological and molecular parameters. (Dissertation). Federal University of Paraná; 2010. Portuguese. Acessed 14 Jun 2019. Available: https://acervodigital.ufpr.br/bitstream/handle/1884/24194/LISANDRA%20SANTOS%20FERREIRA%20150710versao%20que%20foi%20impresssa.pdf?sequence=1&isAllowed=y

56. Carter E, Boudreaux C. Fatal cerebral phaeohyphomycosis due to Curvularia lunata in an imunocompetent patient. Journal of Clinical Microbiology. 2004;42(11): 5419-5423. DOI: 10.1128/JCM.42.11.5419-5423.2004

57. Moura RM, Pedregosa EMR, Guimarães LMP. New data on the etiology of the black bark of yam in northeastern Brazil. Nematologia Brasileira. 2001;25(2):235-237. Portuguese.

58. Herraez P, Rees C, Dunstan R. Invasive phaeohyphomycosis caused by *Curvularia* species in a dog. Veterinary Pathology. 2001;38(4):456-459. DOI: 10.1354/vp.38-4-456.

59. Dasgupta S, Saha D, Saha A. Levels of common antigens in determining pathogenicity of *Curvularia eragrostidis* in different tea varieties. Journal of Applied Microbiology. 2005;98(5):1084-1092. DOI: 10.1111/j.1365-2672.2005.02538.x

60. Shan FY, Wei SW, Jie LY, Zhang JC, Gao DJ. Parasitic fitness and RAPD analysis of *Curvularia* species on corn. Journal of Agricultural University of Hebei. 2008;31(1):37-41. DOI:

61. Pimentel JD, Mahadevan K, Woodgyer A, Sigler L, Gibas C, Harris OC, Lupino M, Athan E. Peritonitis due to *Curvularia inaequalis* in an elderly patient. Journal of Clinical Microbiology. 2005;43(8):4288-4292. DOI: 10.1128/JCM.43.8.4288-4292.2005

62. Schuch UZ, Lucca Filho AO, Peske STP, Dutra LMC, Brancão MF, Rosenthal MD et al. Physiological and sanitary quality of rice seeds stored with differents seed moisture contents and fungicide treated. Revista Brasileira de Sementes. 2006;28(1):45-53. Portuguese. DOI: 10.1590/S0101-31222006000100007

63. Pinto JC, Nabinger C, Maraschin GE. Determination of harvest time for seeds of *Paspalum guenoarum* Arech. f. azulão grass. Revista da Sociedade Brasileira de Zootecnia. 1984;13(1):61-66. Portuguese.

64. Costa RV, Casela CR, Cota LV. Foliar Diseases. Acessed 12 Mar 2019. Available: https://www.agencia.cnptia.embrapa.br/gestor/milho/arvore/CONTAG01_32_161682005111.html.

65. Salgado M, Pfenning LH. Identification and caracterisation of *Phoma* species in Brazil. In: Paulista Congress of Phytopathology. Annals. Campinas: Paulista Association of Phytopathology; 2000. Portuguese.

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66. Aveskamp MM, Gruyter J, Crous PW. Biology and recente developmentes in the systematics of Phoma, a complex genus of major quarantine significance. Fungal Diversity. 2008;31:1-18.

67. Irinyi L, Kövics GJ, Sándor E. Taxonomical re-evaluation of Phoma-like soybean pathogenic fungi. Mycological Research. 2009;113(Pt 2):249-60. DOI: 10.1016/j.mycres.2008.11.003

68. Anjos JRN, Charchar MJA, Anjos SSN, Teixeira RN. *Phoma* sp. (sect. *Peyronellae*a), as causal agent of leaf spot on *Paspalum atratum* in Brazil. Fitapatologia Brasileira. 2005;30(1):72-74. Portuguese. DOI: 10.1590/S0100-41582005000100012

69. Leite GG, Silveira LF, Fernandes FD, Gomes AC. Growth and chemical composition of the grass *Paspalum atratum* cv. Pojuca. Brasília: Embrapa; 2001. Portuguese.

70. Silva LC. Mycotoxines in grain and grain products. Revista Grãos Brasil. 2009;8(39):13-16. Portuguese.

71. Nor Azliza I, Hafizi R, Nurhazrati M, Salleh B. Production of major mycotoxins by Fusarium species isolated from wild grasses in Peninsular Malaysia. Sains Malaysiana. 2014;43:89-94.

72. Carmo ALM. Fusarium in Pinus seeds in Brazil: distribution, pathogenicity, species identification and biological control. Thesis (Doctor degree). Federal University of Paraná; 2017. Portuguese. Acessed 14 May 2019. Avaliable: https://acervodigital.ufpr.br/bitstream/handle/1884/47122/R%20-%20T%20-%20ANA%20LIDIA%20MOURA%20DO%20CARMO.pdf?sequence=1&isAllowed=y

73. Agrolink. Fusarium - dry rot (*Fusarium solani*). Portuguese. Acessed 14 May 2019. Avaliable: https://www.agrolink.com.br/problemas/fusariose_1258.html.

74. Batista ICA, Boari ADJ, Quadros AFF. Molecular identification of *Macrophomina phaseolina* in bean-tube. In: Scientific Initiation Seminar, 20 e Postgraduate Seminar of Embrapa Amazônia Oriental, 4. Annals. Belém: Embrapa; 2016. Portuguese.

75. Lygin AV, Hill CB, Zernova OV, Crull L, Widholm JM, Hartman GL, Lozovaya VV. Response of soybean pathogen to glyceollin. Phytopathology. 2010;100(9):897-903. DOI: 10.1094/PHYTO-100-9-0897

76. Almeida AMR, Seixas CDS, Farias JRB, Oliveira MCN, Franchini JC, Debiasi H. *Macrophomina phaseolina* in soybean. 1st ed. Londrina: Embrapa; 2014. Portuguese.

77. Agrolink. Stretching: Root rot (*Pythium* spp.). Portuguese. Acessed 14 May 2019. Avaliable:https://www.agrolink.com.br/problemas/estiolamento_1711.html

78. Andrade CMS, Valentim JF. Grass brizantão death syndrome in Acre: characteristics, causes and technological solutions. 1st ed. Rio Branco: Embrapa; 2007. Portuguese.

79. Dias PP, Berbara RLL, Fernandes MCA. *Rhizoctonia solani* and *Fusarium oxysporum* f.sp. *phaseoli* control by biopreparation with *Trichoderma* spp. isolates Summa Phytopathologica. 2019;39(4):258-262. Portuguese. DOI: 10.1590/S0100-54052013000400005

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80. Poloni NM, Molina LMR, Mesa EC, Garcia IL, Ceresini PC. Evidence that the fungus *Rhizoctonia solani* AG-1 IA adapted to Urochloa in Colombia keeps a broad host range including maize. Summa Phytopathologica. 2016;42(3):228-232. Portuguese. DOI: 10.1590/0100-5405/2176

81. Goulart ACP. Reaction of cotton cultivars to *Rhizoctonia solani* at seedling stage and benefits of fungicide seed treatment. Summa Phytopathologica. 2016;42(4)308-312. [Portuguese]. DOI: 10.1590/0100-5405/2116

82. Lucon CMM, Koike CM, Ishikawa AI, Patrício FRA, Harakava R. Bioprospection of *Trichoderma* spp. isolates to control *Rhizoctonia solani* on cucumber seedling production. Pesquisa agropecuária brasileira. 2009;44(3):225-232. Portuguese. DOI: 10.1590/S0100-204X2009000300002

83. Lewis JA, Lumsden RD. Biocontrol of damping-off of greenhouse-grown crops caused by *Rhizoctonia solani* with a formulation of *Trichoderma* spp. Crop Protection. 2001;20(1):49–56. DOI: 10.1016/S0261-2194(00)00052-1

84. Pinheiro VR, Seixas CDS, Godoy CV, Soares RM, Oliveira MCN, Almeida AMR. Development of *Sclerotium rolfsii* sclerotia on soybean, corn, and wheat straw, under different soil temperatures and moisture contents. Pesquisa Agropecuária Brasileira. 2010;45(3):332-334. Portuguese. DOI: 10.1590/S0100-204X2010000300014

85. Prahbu HV, Hiramoth PC. Bioefficacy of fungicides against collar rot of cotton caused by *Sclerotium rolfsii* Sacc. Karnataka Journal of Agricultural Sciences. 2003;16(4):576- 579. DOI:

86. Cilliers AJ, Pretorius ZA, Van Wyk PS. Integrated control of *Sclerotium rolfsii* on groundnut in South Africa. Journal of Phytopathology. 2003;151(5):249-258. DOI: 10.1046/j.1439-0434.2003.00715.x

87. Menten JO, Moraes MHD. Seed Treatment: history, types, characteristics and benefits. Informativo Abrates. 2010;20(3):52-71. Portuguese. Acessed 14 Jun 2019. Availiable: http://www. abrates.org.br/images/stories/informativos/v20n3/minicurso03. pdf.

88. Santos FC. Scarification, chemical treatment, seed coating and seed storage of *Brachiaria brizanta* cultivar Marandu. Thesis (Doctor degree); Federal University of Lavras; 2009. Portuguese. Acessed 15 Jun 2019. Available: http://repositorio.ufla.br/jspui/bitstream/1/3099/1/TESE_Escarifica%C3%A7%C3%A3o%2C%20tratamento%20qu%C3%ADmico%2C%20revestimento%20e%20armazenamento%20de%20sementes%20de%20Brachiaria%20brizantha%20cultivar%20Marandu.pdf

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