Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/15218
DOI URL: http://dx.doi.org/10.21474/IJAR01/15218

RESEARCH ARTICLE

EVALUATION OFTHE ANTAGONISTIC ACTIVITY OF INDIGENOUS TRICHODERMA SPECIES AGAINSTCOLLETOTRICHUM GLOEOSPORIOIDES, THE FUNGAL PATHOGEN CAUSINGMANGO ANTHRACNOSEIN SENEGAL

Maodo Malick Cissé[1], Nalla Mbaye[1], Papa M. Diédhiou[2], Hilali Lahoucine[3] and Bouchaib Bencharki[3]

1. Department of Plant Biology, Cheikh Anta DIOP University of Dakar, BP 5005, Senegal.
2. Department of Aquaculture, Agronomic Sciences and Food Technologies, Gaston Berger University of Saint-Louis, BP 234, Senegal.
3. Hassan I[er]University, Department of Applied Biology, AgriFood and Health Laboratory, BP 577, Settat, Morocco.

Manuscript Info

Manuscript History
Received: 18 June 2022
Final Accepted: 22 July 2022
Published: August 2022

Key words:-
Anthracnose, Colletotrichum Gloeosporioides, Biological Control, Trichoderma

Abstract

Mangois a major crop that represent 63% of fruit production in Senegal. The mango business suffers however from major phytosanitary constraints such as mango anthracnose caused by *Colletotrichum gloeosporioides*. Fungicides are usually sprayed for the control of this fungal pathogen with their downside of negative impacts on human health and on environment. Fungi of the genus *Trichoderma* are reported to have great potentialfor biological control on pathogens. Their ability to control *C. gloeosporioides* was tested through confrontation with three isolates of *Trichoderma asperellum*(S3M4ZIG, F3GP3 and F3GP3-5), one isolate of *Trichoderma viride* (F2KV3) anda fifth isolate of*Trichoderma sp*. (S5M5ZN). These isolates, obtained from mango tree organs in Senegal,were used in direct confrontation against *C. gloeosporioidesin vitro* and further onin vivo tests on fruits.The incidence and severity of anthracnose were evaluated after 20 days of incubation.In dual culture in the petri dishes, the isolate S5M5ZN inhibited totally the mycelial growth of *C. gloeosporioides*,followed by the strains F3GP3 (*T. asperellum*), F3GP3-5 (*T. asperellum*), F2KV3 (*T. viride*) and S3M4ZIG (*T.asperellum*), that caused respective reduction of mycelial growth of the pathogen by 89.41 ± 18.33%, 89.01 ±19.01%, 77.25 ± 19, 77%, 77.25 ± 12.95%.For the*in vivo*tests, the mangoes soaked with distilled water (negative control) and those inoculated with only*C.gloeosporioides*(positive control) hada disease severity of respectively 20.36±4.39% and 50.69±6.58%. The *Trichoderma* isolateS3M4ZIG, showed the best efficacy on mango with the lowestdisease severity of 5.55±00.00%.

Introduction:-

Mango is the sixth most produced fruit in the world with more than 50 million tons in 2017,harvested on about 50 million hectares(FAO, 2019). In Senegal, its production is subjected to many constraints related to pests and

Corresponding Author:- Nalla Mbaye
Address:- Department of Plant Biology, Cheikh Anta DIOP University of Dakar, BP 5005, Senegal.

diseases (Diédhiou*et al*., 2007). Anthracnose, caused by Colletotrichum gloeosporioides (Penz.) Penz. &Sacc (Arauz, 2000., Zakaria *et al.,* 2015) remains the most important fungal disease of mango with greater losses in the post-harvest stage (Nelson, 2008; Pardo-De la Hoz*et al*., 2016). In Senegal, anthracnose can cause losses ranging from 42 to 90% depending on climatic conditions (Mbaye, 2006; Diédhiou*et al*., 2014).The intensive use of chemicals for the control of pathogens does not completely solve the problem due to the acquisition of resistance of some strains and public health problems. Many cases of skin irritation, headaches, hot flashes or dizziness, endocrine disruption, congenital malformations of the male reproductive system have been noted worldwide through misuse of chemicals (Hileman, 1994; Ahouangninou*etal*., 2011). Pesticide residues exceeding standards have been found in the groundwater of the Niayes peri-urban area in Senegal(Cissé et al., 2003). In Ivory Coast, organophosphorus compounds have been noted in large quantities in cocoa, coffee, and banana and vegetable plantations (Traoré*et al*.,2006).Due to thesenegative environmental and health impacts caused by pesticides, research for alternative optionsgained popularity and included biocontrol products such as essential oils (Cissé*et al*., 2020), extracts from medicinal plants and also microbial antagonists. Several microbial antagonists such as species of *Trichoderma*, *Beauveria*, *Metharizium*, *Gliocladium*, etc. have been used against pathogenic fungi in fruit crops (Caron *et al*., 2002; Kébé*et al*., 2009; Yan *et al*., 2018; Guèye, 2020; Dièye*et al*., 2021).Fungal species from the genus *Trichoderma* are widely used as biocontrol agents for eco-friendly management of plant pathogens. They produce enzymes and antibiotics, induce plant resistance to diseases and inhibitspore germination of pathogens(Samuels, 1996; Almeida *et al*., 2007; Degenkolb*et al*., 2008; Schuster *et al*., 2010; Cheng *et al*., 2012.; Lopes *et al*., 2012; Mukherjee *et al*., 2013).The effectiveness of *Trichoderma spp.* on*Colletotrichum spp*.(Deepak *et al*., 2020) and on many phytopathogenic agents has already been documented (Kumar *et al*., 2014; Dièye*et al*.,2021; Sharma *et al*., 2021; Matas-Baca *et al*., 2022). However, when the species of *Trichoderma* are applied to cropsother than those from which they were isolated, their efficacy was often reduced (López-López *et al*., 2022). Therefore, the objective of this research work was to assess the efficacy of five isolates of *Trichoderma*isolated directly from mango tree organs to control mango anthracnose due to*Colletotrichumgloeosporioides*.

Materials and Methods:-

Fungal material

The *Colletotrichum*isolate

The isolate of *Colletotrichum gloeosporioides*,used in this study was isolated, from mango fruit showing typical symptoms of anthracnose in Ziguinchor.It was isolated, cultured and maintained on potato dextrose agar plates in the laboratory.

The *Trichoderma* isolates

The isolates of *Trichoderma spp*. originated from different mango production zones in Senegal,such as theCasamance (Ziguinchor, Sédhiou and Kolda) and the Niayes Zone (coastal area between Dakar, Thiès andSaint-Louis) (Table1). They were all isolated from different organs of mango trees, identified and kept in thelaboratory for further tests.

Table 1:- The five isolates of *Trichoderma spp*. used for antagonistic tests with*C. Gloeosporioides.*

Codes	Origin of isolates	Region of isolates	Species
(MA)S3M4ZIG	mango fruit	Ziguinchor	*Trichodermaasperellum*
(MB)F3GP3-5	mangoleaf	Goudomp (Ziguinchor)	*Trichodermaasperellum*
(MC)F3GP3	mangoleaf		*Trichodermaasperellum*
(MD)F2KV3	mangoleaf	Kounkané (Kolda)	*Trichoderma viride*
(ME)S5M5ZN	mango fruit	Niayes Zone (Thiès)	*Trichodermasp.*

In vitro antagonistic activity of *Trichoderma spp.*on*Colletotrichum gloeosporioides*

The isolates of*Trichoderma spp*. were screened for their antagonistic activity against *Colletotrichumgloeosporioides*by using dual culture technique as described by Gueye (2020).Agar discs (5mm) of seven-day-old of *Trichoderma spp.* and *C.gloeosporioides*cultures were placed at two opposite ends of PDA plates (Fig 1). The controlhada culture free disc of PDA and PDA disc colonized by *C. gloeosporioides*atthe opposite ends of the PDA plates. Three replicates were used for each treatment. The petri dishes were then sealed with parafilm and incubated in an oven at a temperature of 25°C.

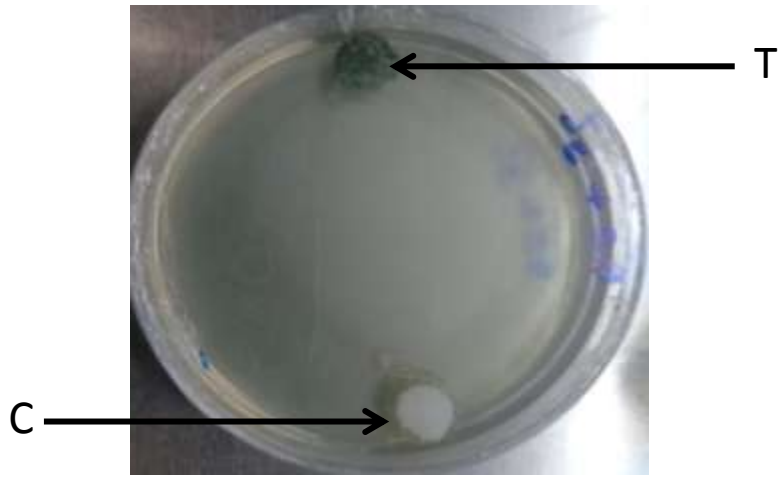

Figure 1:- Direct confrontation set up used for Trichoderma spp. (T) and *Colletotrichum gloeosporioides* (C).

The antagonistic effect of the control agent on the pathogenic fungus *Colletotrichum gloeosporioides*wasassessed after 10 days of incubation, corresponding to the time taken by the pathogento completely fillthe Petri dish.This was determined by calculating the percentage of inhibition of radial growthof *C.gloeosporioides* by *Trichoderma*sppusing the formula proposed by Begum *et al.* (2008).

$$\mathbf{GIR} = \frac{\mathbf{R1} - \mathbf{R2}}{\mathbf{R1}} * \mathbf{100}$$

Where, **GIR**= Growth inhibition rate,
R1 indicates average diameter of fungal colony in the control treatment without antagonist (in cm)
R2 indicates diameter of fungal colony in treated plates with antagonist (in cm)

Invivo*antagonistic activity of *Trichodermaspp*. on *Colletotrichumgloeosporioides

For the*in vivo*test of the efficacy of *Trichoderma* to control the fungal pathogen, mangoes of kent variety were used. After washing with tap water, the fruits were soaked successively in a 1% household bleach solution for 3min, then in 70% ethanol for 60s and finally in sterile distilled water for 10 min. The mangoes were further rinsed a second time under the laminar flow hood with sterile distilled water. Each treatment consisted of 9 mangoes with a mango representingtheexperimental unit. The negative control was made of mangoes treated only with sterile distilled water and the positive control aggregated mangoes soaked with only the spore suspension of the pathogen. The biological control agent was made of a spore suspension of a pure culture of 7days old *Trichoderma* culture. The same process was applied to *Colletotrichum gloeosporioides*with the only difference that a 10days old culture were used.Forboth fungi, the spore suspension was obtained by pouring30mlof sterile distilled water into petri dish, then scrapingthe mycelium together with the water with a sterile scalpel blade into a funnel equipped with multilayer sterile gaze for filtration into an erlenmeyer. A spore suspension free from mycelial fragments was obtained for further experiments.

For the inoculation purposes, the spore suspensions of both the pathogen and antagonists were adjusted at 10^5 spores per ml. Inoculation of mangoes was performed by soaking the fruits one by one in a 1000 mlspore suspension during 5 min. The fruits were thereafter left for drying at room temperature in the laboratory for 30 min. For the treatments involving inoculation with the two fungi, the mangoes were first inoculated with C. gloeosporioides.After dryingat room temperature in the laboratory for 30 min,the fruitswere soaked in the spore suspension of *Trichoderma* for 5 minutes and allowed to dry for another 30 min. For the control treatments, mangoes were soaked in sterile distilled water for 5min in a volume equal to those used for the treated mangoes with spore filtrate (1000ml).The fruits were thereafter incubated at room temperature for 20 days.

Evaluation of fruit disease

Fruit disease was evaluated by assessing incidence and severityof anthracnose 20 days after fruit inoculation.

The incidence (I) of the experimental unit wascalculated using the formula developed by Ngullie*et al.* (2010):

$$\mathbf{I} = \frac{\text{Number of mango showing symptoms of anthracnose}}{\text{Total number of fruits}} * 100$$

The severity (S) of mango anthracnose was evaluated using a visual scale from 0 to 4 where:
0 = mango fruit without symptoms of anthracnose,
1 = 1 to 25% of mango surface with anthracnose symptoms,
2 = 26 à 50% of mango surface with anthracnose symptoms,
3 = 51 à 75% of mango surface with anthracnose symptoms,
4 = 76% à 100% of mango surface with anthracnose symptoms

The severity of the experimental unit was calculated using the formula developed by Ngullie*et al*. (2010):

$$\mathbf{S} = \frac{\sum(\mathbf{Ni} * \mathbf{Si})}{\mathbf{N} * \mathbf{Z}} * \mathbf{100}$$

Where **N** =Number of mango fruits withseverity i, **Si** = Severity value i of anthracnose, **N** = Total number of mango fruit, **Z** =Highest severity index

Statistical Analysis
The statistical analysis was performed using the software R version 3.6.2. All the data were first subjected to a normalitytest. The data were then compared through the Analysis of Variance (ANOVA) when they were normally distributed. The Student-Newman-Keuls (SNK) testwas used to compare the means.

Results:-

In vitro* antagonistic activity of*Trichoderma spp.*on *Colletotrichum gloeosporioides
All isolates tested were able to reduce the mycelial growth of thefungal pathogen (Fig2). *Trichoderma sp* (isolate S5M5ZN)showed the greatest efficacy with complete inhibition of mycelial growth of the pathogen. It was followed by the strains F3GP3 (*T. asperellum*), F3GP3-5 (*T.asperellum*),F2KV3 (*T.viride*), S3M4ZIG (*T.asperellum*), which causedrespective reductionof mycelial growth of the pathogenby89.41 ± 18.33%, 89.01 ± 19.01%, 77.25 ± 19, 77%, 77.25 ± 12.95%.

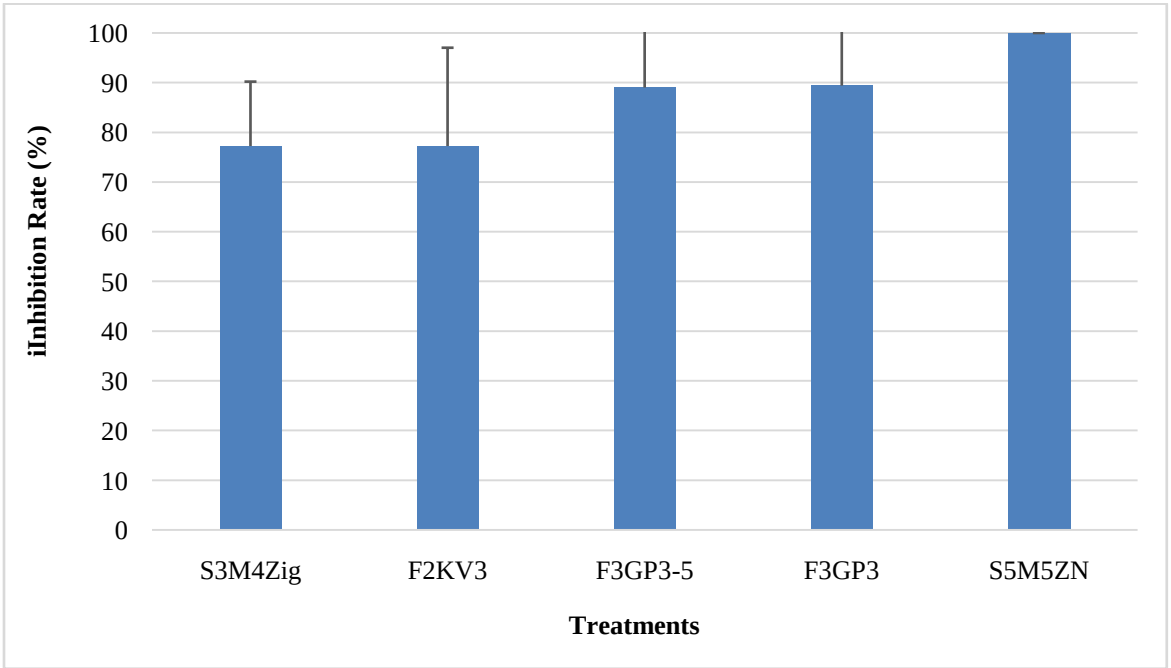

Figure 2:- Performance of different *Trichoderma spp.*at inhibiting mycelial growth of*Colletotrichum gloeosporioides*, in a dual culture confrontation in vitro, n=3, p=0,00103; S3M4ZIG, F3GP3 and F3GP3-5= *Trichoderma asperellum*, F2KV3= *Trichoderma viride*, S5M5ZN= *Trichoderma sp*.

Observation of fungal structures of both the antagonistic *Trichoderma* strains and the *C. gloeosporioides* in the confrontation zone under microscope(Gx400)showed mycelial cord transformation (Fig 3a), coiling (Fig 3b) and cell lysis of the pathogen (Fig 3c).

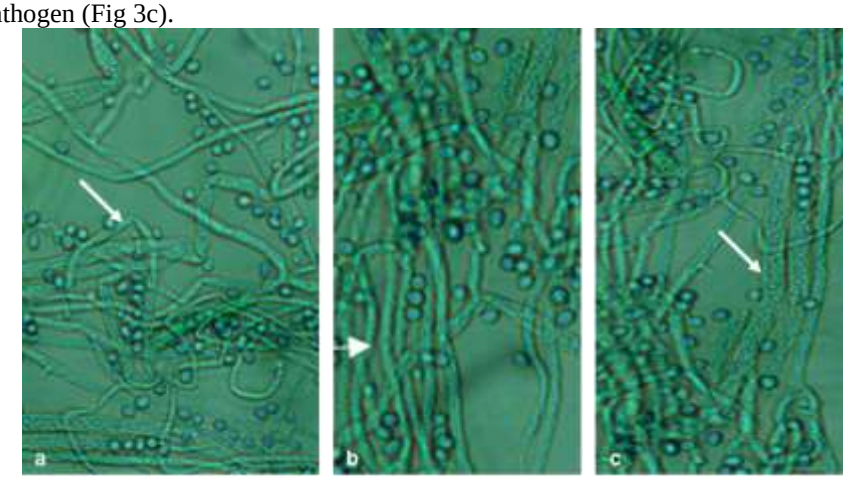

Figure 3:- Modification of the mycelium of *Colletotrichum gloeosporioides*, a= cord transformation (arrow), b= coiling of the mycelium (arrow), c= lysis of the mycelium (arrow) (Gx400).

In vivo* antagonistic activity of *Trichodermaspp*.on*Colletotrichum gloeosporioides

Incidence of mango anthracnose

The evaluation of the efficacy of *Trichoderma* to control mango anthracnose on inoculated mangoes was performed after 20 days of incubation. It showed that fruits that received the isolates F2KV3 (*T.viride*), F3GP3 and S3M4ZIG (*T.asperellum*)after inoculation with *Colletotrichum gloeosporioides*had a low incidence of anthracnose, with a mean value around 22 %(Fig4).At the same time the negative control treatment (T0) that was soaked in sterile water was displaying 44.44 ± 00.00%incidence. The positive control (T+), inoculated with the pathogen presented the highest incidence with 88.88 ± 00.00%.

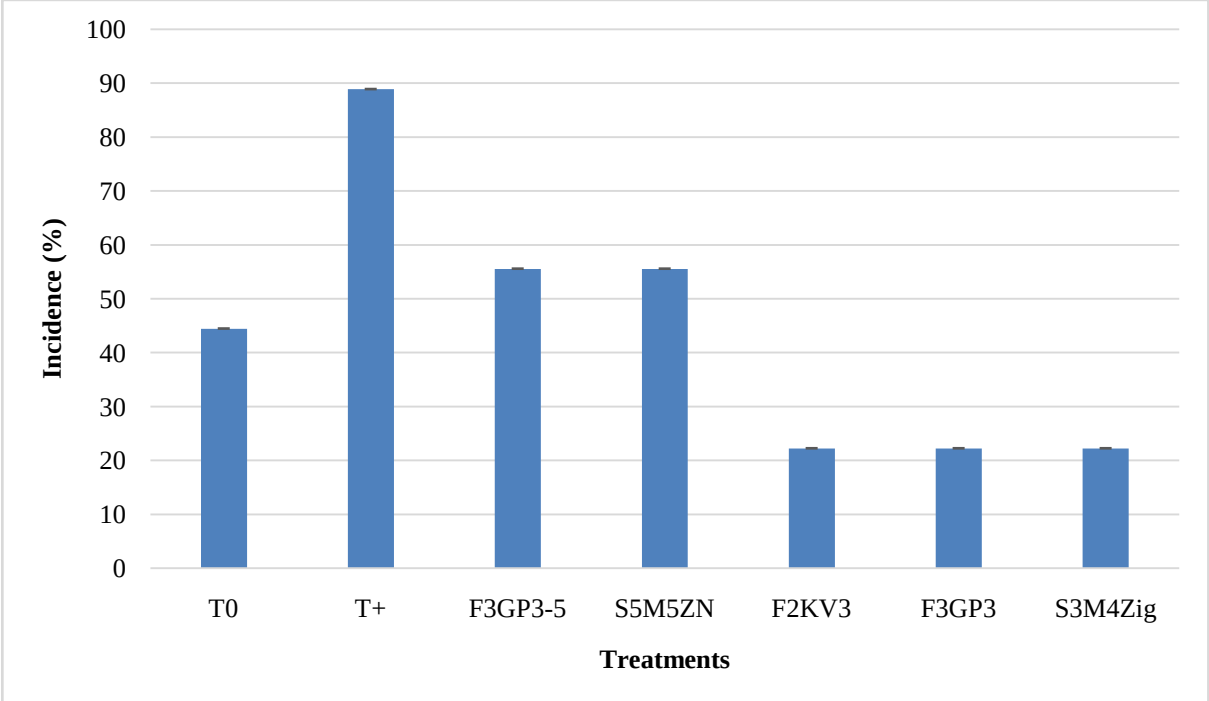

Figure 4:- Incidence of mango anthracnoseon fruits inoculated with*Colletotrichum gloeosporioides* and *Trichoderma spp.* alone or in combination after 20 days of incubation, n = 9, $p<2e^{-16}$; T0= mango treated with sterile distilled water, T+= mango treated with filtrate of pathogenic fungus *Colletotrichum gloeosporioides*,S3M4ZIG,F3GP3 and F3GP3-5 =*T.asperellum*, F2KV3 = *T.viride*, S5M5ZN=*Trichoderma sp.*

Severity of mango anthracnose

Mangoes from the negative control treatment soaked only with sterile water presented a severity of 20.36±4.39% (severity index 1) (figure 5). The positive control treatment with mangoes inoculated with only*Colletotrichum gloeosporioides*showed the highest severitywith a percentage of50.69 ± 6.58% (severity index 2). At the same time, the fruits treated with the isolate S3M4ZIG (*T. asperellum*) after inoculation with *Colletotrichum gloeosporioides*presented the lowest disease severity with5.55 ± 00.00% (severity index 1).

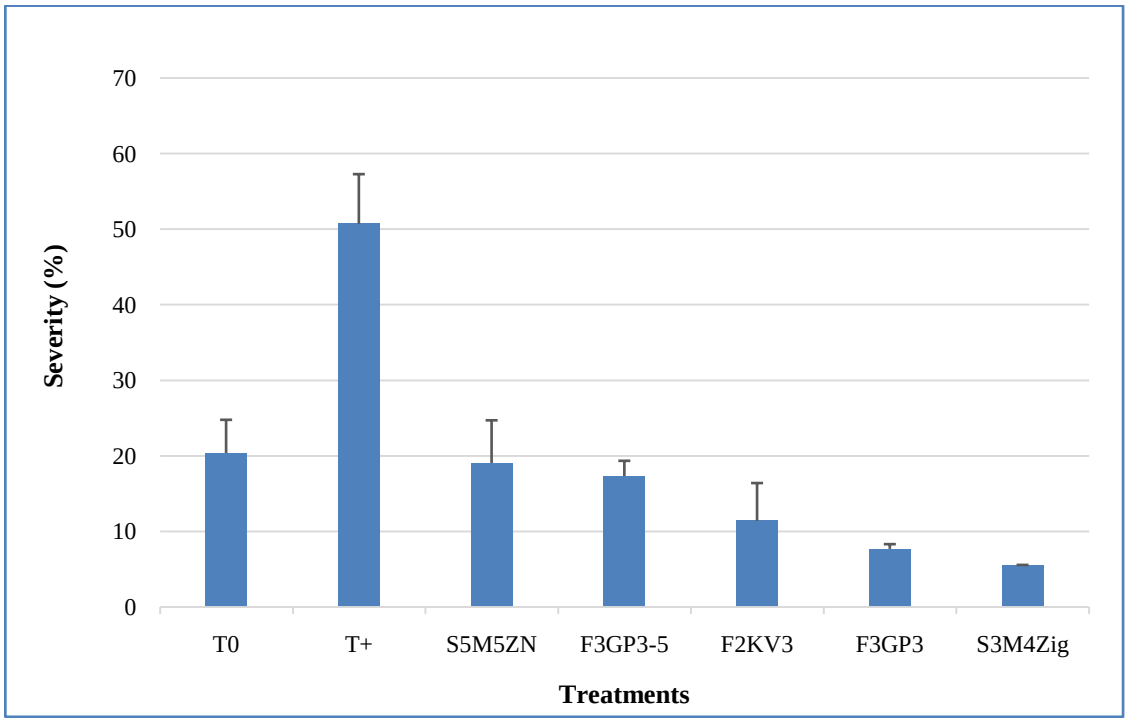

Figure 5:- Severity of mango anthracnose on fruits inoculated with*Colletotrichum gloeosporioides* and *Trichoderma spp.* alone or in combination after 20 days of incubation, n=9;$p<2e^{-16}$; T0= mango treated with sterile distilled water, T+= mango treated with filtrate of pathogenic fungus *Colletotrichum gloeosporioides*,S3M4ZIG, F3GP3 and F3GP3-5= *Trichoderma asperellum*, F2KV3= *Trichoderma viride*, S5M5ZN = *Trichoderma sp*.

Mango appearance at the end of the experiment wasvariable depending on treatment. Departing from an apparently healthy status of the mature not yet ripe mangoes (figure 6 a), symptoms of disease were noticed after 20 days of incubation. Anthracnose spots were prevalent onmangoes from all treatments, but affected more those from the positive control fruits(figure 6 d). The mangoes from the negative control, that were not inoculated, were also affected (figure 6 c). The diseases symptoms were less visible with mangoes inoculated with *C. gloeosporioides* then *T.asperellum*isolate S3M4ZIG, with 7 out of9mangoes that were still showing a marketable aspect after 20 days.

a = mangoes before inoculation

b=mangoes inoculated with both *C. gloeosporioides* and antagonist fungi T.asperellum strain S3M4ZIG after 20 days of incubation

c=mangoes of the negative control treatment, soaked with only sterile distilled water after 20 days of incubation

d=mangoes of the positive control treatment, inoculated with the pathogenic fungi C. gloeosporioides, after 20 days of incubation

Figure6:- Aspects of mangoesat time of inoculation and according to different treatments 20 days later, **a**=mangoes before inoculation, **b**=mangoes inoculated with both *C. gloeosporioides* and antagonist fungi *T. asperellum* strain S3M4ZIG, **c**= mangoes of the negative control treatment soaked with only sterile distilled water, **d**= mangoes of the positive control treatment, inoculated with the pathogenic fungi *C. gloeosporioides*

Discussion:-

Anthracnose is one of the most damaging postharvest diseasesof mango worldwide. It is usually controlled with fungicides, the frequent use of which may lead to environmental pollution, appearance of resistancein number of cases and also serious threat to human health (De Curtis *et al*., 2010; Wong *et al*., 2015).Alternative control methods based on environment friendly and less risky products to human health are being developed. Among those alternatives, natural products such as essential oils and *Trichoderma spp.* have shown a good efficacy on many pathogenic fungi (Begum *et al.*, 2008).In the present work, the experimentations were carried out to test the *in vitro* and *in vivo* efficacy of native *Trichoderma* isolates for the biological control of *Colletotrichumgloeosporioides*, the causal agent of mango anthracnose.On mycelial growth of *Colletotrichum gloeosporioides*, the isolate S5M5ZN (*Trichoderma sp.)* causedtotal inhibition. It was followed by isolates F3GP3 (*T. asperellum*), F3GP3-5 (*T. asperellum*), F2KV3 (*T. viride*) and S3M4ZIG (*T. asperellum*), which allowed respective reductions of mycelial growth of 89.41±18.33%, 89.01±19.01%, 77.25±19.77% and 77.25±12.95%. In previous works, *Trichoderma harzianum* isolate Th-2 was reported to cause 100% inhibition of mycelial growth of *Colletotrichum capsici* (Begum *et al*., 2015). Dièye*et al.* (2021)observed an*in vitro* antagonistic activity of *Trichoderma koningii*Audemas (M35) and *Trichodermalongibrachiatum* Rifai (M37) on thirteen isolates of *Fusarium sp.* isolated from symptoms of mangomalformation disease in Southern Senegal.

The ability of*Trichoderma spp*.on the control of fungal pathogens is related to their capacity to act as antagonist against other microorganisms. This efficacy is associated to their ability of growing fast and occupying the space and rapidnutrientuse as well as lytic actions against the pathogens (Begum *et al*., 2008; Begum *et al*., 2015; Sharma *et al*., 2021). At the end of the experimentations, observations under optical microscope, showed coiling, mycelial cord transformation and cell lysis of the pathogen in the confrontation zone with the *Trichoderma* isolates. This suggests that a potential combination of both competition for space and nutrients as well as chemical activity leading to cell lysis would be the likely mode of action deployed by the tested *Trichoderma* isolates. It is also known that *Trichodermaspp* may also secret volatile compounds such as Trichodermins and Trichodermols to degrade the cells of pathogens (Elad*et al*., 2000).Previous experimentations also documented that metabolites were involved in the efficacy of fungi of the genus *Trichoderma*on *C.gloeosporioides* (Waterhouse *et al*., 1968). Enzymes such as xylanases and chitinases, involved in the degradation of the cell walls of phytopathogenic fungi were also demonstrated to be produced by fungi of the genus *Trichoderma* (Shi *et al*., 2012; Vinale*et al*., 2014; Pandey *et al*., 2015).

The *in vivo*testswere conducted to verify the ability of *Trichoderma spp*. to control mango disease during post-harvest stage and preserve the phytosanitary quality of fruits. When the mangoes inoculated with *C. gloeosporioides* in a spore suspension were soaked with the spore suspension of the antagonist,the incidence and severity of anthracnose were highly reduced. In fact, the negative control and the positive control showed respective incidence of 44.44 ± 00.00% and 88.88 ± 00.00% and severity means of 20.36 ± 4.39 and 50.69 ± 6.58%.In the most effective treatment that involved *T. asperellum*isolate S3M4ZIGthe severity was reduced down to 5.55 ± 00.00% while the incidence was 22.22± 00.00%. In terms of fruit quality 20 days after treatment, 7 out of 9 mangoes treated isolate S3M4ZIG with were still showing a good phytosanitary quality and still had market value.In terms of disease control, this isolate allowed a reduction of incidence by 75% compared to the positive control and 50% with respect to the negative control. The severity was reduced down by 89% for the positive control and 72.7 % for the negative control. Likewise, Sharma *et al.* (2021)reportedthat dipping of mangoes in *Trichoderma harzianum* and *Pseudomonas fluorescens* suspensionsreducedanthracnose by 40.0 to 43.3%. *In vivo* efficacy was also reported for *Trichoderma spp.* on mango anthracnose (Rahman *et al*., 2013).

In addition,application of a culture filtrateof *T. harzianum* on mangoes was reported to reduce significantly the severity of anthracnose (Rahman *et al*., 2012), pointing towards the involvement of biochemical mechanisms to control pathogens. The ability of *Trichoderma* species to reduce disease severity was also put in relation with their ability to inhibit the conidial germination of *C. gloeosporioides* on mango surfaces (Begum *et al*., 2015).In the present study, the efficacy of the isolate S3M4ZIG was higher on the positive control (75% reduction of incidence and 89% reduction of severity) compared to negative control (50% reduction of incidence and 72.7% reduction of severity.This suggests that mangoes from the negative controlwith respective incidence of 44.44 % and severity of 20.36% were very likely to harbor natural latent infectionsof *Colletotrichum*. In fact, developing fruit may be infected in the field, but infections remain quiescent untilthe onset of ripening, which occurs after harvest. Once the climacteric period of the fruit starts, lesions beginto develop (Arauz, 2000). The eventually of a latent infection may therefore explain that our inoculation period came late to control the spore germination stage, reducing thereby the efficacy of Trichoderma control.

The significant suppression of the mycelial growth of *Colletotrichum gloeosporioides*in vitro added to the ability of *T. asperellum* isolate S3M4ZIG to significatively inhibit the development of anthracnose on mangoes inoculated with pathogen suggestsa capacity to produce substances with antifungal effects beside the competition for space and nutrients.

The incidence of 88.88 ± 00.00% and severity of 50.69 ± 6.58% found for the positive control shows that the inoculation method was effective for *C. gloeosporioides.* This data is another demonstration of the ability of the fungus to create own access to the fruit tissues without any help through wounding as already reported by Diallo *et al*. (2017).

The *in vitro* performance of *T. asperellum* isolate S3M4ZIG on *Colletotrichum gloeosporioides*was about 77% while isolate S5M5ZN (*Trichoderma sp.)* inhibited totally the mycelial growth. In many screening works for microbial antagonists, an efficacy threshold of 85% is often set to qualify to further tests (Hermosa *etal*.,2012; Sabbagh *et al*., 2017; López-López *et al*., 2022). The results of this study corroborated those ofKumar *et al.*

(2014) that the testing environment may play an important role on the performance of livingagents to control pests and diseases.

Conclusion:-

The *Trichoderma* isolates tested showeda good controlactivity against *Colletotrichum gloeosporioides*, the causal agent of mango anthracnose.The isolate S5M5ZN (*Trichoderma sp.)*showed the greatest*in vitro* efficacy against *C. gloeosporioides* with a total inhibition of mycelial growth. While not being among the best performing isolates duringthe in vitro tests, S3M4ZIG (*Trichoderma asperellum*) allowed a better control of mangoanthracnose with the lowest incidence and severity on mangoes 20 daysafter inoculations. The negative control showedanthracnose spots deriving from natural contaminations that were further enhanced through inoculation as shown by the positive control. Differences on control efficacy on the negative and positive control treatments suggests that early inoculation with the antagonist to cover spore germination stage of the pathogen may enhance the efficacy of *Trichoderma* species.

Acknowledgements:-

This research work was supported by the European Commission through LEAP-Agri and AfricanInternational Programs for Mobility (CAPITUM). The research work was conducted in the Laboratory of Phytochemistry and Plant Protection of the University Cheikh Anta DIOP of Dakar and the Laboratory of Agri-Food and Health of Hassan 1er University in Morocco.

References:-

1. Sharma, A., Sharma, I., Sharma, M. (2021): Effectiveness of fungal, bacterial and yeast antagonists for management of mango anthracnose (Colletotrichum gloeosporioides). Egypt J Biol Pest Control 31:135. https://doi.org/10.1186/s41938-021-00480-9
2. Ahouangninou, C., Fayomi, E., Benjamin., Martin T. (2011) : Evaluation des risquessanitaires et environnementaux des pratiques phytosanitaires des producteursmaraichers dans la commune rurale de Tori-Bossito (Sud-Benin). Cah Agric. 20 (3) : 216-222.
3. Almeida, F.B., Cerqueira, F.M., Silva, R.N., Ulhoa, C.J., Lima, A.L. (2007):Mycoparasitism studies of Trichoderma harzianum strains against Rhizoctonia solani: evaluation of coiling and hydrolytic enzyme production. Biotechnol Lett 29 :1189–1193, doi :10.1007/s10529-007-9372-z
4. Amin F., Razdan, V.K., Mohiddin, F., Bhat, K.A., Sheikh, P.A (2010): Effect of volatile metabolites of Trichoderma species against seven fungal plant pathogens in-vitro. Journal of Phytology, 2(10): 34-37.
5. Arauz, L.F. (2000): Mango Anthracnose: Economic impact and current options for integrated management". Plant Diseases 84(6): 600-611
6. Begum, S., Nath, P.S. (2015): Eco-friendly management of anthracnose of chilli caused by Colletotrichum capsicums. Journal of Applied and Natural Science, 7(1): 119 – 123.
7. Begum, M.M., Sariah, M., Abidin, Z.M.A., Puteh, A.B., Rahman, M.A: (2008): Antagonistic potential of selected fungal and bacterial biocontrol agents against Colletotrichum truncatum of soybean seeds. Pertanika Journal of Tropical Agriculture Science, 31: 45-53.
8. Caron, J., Laverdière, L., Thibodeau, O. P., Bélanger, R. R. (2002) :Utilisationd'unesoucheindigène de Trichoderma harzianumcontre cinq agents pathogènes chez le concombre et la tomate de serre au Québec. Phytoprotection; 83: 73-87.
9. Dièye, C., Diédhiou, P.M., Houmairi, H., Mbaye, N., Diallo, Y., Bencharki, B. (2021): In vitro Antagonistic Effect of Trichoderma koningiiAudemas and Trichoderma longibrachiatum Rifai on Mango Malformation Disease in Southern Senegal. International Journal of Agriculture Innovations and Research, 10 (2): 89 – 96.
10. Cheng, C.H, Yang, C.A., Peng,K.C. (2012): Antagonism of Trichoderma harzianum ETS 323 on Botrytis cinerea mycelium in culture conditions". Phytopathology 102:1054–1063, doi:10.1094/PHYTO-11-11-0315
11. CISSE, M.M, MBAYE, N., DIEDHIOU, P.M. (2020): In vitro antifungal activity of essential oils of aromatic plants of the Senegalese flora on Colletotrichum gloeosporioides (Penz.) Penz and Sacc., the causal agent of mango anthracnose" International Journal of Science, Environment and Technology, 9(3): 301 – 311
12. Cissé, I., Tandia, A. A., Fall, S. T., Diop, E. H. S. (2003): Usage incontrôlé des pesticides en agriculture périurbaine: cas de la zone des Niayes au Sénégal. Cah. Agric. 12: 181.

13. De Curtis, F., Lima, G.V., De Cicco, V. (2010): Biocontrol of Rhizoctotoniasolani and Sclerotium rolfsii on tomato by delivering antagonistic bacteria through a drip irrigation system. Crop Prot. 29 :663-570.
14. Deepak, Kumar., Ria, Mukhopadhyay. (2020): Trichoderma: a beneficial antifungal agent and insights into its mechanism of biocontrol potential". Egyptian Journal of Biological Pest Control. 8: 30-133
15. Diedhiou, P. M., Mbaye, N., Dramé, A., and Samb, P.I. (2007): Alteration of post-harvest disease of mango (Mangifera indica) through production practices and climatic factors. African Journal of Biotechnology 6: 1087-1094.
16. Diedhiou, P.M., Diallo, Y., Faye, R., Mbengue, A.A., Sene, A. (2014): Efficacy of Different Fungicides against Mango Anthracnose in SoudanianAgroclimate. American Journal of Plant Sciences, 5 :2224-2229
17. Degenkolb,T., von Döhren, H., Nielsen, K.F., Samuels, G.J., Brückner, H. (2008): Recent advances and future prospects in peptaibiotics, hydrophobin and mycotoxin research and their importance for chemotaxonomy of Trichoderma and Hypocrea. Chem Biodivers 5 :671–680, doi :10.1002/cbdv.200890064
18. Elad, Y. (2000): Biological control of foliar pathogens by means of Trichoderma harzianum and potential modes of action. Crop Protection, 19: 709-714
19. FAO. (2019): Food and Agricultural Organization, FAOSTAT" http://faostat.fao.org. data obtained on 20 January 2020
20. Guèye, N. (2020): Caractérisation de Trichoderma spp. indigènes et évaluation de leurspotentialitésantagonistes sur deux agents pathogènes de la tomate (Solanum lycopersicum L.) au Sénégal : Fusarium oxysporum et Sclerotinia rolfsii. These de Doctorat Unique, UCAD, Fac Sciences, 183p.
21. Hermosa, R., Viterbo, A., Chet, I., Monte, E. (2012) : Plant-beneficial effects of Trichoderma and of its genes. Microbiology, 158, 17–25. [CrossRef] [PubMed]
22. Hileman,B. (1994): Environnemental Estrogens linked to Reproductive Abnormalities. Cancer Chem. Eng. News, 72 (5), pp 19–23.
23. Kebe, I.B., Mpika, J., N'guessan, F., Kouamé, H.K.P., Gary, S.S., Severin, A. (2009): Isolement et identification de microorganismesindigènes de cacaoyèresen Côte d'Ivoire et mise enévidence de leurseffetsantagonistes vis-à vis de Phytophthora palmivora, agent de la pourriturebrune des cabosses. Sciences & Nature, 6(1): 71 – 82
24. Lopes, F.A.C., Steindorff, A.S., Geraldine, A.M., Brandao, R.S., Monteiro, V.N., Lobo, M., Coelho, A.S.G., Ulhoa,C.J., Silva, R.N. (2012): Biochemical and metabolic profiles of Trichoderma strains isolated from common bean crops in the Brazilian Cerrado and potential antagonism against Sclerotinia sclerotiorum. Fungal Biol 116:815–824, doi:10.1016/j. funbio.2012.04.015
25. López-López, M.E., DelToro-Sánchez, C.L., Gutiérrez-Lomelí, M., Ochoa-Ascencio, S., AguilarLópez, J.A., Robles-García, M.A., Plascencia-Jatomea, M., BernalMercado, A.T.,Martínez-Cruz, O., Ávila-Novoa, M.G. (2022) : Isolation and Characterization of Trichoderma spp. for Antagonistic Activity against Avocado (Persea americana Mill) Fruit Pathogens. Horticulturae 8, 714.
26. Mbaye, N. (2006) :Inventaire et caractérisation des champignons phytopathogénesresponsables des maladies post-récoltes chez deux variétés de mangues (Mangifera indica L), Kent et Keitt, destinées à l'exportation dans la zone des Niayes du Sénégal. Dissertation :Départementbiologievégétale : Université Cheikh Anta Diop, 105 p
27. Mukherjee, P.K., Singh, U.S., Horwitz, B.A., Schmoll, M., Mukherjee,M. (2013): Trichoderma: biology and applications. Wallingford: CABI.
28. Nelson, S.C. (2008): Mango anthracnose (Colletotrichum gloeosporioides). Plant Disease. Department of Plant and Environmental Protection Sciences, College of Tropical Agriculture and Human Resources, University of Hawaii, Manoa, pp.1-9.
29. Ngullie, M., Daiho, L., Upadhyay, D.N. (2010): Biological management of fruit rot in the world's hottest chilli (Capsicum chinense Jacq.). Journal of Plant Protection Research, 50(3): 269-273.
30. On, A., Wong, F., K.O. Q., Tweddell, R.T., Antoun, H., Avis, T.J. (2015): Antifungal effect of compost tea microorganisms on tomato pathogens. Biol. Control 80 :63-69.
31. Pandey, S., Srivastava, M., Shahid, M., Kumar, V., Singh, A., Trivedi, S., Srivastava, Y.K. (2015): Trichoderma species cellulases produced by solid state fermentation". Journal of Data Mining in Genomics & Proteomics, 6(2): 170.
32. Pardo-De la Hoz, C.J., Calderon, C., Rincon, A.M., Cardenas, M., Danies, G., Lopez-Kleine, L., Restrepo, S., Jimenez, P. (2016):Species from the Colletotrichum acutatum, Colletotrichum boninense and

Colletotrichum gloeosporioides species complexes associated with tree tomato and mango crops in Colombia. Plant Pathology, 65, 227-237

33. Rahman, M.A., Rahman, M.M., Kamruzzaman, M., Begum, M.F., Alam, M.F. (2012): Use of culture filtrates of Trichoderma strains as a biological control agent against Colletotrichum capsici causing anthracnose fruit rot disease of chilli. Journal of Biodiversity and Environmental Sciences, 2(1): 9-18.
34. Rahman, M.A., Razvy, M.A., Alam, M.F. (2013): Antagonistic activities of Trichoderma strains against chili anthracnose pathogen". International Journal of Microbiology and Mycology, 1(1): 7-22
35. Sabbagh, S., Roudini, M., Panjehkeh, N. (2017): Systemic resistance induced by Trichoderma harzianum and Glomus mossea on cucumber damping-off disease caused by Phytophthora melonis. Arch. Phytopathol. Plant Prot, 50, 375–388. [CrossRef]
36. Samuels, G.J. (1996): Trichoderma: a review of biology and systematic of the genus. Microbiol Res 100 :923–935, doi :10.1016/S0953-7562(96)80043-8
37. Sanjeev, K., Manibhushan, T., Archana, R. (2014). Trichoderma, Mass production, formulation, quality control, delivery and its scope in commercialization in India for the management of plant diseases. African Journal of Agricultural Research, Vol. 9(53), pp. 3838-3852
38. Schuster, A., Schmoll, M. (2010): Biology and biotechnology of Trichoderma. Appl MicrobiolBiotechnol 87 :787–799, doi:10.1007/s00253-010-2632-1
39. Shi, M., Chen, L., Wang, X.W., Zhang, T., Zhao, P.B., Song, X.Y., Sun, C.Y., Chen, X.L., Zhou, B.C., Zhang, Y.Z. (2012): Antimicrobial peptaibols from Trichoderma pseudokoningii induce programmed cell death in plant fungal pathogens. Microbiology, 158: 167-175
40. Traoré, S.K., Mamadou, K., Dembele, A., Lafrance, P., Mazelliert, P., Houenou, P. (2006): Contamination de l'eausouterraine par les pesticides enrégionsagricolesen Côte d'Ivoire (Centre, Sud et Sud-Ouest). Journal Africain des Sciences de l'Environnement 1: 1-9.
41. Udhayakumar, R., Usha Rani, S. (2010): In vitro efficacy of bacterial antagonists on the incidence of mango anthracnose and development of its pathogen. Agric Sci Digest 30(4):293–295
42. Vinale, F., Sivasithamparam, K., Ghisalberti, E. L., Woo, S.L., Nigro, M., Marra, R., Lombardi, N., Pascale, A., Ruocco, M., Lanzuise, S., Manganiello, G., Lorito, M. (2014): Trichoderma secondary metabolites active on plants and fungal pathogens. The Open Mycology Journal, 8, (Suppl-1, M5): 127-139.
43. Waterhouse, G.M. (1968): The genus Pythium Pringsheim. Mycological Papers, 110: 1-50.
44. Yan, K.Y; ANH, V.T.U (2018): Effect of Trichoderma sp. on Anthracnose Disease of Stored Chilli. Borneo Journal of Resource Science and Technology, 8(2): 90-102
45. Yaya, D., Papa, M.D., Elizabeth, B., Mizuho, N., Anton, B. (2017). BIOFUNGICIDES AN EFFICIENT ALTERNATIVE CONTROL STRATEGY AGAINST MANGO ANTHRACNOSE IN SENEGAL. Int. J. Adv. Res. 5(6), 990-995.
46. Zakaria, L., Juhari, N.Z., Vuaya, S.I., Anuar, I.S.M. (2015): Molecular Characterization of Colletotrichum Isolates Associated with Anthracnose of Mango Fruit.SainsMalaysiana, 44 (5): 651-656.