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IMPACT OF CULTURAL PRACTICES ON TRICHODERMA STRAINS IN PAPAYA RHIZOSPHERE, DIAMARE DIVISION, CAMEROON

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ABSTRACT

Organic farming is a method of agricultural production that aims to respect natural systems and cycles, maintain and improve the condition of soil, water, and air, and the health of plants and animals. It is an answer to the environmental sufferings caused by chemical pesticides and synthetic fertilizers. Microscopic soil fungi in the genus *Trichoderma* are important in agricultural contexts as they induce soil fertility and plant resistance to pathogens. The present work assesses the presence of *Trichoderma* spp. in soil samples from the papaya rhizosphere in the Sudano-Sahelian area of Cameroon. Cultural practices were recorded in papaya orchards through semi-structured interviews addressed to papaya growers identified in this region. Ten papaya trees were randomly selected for soil samples in four treated plots. Three samples of soil were collected around each labelled papaya tree at 25, 50, and 75 cm from the trunk for a depth of up to 40 cm, and a composite sample consisting of the mixture of the resulting 30 soil samples performed per plot was obtained and kept for further analysis. Moreover, an additional composite soil sample from experimental papaya in the organic experimental farming site of Meskine was committed as a control plot. Microbiological studies were performed using a specific TSM at different concentration levels from 10^{-4} to 10^{-5}, 10^{-6}, 10^{-7}, and 10^{-10} in Petri dishes with 6 repetitions each. The mean colonisation rate of *Trichoderma* spp. was compared between plots. Results showed that the common use of agrochemicals by papaya producers and the fire-prone when implementing papaya fields negatively impacted the development of useful *Trichoderma* strains in their farms. No *Trichoderma* strain was found in soil samples for each papaya farm from treated plots (0%). While, all samples analysed from the control plot were 100% productive of the soil-born microorganism sought. Farmers in the Diamare division are encouraged to use eco-friendly cultural methods for preserving *Trichoderma* spp. in the rhizosphere of papaya trees.

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INTRODUCTION

The papaya tree *Carica papaya* Linnaeus 1753 (Caricaceae) commonly called island fig is a native crop from southern Mexico (Lebégin, 2021). This exotic plant species grows well in tropical regions of the globe including Africa, America, and Asia (Fournet, 2002). It is commonly grown for its edible fruits namely papayas (Delange, 2002). The tree has an upright habit, varying in height from 2 to 10 m depending on the variety (Lebégin, 2021). The papaya tree is dioecious, made up of male plants and female plants which are subject to cross-pollination; however, there are also bisexual or hermaphroditic stands that are subject to self-fertilize and produce uniform fruit (Tchio et al., 2014). The male flowers are formed on long branched panicles in the axils of the leaves, while the female flowers are born isolated or in groups of 2 or 3 on the upper part of the trunk (Fournet, 2002). If the pollination of the female and bisexual flowers is successful, large berries are formed that are orange-yellow in color, ovoid in shape, and whose mass varies following varieties. The flesh, in the center of which are numerous black seeds, is orange or red and sweet when ripe.

Papaya cultivation is still subject to several constraints, including losses to plant pathogens of which the main is Anthracnose (Triphati et al., 2008). In Cameroon, most farmers use chemical fungicides to ensure the fruit protection of papaya (Tchio et al., 2014). Yet, the chemical-based fruit protection practices endanger human, animal, and ecosystem health (WHO, 2023); hence the need to encourage alternative management practices to control fungal pathogens, such as by promoting plant resistance.

Agrobiodiversity performs several natural services such as maintaining soil fertility and biota, and soil and water conservation, all of which are essential to human survival (Zimmerer and de Haan, 2017). Biodiversity supports food producers' livelihoods while reducing negative environmental impacts (Caillon and Degeorges, 2007). It constitutes the variety and variability of animals, plants, and microorganisms that are used directly or indirectly for food and agriculture (Bais et al., 2006). Microorganisms live in large communities and usually develop multifunctional interactions with plant species in nature (Bais et al., 2006). Among the diversity of these microorganisms, some are beneficial and play a dynamic role in promoting the health of plants and soils thus contributing to the improvement of agricultural yield (Meliani et al., 2017). Agricultural lands are particularly full of endophyte microorganisms that live in symbiosis with the roots of plant species (Parkash and Saikai, 2015).

Mycelial microorganisms belonging to the genus *Trichoderma* are important symbionts with a wide range of cultivated and wild plant species (Ryan et al., 2007). *Trichoderma* fungi are known for their antagonistic properties and are used as biological control agents against a broad spectrum of phytopathogens (Ozbay and Newman, 2004). The genus *Trichoderma* can induce the systematic resistance of plants to various pathogens through antibiosis (Vinale et al., 2008); indeed, the presence of these fungi in the soil is an indicator of the bioavailability of phosphorus, which is an important ingredient of its fertility (Borges et al., 2015). Members of the genus *Trichoderma* appeared as promising groups of microbial inoculants that can induce plant growth and resistance to several diseases (Tchameni et al., 2011). Recently, some studies have demonstrated the ability of *Trichoderma* to stimulate the growth of certain crops such as tomatoes (Mourina et al., 2008) and cacao (Tchameni et al., 2011). The isolation of mycelial species belonging to the genus *Trichoderma* and its impregnation in the form of biopesticide or biofertilizer is a contribution to the amendment of the topsoil layer (Luo et al., 2019). Nowadays, *Trichoderma*-based bio-inputs make it possible to reduce the use of chemical inputs whose harmfulness has already been clearly established (Vinale et al., 2007). However, unsuitable agricultural practices and environmental constraints can negatively influence the activity and relative abundance of these fungi in the soil, thereby reducing or inhibiting the effectiveness of their action (Ryan et al., 2007).

Cameroon's soil microflora is very diverse, as evidenced by some previous findings (Tondje et al., 2005; Mbarga et al., 2014; Ntah et al., 2018). Several strains of fungi of the genus *Trichoderma* have already been isolated from the soil layer of this country (Tondje et al., 2005; Mbarga et al., 2020). Among many others are for example *T. asperellum* (Mbarga et al., 2014), *T. harzianum*, and *T. aureoviride* (Ntah et al., 2018). However, no study has yet been done on the influence of cultural practices on the presence of beneficial microorganisms to improve crop health and soil integrity. The present study aims to determine the impact of cultural practices on the prevalence of the beneficial microorganisms belonging to the genus *Trichoderma* in the rhizosphere of papaya trees in the Far North region of Cameroon. To do so, it is important: 1) to record different cultural practices used by papaya growers identified, 2) to carry out the microbiological analysis of the soil samples taken from the various prospecting sites, and if possible, 3) to determine the presence or absence of symbiotic microorganisms belonging to the genus *Trichoderma* from these soils.

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MATERIALS AND METHODS

Study site

The present study was carried out from September to March 2020 and 2021 in two districts of the Diamare division from the Far North region of Cameroon. The local climate here is of the unimodal Sudano-Sahelian type (Raunet, 2003), the dry season being longer (7-9 months) than the rainy season (3-5 months). The average precipitation shows significant inter-annual variations from 400 to 1100 mm (Morin, 2000). Temperatures are very high and can exceed 40°C in March. During periods of low temperature, from December to January, mean temperatures can drop to 32°C with a minimum of about 16°C. The relative humidity is minimal between February and March (23 to 25%); yet, during periods of heavy rains (August and September), it is highest and varies from 95 to 100% (Raunet, 2003).

The soils of the Far North region are variable from site to site but unstable and predominantly sandy clay (Raunet, 2003). The most striking sign of land degradation in this area is the presence of large surfaces of bare soils (Morin, 2000). The soils of the Far North of Cameroon have specific soil forms and are adapted to different crops; thus are the sandy soils in the plains, favorable to the cultivation of sorghum, cowpea, and groundnut; loamy soils rich in alluvium and located along seasonal watercourses or 'mayos' which are favorable for the cultivation of cotton, sorghum, sweet potato, and market gardens, as well as clay soils or vertisols suitable for cultivation of off-season sorghum locally called 'Muskwari'.

Survey of papaya growers in the Diamare division

Several field trips were carried out in the different districts of the Diamare division, the once over five divisions that constitute the Far North region where papaya is cultivated according to our preliminary investigations and a report of the regional delegation of the Ministry of Agriculture and Rural Development of the Far North in 2020. In each of these cities, we interviewed at random 80 people to identify and count the different places where papaya is sold, the types of sales on display or on the street, and above all, the origin of the fruits sold. When the papayas had a local origin according to the seller, he was required to give either his contact as the owner of the orchard or that of his employer for whom he sold the papayas. Only, localities where at least a papaya field was recorded were included in our study. Each farm owner was the subject of additional and specific surveys about the management of his exploitation. After identification, each respondent was surveyed on their acquired experience, the cultivation system, motivation for cultivation, the difficulties encountered, and the usual cultivation techniques for optimal production.

Soil sampling

Soil samples were used to search for strains of symbiotic fungi of the genus *Trichoderma*. Sampling was carried out in papaya monocultures in September (2020 and 2021), which marks the end of the rainy season in the Far North region. During each survey in 2021 cropping season, values of temperature and humidity in each site were recorded using an indoor/outdoor hygro-thermometer (HT 9227). pH analysis of five (05) soil samples from treated and control plots were performed in the soil analysis section of the IITA (International Institute of Tropical Agriculture) Laboratory located at Nkolbisson, Yaounde, Cameroon. Overall, 10 papaya trees were labeled at random for soil samples in orchards formally identified in four locations namely Gazawa, Katoual, Makabaye, and Meskine considered as treated plots. Three samples of soil were collected around each labeled papaya tree at 25, 50 and 75 cm from the trunk for a depth of up to 40 cm, and a composite sample consisting of the mixture of the resulting 30 soil samples performed per farm was obtained (Bourou et al., 2010). Moreover, an additional composite soil sample from experimental papaya in an organic experimental farming site belonging to the Institute of Agricultural Research for the Development (IRAD) in Meskine was committed in the same sample conditions as a control plot. After being air-dried, each composite sample was stored in a plastic bag at 4°C for one month for future analysis. Table 1 shows the codes assigned to the different composite soil samples as well as their different origins which were from the Diamare division and only concerned the following locations: Gazawa, Katoual, Makabaye, and Meskine; while Figure 1 is illustrative of how the five composite soil samples from treated and control plots were conditioned in plastic batches for further microbiological analysis and comparison.

Table 1. Soil samples used for microbiological analysis

Origin of sampling			
Sampling code	Region	Division	Sampling location
END-GS	Far-North (EN)	Diamare (D)	Gazawa (GS)
END-KS	Far-North (EN)	Diamare (D)	Katoual (KS)
END-BS	Far-North (EN)	Diamare (D)	Makabaye (BS)
END-MS	Far-North (EN)	Diamare (D)	Meskine (MS)
END-ES	Far-North (EN)	Diamare (D)	Meskine (MS)

Figure 1. Composite soil samples

Isolation of microorganisms of the genus *Trichoderma* from soils

Microbiological studies were conducted in Laboratory of Biological Control and Applied Microbiology of the Institute of Agricultural Research for the Development (IRAD) of Nkolbisson, Yaounde, Cameroon. The search for *Trichoderma* strains was determined from soil samples using a *Trichoderma* Selective Medium (TSM) which allows direct identification of the *Trichoderma* colonies (Parkash and Saikai, 2015).

Seeding of soil samples in TSM medium

Preparation of culture medium

The preparation of the culture medium is progressive and determines the success of the seeding process of the *Trichoderma* strains sought in this study. The culture medium that was used in this study was obtained from the V8 medium (Barbier et al., 2022). 1) After autoclaving at 121°C for 15 minutes at a pressure of 1,2 bar, a mixture of 200 ml of V8 juice, 3 g of $CaCO_3$, and 15 g of Agar-Agar was placed on the laminar flow hood for cooling to at least 45°C. 2) Antibiotic solutions (1 g of Penicillin G, 1 g of Nystatin, 1 g Berneocin) and 2 μL of Triton X were added into the culture medium. 3) The TSM medium obtained was poured into the Petri dishes (Tondje et al., 2007).

Seeding soil samples

4) After hardening the TSM in the Petri dishes, decimal dilutions were performed: 1g of soil taken from a given composite sample was weighed using a precision balance and introduced into a test tube then the volume was supplemented with 9 ml of sterile distilled water; this mixture was homogenized using a vortex and constitutes the mother suspension which will be used for decimal dilutions by progressive addition of distilled water. 5) 1 ml of each decimal dilution from 10^{-4} to 10^{-10} was introduced into the Petri dishes and spread using a disposable sterile loop; for each dilution concentration used and for each composite soil sample, 6 repetitions were performed.

Incubation of seeded plates

The seeded Petri dishes were sealed with adhesive tape and then incubated at 25°C in an incubator for 14 days.

Data Analysis

An Excel spreadsheet was used to record the data collected. SPSS v.20.0 (https://www.ibm.com/products/spss-statistics) was used to calculate basic statistics i.e. means and SD. The mean of the colonization rates of *Trichoderma* [(number of positive soil sample reactions/Total number of soil samples tested) x 100)] were compared between treated and control plots using ANOVA and the post hoc analysis of Tuckey Kramer at 5% which was continued for the pairwise comparison between plots. Correspondence analysis allows us to determine the variability of the use of agrochemicals by papaya growers as a function of locations.

RESULTS

Survey of papaya cultural practices in the study area

Extent of papaya cultivation in the Far North region

Of the nine districts in the Diamare division in the Far North region of Cameroon, only two of them Maroua I and Gazawa have made it possible to identify the effectiveness of papaya cultivation. Table 2 shows that papaya cultivation is effective in 4 localities and among 4 farmers in the Maroua I district in Meskine, Makabaye, and Katoual; while, in the district of Gazawa only, 5 farmers were identified as cultivating papaya for economic purposes.

Table 2. The number of papaya producers listed in the Diamaré division.

Districts	**Localities**	**Effective**
Maroua I	Meskine	2
	Makabaye	1
	Katoual	1
Gazawa	Gazawa	5
Control	Meskine	-
Total		9

Cultivation practices used by papaya producers in Diamare

Table 3 illustrates the arrangement of the different cultural practices commonly used by papaya producers during the establishment of their agricultural operations. Among them are: clearing, burning, animal traction, as well as the recurrent use of certain pesticides such as fungicides and herbicides in the study region. Insecticides are used in less frequently given their very high cost which is not within the reach of all budgets. The other cultural practices were used generally by all farmers of the Diamare division.

Inventory of fungicides used by papaya producers in Diamare

There is a range of phytosanitary products in local agroshops that the farmers surveyed purchase to treat their plantations to limit fruit losses linked to various pathogens and to optimize expected yields. Table 4 shows the commercial names of the different phytosanitary products used to treat pathogens that affect fruit production in the long or short term in the different treated survey sites as well as some of their characteristics (active ingredients, family dosage, and principal uses). Apart from Katoual (KS) where three phytosanitary products have been listed in permanent use among papaya producers, Meskine, Gazawa, and Makabaye are characterized by the use of seven phytosanitary products by producers in the Diamare division for the protection of their fruit production during the year. The following agrochemicals close to the center of Figure 2 namely Fungioff 720 WP; EagrowCare 720 WP and Five Star 200 SP are commonly used in different study sites by farmers.

Table 3. Field activities for establishing and maintaining papaya farms.

Cultivation practices	Number of respondents	Positive responses	% of respondents
Clearing	9	9	100%
Burning	9	9	100%
Animal traction	9	9	100%
Fungicide	9	9	100%
Insecticidal products	9	4	44,5%
Weed killers	9	9	100%

Table 4. Agrochemicals usually used by papaya farmers from Diamaré division.

Commercial name	Active ingredient (s)	Family	Dosage	Uses
Five Star 200 SP (FS 200 SP)	Azoxystrobine Difenoconazole	Systemic fungicide	30-40 mL/10 L of water	Cereals, legumes, trees, ornemental plants
Super champs 36 WP (SC 36 WP)	Chlorothalonil cymxanil	Systemic Fungicide	40-60g/15 L of water	Diseases of tropical crops Market gardeners
Penncozeb 80 WP (P 80 WP)	Mancozeb	Contact fungicide	80-100g/16 L of water	Fungal diseases of crops
Metro star 500 WP (MS 500 WP)	Thiophanate-methyl Oxychloride of copper and sulfur	Systemic Fungicide	1 sachet/16 L of water	Diseases of tropical crops
Guadien 100 WP (Gd 100 WP)	Mancozeb	Contact Fungicide	80-100g/16 L of water.	Fruit crops, banana trees, rubber trees…

EagrowCare 720 WP (EC 720 WP)	Dimethomorph Copper Oxyd	Systemic Fungicide	50g/15 L of water	Cocoa
Fungioff 720 WP (Fg 720 WP)	Metalaxyl Copper Oxyd	Systemic Fungicide	50g/15 L of water	Cocoa

Note: Abbreviations to denote agrochemicals in figure 2 are given in parenthesis

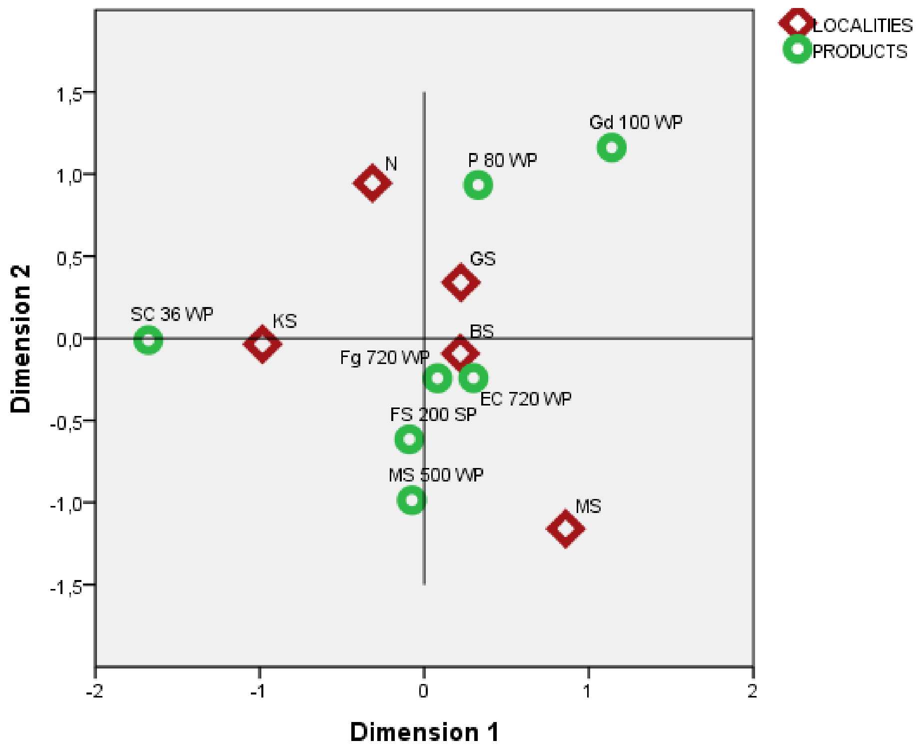

Figure 2. Correspondence analysis showing chemicals used by farmers in different localities.
Legend: N: No product used.

Search for *Trichoderma* spp. in the soil samples
The search for *Trichoderma* spp. in the petri dishes was done after 14 days of incubation by assessing the growth of the mycelia in the culture medium. The different values of the mean colonization rate from treated and control plots are reported in Table 5.

Table 5. Value of the mean colonization rate of *Trichoderma* spp. as a function of plots

Plots	Localities	Number of samples	Positive reactions	Mean colonization rate ± SD
Treated	Gazawa	30	0	0.00 ± 0.00[a]
	Katoual	30	0	0.00 ±0.00[a]
	Makabaye	30	0	0.00 ±0.00[a]
	Meskine	30	0	0.00 ±0.00[a]
Control	Meskine	30	30	100.00 ±0.00[b]

Column followed by the same letter are not significantly different

From the Table 5, the results vary from the control sample of soil without fire-prone and agrochemicals to the four other treated soil samples where papaya seedlings from the nursery were transplanted onto a burned plot and adult plants were impregnated with different chemical substances to promote the protection in view to boosting the fruit yields of papaya. In the different dilutions of the END-ES soil sample considered as a control, the culture medium illustrates the invasion of the desired microorganism *Trichoderma* spp. even at the lowest substrate concentration 10^{-10} (Figure 3). All samples analysed from the control plot were 100% (n=

30) productive of the soil-born microorganism namely *Trichoderma*. The soils of the Diamare division are illustrative of the presence of fungi of the strain *Trichoderma* in the state of nature which can be exploited in agriculture to protect crops and optimize expected yields. The analysis of soil samples from the papaya orchards of Makabaye (END-BS), Katoual (END-KS), Meskine (END-MS), and Gazawa (END-GS) illustrates that whatever the level of dilution, there is no colonization of the culture medium by microorganisms of the strains *Trichoderma* (Figure 4). No *Trichoderma* strains were found in soil samples for each papaya farm from treated plots in Gazawa (0%; n = 30), Katoual (0%; n = 30), Makabaye (0%; n = 30), and Meskine (0%; n = 30). This is reflected by a total absence of *Trichoderma* in the different samples from the papaya rhizosphere in the different localities surveyed. Overall, significant differences between treated and control plots were obtained ($P < 0,05$; $df = 4$; 145). Tuckey Kramer's post-hoc HSD test shows that the difference is always significant between each treated batch and the control ($P < 0,05$), and is illustrative of the importance for papaya growers to preserve the soil of their exploitation for the promotion of the presence of strains of *Trichoderma* spp. in their plots.

Figure 3. Emerging *Trichoderma* culture medium form control plot (END-ES)

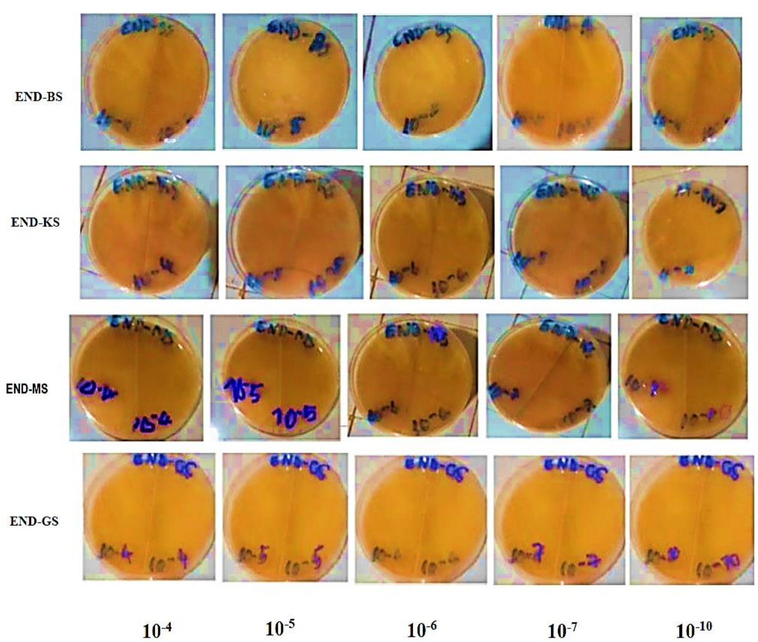

Figure 4. Culture medium free from *Trichoderma* spp. in different treated plots

Abiotic parameters from study sites

Table 6 show the values of abiotic parameters such as air temperature and humidity as well as the pH of the soil at each study site. The temperature values for the studied localities are similar and present a mean value of 29.21 ± 0.17°C. The Table 6 also shows that the values of relative humidity vary somehow in the same trend as the temperature values and present a mean value of 90.93 ± 1.05%. As for pH values, Gazawa and Katoual localities have a basic pH, and the other sites namely Makabaye and Meskine present an acidic pH; the mean value of the pH is 7.16 ± 0.92.

Table 6. Temperature, humidity and pH values from different plots.

Plots	Localities	Temperature (°C)	Humidity (%)	pH
Treated	Gazawa	29.27	92.34	7.79
	Katoual	29.12	89.96	8.49
	Makabaye	29.18	91.41	6.68
	Meskine	29.23	89.83	6.48
Control	Meskine	29.18	91.12	6.39
Mean value ± SD		29.21 ± 0.17	90.93 ± 1.05	7.16 ± 0.92

DISCUSSION

Papaya is an edible fruit that has been highly appreciated and used for several reasons by humans for a very long time. With its juicy pulp, the papaya is a fruit that is generally eaten fresh when ripe as a dessert. Papaya slices can be spiced up with a pinch of salt or a squeeze of lime. In addition, papaya can be consumed in the form of a salad which can be mixed with other fruits such as pineapple, mango, and watermelon (Lebégin, 2021). In Cameroon, papaya juice is highly appreciated and is often marketed on the streets along with other natural juices made from tropical fruits. Papaya is rich in papain and vitamins A, B1, B2 and C. Besides the use of its fruits in food, young leaves, seeds, and roots are used in herbal medicine as a laxative, anthelminthic, antiparasitic, anti-inflammatory, analgesic, healing, and antioxidant (Santana et al., 2019).

Papaya cultivation is not common in the Far North region including in the Diamare division. This crop is beginning to be introduced by certain farmers who profit from papaya sales due to its scarcity which justifies high prices in local markets. In these markets, the most papayas sold come from the great South, the coastal region being a major producer in Cameroon.

Papaya production in the Far North is associated with several constraints including the harsh climate and the spread of fungal diseases, particularly Anthracnose which weakens the leaves and causes subsequent losses in fruit yield. In an attempt to improve production, farmers use outdated methods of supplying water during drought and spread phytosanitary products consisting of a wide range of fungicides not specific to papaya. Furthermore, these farmers are much less familiar with bio-pesticides and are unaware that in the absence of mycelial soil microorganisms belonging to the genus *Trichoderma*, or in the presence of their low numbers, the expected fruit yields can decrease considerably or have a no commercial value. It is well established in the literature that the soil microorganisms from which the majority of fungi belonging to the genus *Trichoderma* originate contribute not only to the fertilization of the soil but also and above all to the protection of associated crops against various pathologies including fungal diseases such as than Anthracnose (Ruangwong et al., 2021).

Our study focused on the detection of the presence or absence of *Trichoderma* strains, in soils collected under the papaya rhizosphere in Diamare. It emerged that regardless of the dilution level of the soil sample used, no presence of *Trichoderma* spp. from the rhizosphere of papaya was detected in Gazawa, Meskine, Makabaye, and Katoual from local producer farms. Only the control soil sample taken from the experimental plot from Meskine was productive of the desired microorganism at all dilution levels of the culture medium. The presence of this microorganism in the culture medium is perceptible by the green color in the Petri dishes as an indication of previous works (Rezaee et al., 2022). The particularity of this last control soil sample is its exemption from the use of phytosanitary products and the slash-and-burn cultural technique.

The current use of synthetic chemicals is not without harmful consequences on the overall microbiological activity of the soil (Ouattara et al., 2010). The disruption of edaphic life linked to the use of fungal products by farmers remains a significant risk for sustainable soil productivity to the extent that biological activity is an indicator of good soil health (Luo et al., 2019). Excessive and uncontrolled use of chemical pesticides can therefore be enormously detrimental to the balance of the soil (Mäder et al., 2002). Generally, the doses provided can affect the total elimination of specific groups of microorganisms such as fungi of the genus *Trichoderma*. Several other studies have confirmed that the use of chemical pesticides overall is a major factor in the collateral destruction of soil microorganisms (Howell, 2003; Luo et al., 2019; Shigyo et al., 2019).

Generally, when preparing agricultural plots at the start of the agricultural season, farmers use the itinerant slash-and-burn cultural technique to clean the plots after clearing. This cultivation technique unfortunately has equally serious consequences in agriculture, notably the destruction of soil microorganisms by fire (Mavinga et al., 2022). According to the work of Conedera et al. (2010), the most fertile agricultural plots are those spared from vegetation fires and therefore are predisposed to the good development and dissemination of several soil microorganisms. In the Diamare division, burning and the use of herbicides are also practiced by producers in this location.

If our research indicates the total absence of microorganisms of the *Trichoderma* genus in our samples from papaya orchards under phytosanitary plots, the control treatment is enriched with the presence of strains of *Trichoderma*. Several other studies have already investigated the presence of soil-borne microorganisms of the strains *Trichoderma* in agricultural land samples worldwide; the work of Bin et al. (2020) made it possible to identify 181 strains of *Trichoderma* in 16 soil samples in Harbin in China with dilutions of around 10^{-5}; In northern China, 10 species belonging to the genus *Trichoderma* were detected on soil substrates (Cao et al., 2022); In the western province of Azerbaijan in Iran, 11 species belonging to this genus were identified under sunflower cultivation (Rezaee et al., 2022). Moreover, the effects of pesticides used in cotton cultivation on soil global microbial activity were studied on tropical ferruginous soil in Burkina Faso; from this work, the doses of pesticides disrupt soil life by affecting microorganisms' efficiency or inhibiting their activity (Ouattara et al., 2010). Overall, excessive and uncontrolled use of pesticides can therefore be a risk for the degradation of soil fertility due to the disruption of soil life (Jacobsen and Hielms, 2014). Yet, papaya producers in the Diamare division repeatedly use these different cultural practices which deplete the soil of their useful microorganisms.

The values of temperature and related relative humidity, as well as the pH obtained in our study fall within the range of values required for a good growth of *Trichoderma* strains. According to Gueye et al. (2016), the temperature value of 29°C was found to be suitable for *Trichoderma* growth. In terms of pH values, Srivastava et al. (2014) reported that *Trichoderma* strains can grow at pH ranging from 1 to 9 with optimal values falling between 4.5 to 7. Despite these favorable environmental conditions in our study, the absence of the development of *Trichoderma* strains remains notable in the treated plots. Yet, all the control treatment samples, free from harmful cultural practices allowed *Trichoderma* strains to germinate by 100%. The cultural practices locally used by papaya producers in the Diamare division of the Far North Region of Cameroon are of great harm to the preservation of *Trichoderma* strains, as particularly demonstrated from soil samples analysed in their farms.

The use of agrochemicals has become a habit of agricultural producers in the Far North region of Cameroon. These pesticides generally allow them to protect target crops against various pathologies and antagonists or to improve yields on their farms. Unfortunately, repeated use of these products can present significant risks to human health, the balance of agroecosystems, and the preservation of nature (WHO, 2023). Overall, the usual local cultural practices for papaya production in Diamare lead to the observed absence of strains of *Trichoderma* in the orchards surveyed. The practices most often involve the use of pesticides whose nature, quality, and doses provided do not always respect the recommendations for ecologically rational use (Sawadogo et al., 2006). In addition to papaya, most cash crops are subject to phytosanitary impregnations by farmers for their protection against depredations to guarantee optimal production in the broad Far North region. This is particularly the case for onions, cotton, tomatoes, maize, and especially watermelon exploitations where broad-spectrum insecticides, weed killers, and fungicides are commonly taken into account in the various technical sheets by peasants and industrialists (Azo'o et al., 2021; Sakataï et al., 2018; 2021; 2023).

CONCLUSION

This work illustrates the effective presence of microorganisms of the *Trichoderma* genus in the telluric microflora of the Diamare division from the Far North region. These fungi are present in soil samples taken from a control plot of a monoculture of papaya tree exempted to slash-and-burn roaming, much less the impregnation of synthetic phytosanitary products to guarantee protection and yields of this crop. On the other hand, soil samples from the papaya rhizosphere in peasant monocultures are subject to burning before transplanting seedlings from the nursery and to regular impregnation of pesticides during the development cycle of the crop in order to protecting against diseases that affect fruits. Thus, these previous cultural practices lead to a total absence of useful microflora based on strains of *Trichoderma* which play an important role in the bio-fertilization of the soil and the natural protection of the papaya against various pathogens.

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