Biological Activities and Phytochemical Constituentsin theStimulatory Potentialof *Tithonia diversifolia*Fermented Extracts:A Review

Abstract

The world food production must increaseby 70% to feed this massive population with using chemicals inputs since the new millenary. Crop culture is challengedby parasitic constraints, seedlings unavailabilityandsoil fertilityissues, which can severely reduce productivity. However, the repeated uses of chemical inputs negatively impact environment, plant and human health equilibrium. So, pathogen resistance,seedling quality andplant fertilization are severely concernedover the course of time. In this context, the use ofa plant extract as*Tithoniadiversifolia*, could be a good natural alternative to chemical stimulants. The lack of knowledgeofphytochemical constituentsinvolving biologicals activitiesin liquid form of*T. diversifolia* extract,need to be improved to ensure theirlabeling. This study reviews biological activities and main phytochemical constituents in the stimulatory potential of *T. diversifolia*fermented liquid extracts. Thestimulatory potential bio-efficacyof*T. diversifolia*extractsconcernsthe combinationofbiocontrol and green fertilizereffects. The green manureis conducted bywatering or mulchingon varied crops, suchas rice, maizeor plantain banana. Existing concerns are to expand the information amounts concerning the stimulating properties of the bioactive compounds contained in the fermented liquid extracts. It would be a key to fully demonstrate their effectiveness in stimulating the mechanism of plant growth and the protection against phytopathogens. However,this reviewupdates on the challenge of the possibility to characterize the major bioactive compounds inthe extracts. The otherchallenge of this current workis to suggest aneco-responsible and biological labelingproduct based on *T. diversifolia* fermented liquid extract.

Keywords:*T. diversifolia*, fermented extract, biological activity,phytochemical constituent, stimulatory

1. Introduction

The fundamental preoccupation of the Food and Agricultural Organization and United Nation is to feed theincreasing world population. This population is estimated to reach around 9.6 billion in 2050, with no corruptible and unpolluted nutrients. Therefore, world food production must increase by 70% to feed this massive population (Foley *et al.,* 2011). However, some agricultural constraints remain, preventing this objective to being achieved. In agriculture, pathogens attacks and seeds qualitiesarethe main constraints causingproduction reductions. They are in constant competition with crops for water, light and nutrients resources coupled sometimes with soil fertility, which lead to huge economic losses. Among the physical or mechanical control methods, including stripping or cutting, chemical inputs such as pesticides, insecticidesor fertilizers are the most used ones. However, it is well known that their repetitive and intensive uses, impact negatively human health, plant and environment equilibrium as well as increasing pesticide resistances. The use of phytopharmaceuticals is yet more rigorous, with more than 90% of the cost of the study conferred to approval expenses against a few for efficiency agronomic analysis approach (Jaulneau, 2010). Therefore, the number of active products implied the development of alternative methods is decreasing. The plant protection strategies could increasethe food production while greatly reducing the environmental impacts of agriculture. One of these strategies relies on the optimization of natural defense mechanisms of plants,set up during plant-parasite interactions (Pusztahelyi*et al.,* 2015). In this context, natural products based on*T.diversifolia*liquid extracts containing several bioactive compounds, could be a real alternative to phytopathogen attacks and soil fertility issues(Kadungu*et al.,* 2013; Diby *et al.,* 2015; Tatsegouock*et al.,* 2020).

T.diversifolia is a woody herb of 2-3 meters tall which is native to East of Mexican country and Central America. The species is spreading quickly and has naturalized in more than 70 countries in tropical areas, with an invasive feature (Chukwuka *et al.,* 2007). The plant is rich in elementssuch as nitrogen (N), phosphorus (P) and potassium (K).Its applicationson soilsresult to rapid decompositions.Thereby,it contributes to the growth promotion of plants, by enriching the soil with N, P and K(Farni *et al.,* 2022; Aboyeji, 2022). *T.diversifolia*extract is rich in followingsecondary metabolites: flavonoids, tannins, alkaloids, pathogenesis-related proteinsand terpenoids.This chemical compositionseems to stimulatethe plant growth andits accumulation of defense biomarkers. The plant is known to be a good source of bioactive compounds and to have therapeutic potential withantifungal, antimicrobial, insecticidal and organic fertilizing(green manure) properties. These characteristicsreinforce the importanceofdevelopinga product based on biostimulantpotentials(Odeyemi *et al.,* 2014; Jama *et al.,* 2000). The stimulatory potential of*T. diversifolia*extracts andtheir compounds can be isolated from new forms as concentrated fermented liquid, mulch, and powder and especially studied in some plant models as plantain banana, rice, andmaize. This current study on fermented liquid showed a large spectrum of their biologicals activities.

Recent studies onplantain banana seedlings "Plants Issus de Fragments de tiges: PIFs"in Cameroon have shown that*T. diversifolia* extracts,usedalone or associated with clam shells, are profitable for plants. Indeed, it stimulates theplant growth and the protection against biotic and abiotic stresses,with watering, mulching or amendment applications(Ewané*et al*., 2020c; Meshuneke*et al*., 2020; Tatsegouock*et al*., 2020).Moreover,plantain banana is an important cash crop that serves as a stable food for millions of people in the world and contributes to coming generations.Nevertheless, this production encounters many problems, concerning parasitic constraints, availability of good seedlings in quantity and quality, and soil fertility which have caused the lack of creation of new plantations.All these points increase the demand and generate very high prices with an average of 300 to 500% on the local market (Ewané*et al*., 2019). In the fields,*Mycosphaerellafijiensis* fungus is known toattack speciallyplantain banana, which is one of the main concerns target pathogen in its cultivation. Indeed, the strain can severely reduce the photosynthetic leaf area,leading to losses of plantain banana production beyond 80%. Soil fertility constitutes another main preoccupation, becausetheir combination with black sigatoka disease cantotally reduce plantain banana productivity.Many studies casesin the fields and the greenhouse concern plantain banana, *T. diversifolia*extracts increased the plant growth, plant protect and the productivity of other plants.Here will be presented the relationship between phytochemical constituentscontained in *T. diversifolia* extracts andsomebiological activities in stimulatory potential on plantain banana. The challenge of this study is toput forward an eco-responsible and biological labelingproduct based on a *T. diversifolia* fermented liquid extract,withtheknowledge of itsmajor bioactive constituents.

2. Method

Many studies on *T. diversifolia* extracts published were obtained from biopesticidals and biofertilizers efficiency treatment databases. Some publishers or data base such as Google Scholar, Science Direct, African Journal of Botany, Agricultural Sciences, American Chemical and Agriculture Society, Plant Pathology, Science Direct, Royal Society of Chemistry, Scopus and SciFinder permitted to collect the right information for understanding the stimulatory potential of extracts and the biologicals activities of phytochemicals constituents. The keywords used were *T. diversifolia*, fermented extract, biostimulant, biological activities, and phytochemical constituent. In addition, words like extraction of volatile and non-volatile components were used of during the search.

3. Results and discussions

3.1. Biological activities of *T. diversifolia*

3.1.1. Fertilizer

*T. diversifolia*plant cut from bushes or harvested in cultivated areas, are incorporated into subtropical crop fields as sources of nutrients in dried, ash or liquid forms.It is as green manure that can bring positive modifications in soils.It increases N, P and K levels compared to an inorganic fertilizer or other plants such as *Tephrosia* or maize stover.*T. diversifolia* biomass canbe decomposed rapidly to release N, P and K into the soil. This is the reason why this biomass has been extensively used to improve soil fertility (Nagarajah and Nizar, 1982). The shoot biomass of *T. diversifolia*ishawked as a potential source of nutrients for lowland rice in Asia and more significantly for maize and vegetables. During the first season of maturing, the application of 3 to 4.5 mg of *T. diversifolia*fresh extract of leaves gives similar yield rates to those with 90 mg of N as inorganic fertilizer. *T.diversifolia* fresh extractincreasessignificantly maize yields, when it is available or growing naturally on fields, and properly used. *T. diversifolia* is assumed to be rich in nutrients, so leaves are used as green manure on poorly fertile soils (Ganunga*et al.*, 2005). Therefore, the soil is improved through N and P release, resulting in an enhancement from the firstmaize (*Zea mays*) season in yield and quality (Nziguheba*et al.*, 1998). Similarly, physicochemical and biological properties as fertilizer or green manure conferred to *T. diversifolia*turn it into an excellent supplier in N, P and Kelements. The high rate of its quickly decomposition also enrich poor fertile surrounding soils in fertilizer substances including mineral elements (kaho*et al.*, 2011; Bilong *et al.*, 2017).

3.1.2. Pesticidal

T.diversifolia is widely used to control a lot of phytopathogens or plants diseases. The extract efficiency depends on the choice of the tree section and the extraction solvent. The various processes and solvents used before obtaining an extract make possible to show this potentiality. However, cold infusion of the leaves, stems, roots or the whole mixture of *T. diversifolia* has been shown to be effective as a pesticide against aphids, weevils and beetles (Anjarwalla*et al.,* 2013) on common bean plants (Mkenda*et al*., 2015). Crushed and ethanolic extracts of *T. diversifolia* leaves,applied at concentrations between 2% to 5%on cowpea, alloweda mortality of *Callosobruchus maculatus*reaching 100%.In addition, flower extracts showedtheir repellency potential against *Sitophilus zeamais*when applied to corn grainsand weight loss (3.28 ± 0.45%) (Adedire and Akinneye, 2004). Ambrosio *et al*. (2008) reported that dichloromethane leaves rinse extract at a concentration of 5% of fresh leaves, has antifeedant potential on *Chlosyne lacinia*. Nthoingambi and Singh (2013) showed the antifungal and antibacterial efficiency of petroleum ether, chloroform and methanol extract of *T. diversifolia*, using a poisoned food technique and a disc diffusion method, respectively. Petroleum ether extract displayed the most potent antifungal activity, by inhibiting all the fungi by confrontation tested or by diffusion with well disc methodagainst some phytopathogensas*Alternaria solani*, *Aspergillus niger*,*Drechslera oryzae*, *Fusarium oxysporum*.

3.1.3. Antioxidant

*T. diversifolia*extracts displayed cytotoxic effects with half maximal inhibition (IC_{50}) values of 3.02 to 12.82 µg/mL at variable pathogen cells.It also showed radical scavenging activities on DPPH (1,1-diphenyl-2-picrylhydrazine) and ABTS (2,2-Azino-bis, 3-ethylbenzothiazoline-6-sulphonic acid) radicals, with IC_{50} values of 108.8 and 41.7 µg/mL, respectively (Orsomando*et al.,* 2016). However, the antioxidant capability of *T. diversifolia* extracts have been shown by its sequestering capacity on DPPH by reacting with free stable radical to form DPPH (Mayara *et al.,* 2016). The aqueous and ethanolic concentrations of extracts causing IC_{50} were respectively evaluated around 2.27 and 0.63 mg/mL.The aqueous extract of *T. diversifolia* also elicited a good antioxidant property, withan N-acetyl cysteine equivalent antioxidant capacity of 32.62 and 20.99 mg of N-acetyl cysteine/g for ABTS and DPPH radical assays, respectively (Hiransai*et al.,* 2016). In addition, *T. diversifolia*is a good source of phenolic antioxidantsand can be used to manage oxidative stress associatedto illnesses (Tamfu *et al*., 2022) Ethyl acetate (IC_{50}: 30.81 ± 0.48 µg/mL) extracts of *T. diversifolia*exhibit a good inhibition against acetylcholinesterase and butyrylcholinesterase.*T. diversifolia*extract shows higher inhibitions than galantamine (IC_{50}: 42.20 ± 0.44 µg/mL) against butyrylcholinesterase. Equally, good inhibitionsare showed on α-amylase and α-glucosidase. Table I highlights theimportance of some antioxidant molecule activities in the growth and the protection of the plant.

Table I. Antioxidants: importance in the plant(Anonyme, 2021).

Antioxidants	Role in plant
Ascorbic Acid	Allows the development of tissues and the plant, it is related to the respiratory intensity of the plant.
Pyridoxin	Involved in the synthesis and degradation of amino acids and proteins.
β-Caroten	Absorbs the full energy of the chlorophyll in order to avoid the formation of reactive oxygen species which would destroy the leaves.
Tocopherol	Promotes fertility.
Phenolic compounds (phenolic acids, flavone, chlorogenic acid, quinones…)	Antimicrobial power, they participate in the defense of the plant, in the reinforcement of the walls of the plant cells and in their capacity to modulate and induce the defense reactions of the host.
Lycopen	Responsible for the color of the plant, flowers, fruits, leaves ...

3.2. Phytochemical studies on *T. diversifolia*extracts

3.2.1. Globalcomposition of *T. diversifolia*

Analysis of the leaves, stems, flowers and roots of *T. diversifolia* have shown the presence of carbohydrates, crude fibers, moistures, total ashes, crude proteins and crude fats in the parts of the plant. Crude fiber contentsare high in stems followedby carbohydrates in leaves and fat in stems (Umar *et al.*, 2015). Leaves and roots contain high nutritive substances values that can be explored for several purposes, such as agricultural and pharmacological ones. All *T. diversifolia*organsare employed in the management of soil fertility, plant growth promotion and biocontrol of diseases, thanks tothe biological active components.Moreover, secondary metabolitescontained in the extracts as totals proteins and phenolic compounds,areinvolved in physiological role of plants.Table II shows the presence of secondary metabolites depending on the different plant parts and the solvents used, thanks to the analysis of the crude extracts of *T. diversifolia*.Leaves of the studied plant contain the higher number of metabolites, compared to the other plant parts.Yet, saponins in acetone extracts,steroids in aqueous extracts andterpenoids in methanol and acetone extractsare not present in the leaves.Moreover, phytochemical and mineral analysis have shown, in the different parts of the plant,the presence of secondary metabolite contents such as phenols,terpenoids, flavonoids, alkaloids, tannins, saponins(Olo'o and Mengue, 2020).The green leaf biomass of *T. diversifolia* is higher in nutrients compared to a dry matter basis of some agroforestry species, whose leaves are most often used for biofertilization in crops (Table III). The following mineral element contents of*T. diversifolia*are clearly superior, compared tothose of themain agroforestry species used to improve productivity:nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg)(Table III). This Ability of*T. diversifolia*depends on the biomass yield, their quality and their rate of decomposition (Kaho *et al.*, 2011).

Table II. Phytochemicalconstituents in leaves, stems and roots of *T. diversifolia*(Olo'o and Mengue, 2020).

		Extraction		
Phytochemicals constituents	Plant parts	Methanolic	Acetone	Aqueous
Saponins	Leaves	+	-	+
	Stems	-	-	+
	Roots	-	-	+
Flavonoids	Leaves	+	+	+
	Stems	+	+	+
	Roots	+	+	+
Alkaloids	Leaves	+	+	+
	Stems	+	+	+
	Roots	+	-	+
Steroids	Leaves	+	+	-
	Stems	-	-	+
	Roots	+	-	-
Terpenoids	Leaves	-	-	+
	Stems	-	+	-
	Roots	-	-	-
Tannins	Leaves	+	+	+
	Stems	+	+	+
	Roots	+	+	+
Glycosides	Leaves	+	+	+
	Stems	+	-	+
	Roots	+	-	-

Keys: (+) Presence of metabolites; (-) Absence of metabolites

Table III. Majors minerals contents of leaves of *T. diversifolia*compared to agroforestryspecies.

Species	**Concentration (%)**				
	N	P	K	Ca	Mg
T.diversifolia	3.53	0.42	4.70	3.52	0.45

D.intortum	1.79	0.30	0.58	1.70	0.28
P.phaseoloides	2.17	0.37	0.59	2.75	0.32
C. calothyrsus	3.40	0.15	1.10	nd	nd
L. camara	2.80	0.25	2.10	nd	nd
T. vogelli	3.00	0.19	1.00	nd	nd

nd: not determined.

3.2.2. Phytochemicals constituents of *T. diversifolia*

T. diversifolia extract efficiency is important but results could be improved.Indeed, a better knowledge of chemistry and biological activities, such as fertilization and stimulation,couldenhance the identification of bioactive components. The bioactivity is due to a single ora mixture of compounds, which contributes to additive or synergistic effects (Passoni*et al.*, 2013). The great challenge is to characterize most of the complex compounds in the fermented liquid extract, to understand this mixture effect. This would lead to a phytochemical fingerprinting of the extract. A phyto-complex consisting of a combination of both substances:an active principle and a mixture of the three parts of the plant (leaves, stems, roots).This phyto-complex can contribute to the overall biological effects (de Toledo *et al.*, 2014; Riondato*et al.*, 2019). Many phytochemical constituents have been identifiedin aqueous and ethanol extracts of leaves, stems and roots of*T. diversifolia*plant(Olayinka et *al.*, 2015).Table IVshows that leaves have a good accumulation of secondary metabolites compared to stems and roots.

Table IV. Phytochemical constituent quantities of *T. diversifolia*according toplant organs(Kaho *et al.*, 2011).

Composition (mg/100g)	**Organs**			
	Leaves	Stems	Roots	Mean
Alkaloids	1535.00	361.67	863.33	853.33
Tannins	540.00	125.00	481.67	382.22
Flavonoids	851.67	33.33	131.67	338.89
Saponins	761.70	38.33	183.33	327.78
Terpenoids	126.67	18.33	50.00	65.00
Totals phenols	64.58	9.77	71.03	48.46

3.2.2.1. Terpenoids

Terpenoids are the largest and most diverse group of secondary metabolites derived from *T. diversifolia*. Several bioassays refer to the therapeutic potentials of terpenoids against parasitic diseases. The versatility of the parent terpenoid backbones allows structural diversity among the group.This property leads to multiple cellular targets and consequently varied mechanisms of antiparasitic actions.Terpenoids are the most common metabolites in *T. diversifolia*, of which sesquiterpenes is the most available. These sesquiterpenes are the largest group of secondary metabolites, which have a C_{15} skeleton formed by three isoprene units (Pulido *et al.*, 2017). The oxidation of one isoprene unit into a methanol group conducts to a lactone. Sesquiterpene lactones are well known asthe most variedclasswith over 35,000 known structures. Many of these sesquiterpenes have high biological activities(Zulfiana*et al.*, 2020). They synthesize in the plant terpenoids as*Asteraceae*.They also play an important role in plant defense, as antibacterials, antifungals and insecticides agents.

The phytochemical investigation leading to the identification and the classification revealed that the major sesquiterpenoid groupssuch as furanoheliangolides, eudesmanolides, guaianolides and germacranolides, are the most studied (Zhao *et al.*, 2012; Herrera *et al.*, 2007; Kuo and Chen, 1998). Extracts obtained by hydrodistillationpresented components of essential oils.Forty-five compounds were identified and characterized in the non-volatile fraction compared to more than fifty complex compounds in volatile fraction. The tagitinine is one of the mostly knownsesquiterpene lactone isolated of interest.Many more sesquiterpenes lactones arerelated to some biological activitiesas antifeedant activities on several arthropod pests (Susurluk*et al.*, 2007; Chukwuka and Ojo, 2014).

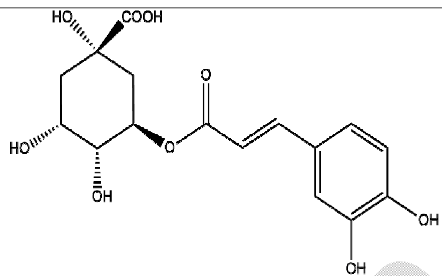
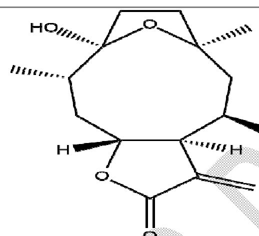
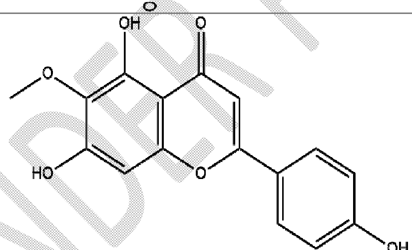
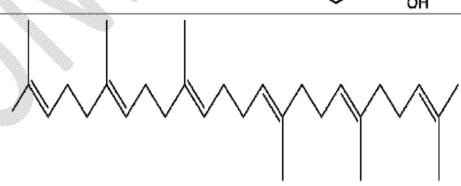
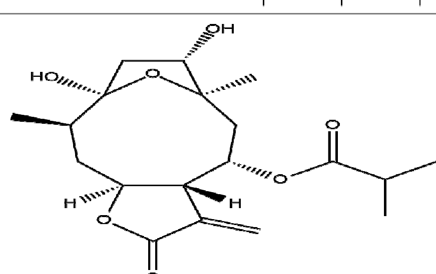
3.2.2.2. Phenolic compounds

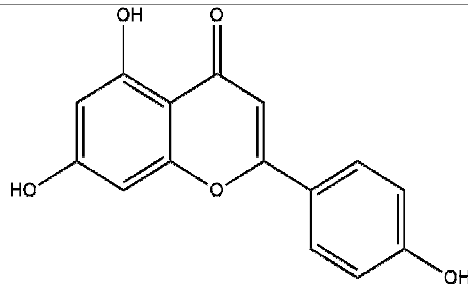
Phenolic compounds, known to be contained in *T. diversifolia* plant,belong to its major bioactive constituents (Ambrósio *et al.*, 2008; Chagas-Paula *et al.*, 2011; Pulido *et al.*, 2017). The reports have shown the effectiveness of some phytochemical compound contents in *T. diversifolia*.These compounds are phenolic acids and various classes of flavonoids, present in the dry powder form and related to rice meal moth and *Corcyra cephalonica*(Ojo *et al.*, 2020; Roopa *et al.*, 2020).Polyphenols react like chemical entities that prevent Reactive Oxygen Species (ROS). ROS induce oxidative damage by inhibiting the enzymes involved in carbohydrate hydrolysis (Ruiz *et al.*, 2017).Studies have reported that *T. diversifolia* extracts were a good source of natural antioxidants. Studies also demonstrated their usefulness as medicinal supplements and alternative drugs, in the green synthetic processes of metallic nanomaterials (Flieger *et al.,* 2021).

3.2.3. Bioactive compounds of *T. diversifolia* extracts

Generally, *T. diversifolia*fermented extractsbased on bioactive compounds are exploited in a sustainably manner. They can be an alternative source of biological andeco-responsible agriculture, as well as an affordable and accessible natural biostimulant for smallholders and compagnies.These compoundswould require the characterization in the fermented extractto provide new informationabouttheir potential. Complete characterization of an extract is possible for commonly used plants, because chemicalconstituents are not all well-known in *T. diversifolia* extract(Table V). *T. diversifolia*fermented extractwhich couldbe influence by fermentation duration protocol inbioactive compounds extraction come from microbial active fraction as metabolic product andorganic partconcern a non-degraded vegetal material.The extract can be used by soil orfoliar applications, which will be the guideline of this work(Fahrurrozi*et al.*,2019). The variations of agro-environmental conditions canaffect phytochemicalsconstituentsaccumulationsidentified in *T. diversifolia* extract,or can make a lot ofcomplex structurein characterization ofextract.These variations are proved byLiquid Chromatography-Mass Spectrometry (LC–MS); Nuclear Magnetic Resonance (NMR) and Flamme Atomic adsortionSpectroscopy (FLAA) techniques. Even the most sensitive and advanced method of metabolite profiling,an exploration of resultswould generated a long list ofcomplex not identified compounds or new identified compounds inside extract probably in *T. diversifolia* database. Several analytical techniques have been used on crude extracts in order to characterize plant species as sources of biological active compounds. So, large amountsof fresh vegetal materials are initially used to identify a single compound.The identification depends on the chosen extracting solvent (Kerebba*et al.,* 2019). The appreciated method to analyze the extract involves an efficient HPLC with apressure control and anisocratic system,to reducethe running time and optimizeseparations. Reverse phase chromatography using C_{18} as stationary phase, is able to separate compounds found in the extracts. The resolution of mass spectrometry achieved with liquid chromatography allows the detection and quantification of a large number of molecules in a single measurement.Various ionization methods can be utilized with MS, but Electron Spray Ionization (ESI)is the most adapted here. ESI is preferable because this ionization preserve molecular ions and allow identification of unknown compounds (Bowen and Northen, 2010). In addition, the NMR 2D experimentscan provide a useful phytochemical fingerprinting” on a range of compounds present in crude extracts (Ward *et al.*, 2003).Nowadays, studies have not been yet reported or executed for the *T. diversifolia*fermentedextract andits bioactive compounds.Itsbroken-down metabolites could increase the microbial propertiesas well theirbiostimulant effects.

Table V. Some biologicals properties of *T. diversifolia* constituents and their applications

Chemical compounds	**Structures**	**Biological properties**	**Application fields (References)**
Chlorogenic Acid $C_{16}H_{18}O_9$		A nutritional antioxidant in plant-based foods. Inhibits irreversible hydrolysis of G-6-Pase (reduction of glycogenolysis).	Antioxidant activity, antibacterial, antiviral, anti-microbial (Ojo *et al.*, 2018)
Tirotundin $C_{19}H_{28}O_6$		Potential neurotoxins to nematodes.	Nematicid Activity (Lan *et al.*, 2022)
Hispidulin $C_{16}H_{12}0_6$		Inhibits glutamate release in benzodiazepine receptor ligand nerve endings to the allosteric-positive.	Antifungal activity (Baruah *et al.*, 1994)
Squalen $C_{30}H_{50}$		Intermediate of sterol and hopanoid biosynthesis in various types of cells from bacteria.	Antioxydant Adjuvant Vaccinal (Ragasa*et al.*, 2007)
Tagitinin A $C_{20}H_{31}O_7$		Reduces lipopolysaccharides induced by interleukins 6, 8 and tumor necrosis α factors.	Potential botanical insecticide Antifeedant activity (Pavela *et al.*, 2018)

Apigenin $C_{15}H_{10}O_5$		Insect feeding Deterrent repellent agent CYP2C9 inhibitor (responsible for drug metabolism).	Insecticideactivity (Ojo *et al.*, 2018)

3.3. Stimulatory effect of *T. diversifolia*on plantainbanana plants

Recent studies carried out in Cameroon have demonstrated that *T. diversifolia*extracts are used as biofertilizer and biocontrol agents. These agents involve different application forms of the plant parts extracts.Different treatment applicationsbased on extracts have been developed to promote the plant growth and to decrease the risk of Black Sigatoka Disease:mulching ormixing with powder or dry form, watering with fermented liquid formon the PIF seedlings. Dried leaves and stems of*T. diversifolia* have been used as substrate amendment on plantainbanana and have permitted to obtain vigorous vivoplants. Both leaves and stems have shown better results with 56% treated plants compared to control ones (Ewané*et al.,* 2020).Indeed, the bioefficiency of *T.diversifolia* dried mulch is stimulant in the plant growth of plantain banana PIF seedlings in the nursery and prevent the*M. fijiensis*apparition. It also enhances the accumulation of biomarkers such as proteins, polyphenols and defense-related enzymes (such as peroxidase, polyphenol oxidase and glucanase) (Meshuneke*et al*., 2020).*T. diversifolia*fermented liquid extracts were found to significantly influence the vegetative and germination stages of PIF plantain bananas seedlings at 21 first days after lunching methodcompared for the control ones. So, the germination has reached 100% for treated plants against 66% for controls ones.Concerninggrowth parameters, their average increase by 27% in diameter, 27% in the length of the pseudo stems and 30% in the photosynthetic leaf area. Treated seedlings showed maximum protection against Black ShigatokaDisease (BSD) beyond 87% compared to seedling controls (Tatsegouock*et al.,* 2020). However, in the field stage with the mature plantain banana tree, fermented liquid base on *T. diversifolia* extract showed their bioefficiency with biopesticidal potential to reduce the severity of Black Sigatoka Disease in the course of time, and confirmed by the very low concentration (Ewané*et al.,* 2020d).

T. diversifolia mulch stimulates the plant growth, directly on PIF plantain banana seedlings physiology, and indirectly on substrate in nursery (Meshuneke*et al.,* 2020).

Effectively, this organic amendment has modified the physical properties of the soil such as the stability of aggregates and the porosity that can improve the roots growth, rhizosphere and stimulate plant growth. In the same way, vegetative growth parameter on plantain has been increased by the treatment of liquid extract of *T. diversifolia*. Beneficial effects of fermented liquid extracts begin with the amelioration of the soil properties.Thisinvolves physicochemical and biological characteristic modifications as microbiota around plant roots to better assimilate uptakes.Root assimilations,length development and leave area developmentare observed on treated plantain banana seedlings compared to controls. It shows the potential stimulatory role of liquid extract to increase the availability of assimilated nutrients during the growth. This efficiency on plantainbanana is confirmed by Tatsegouock*et al* (2020), with 87% of the plant protection and the good accumulation of biomarkers concerning growth promotion in leaves with 900 to 1200 mm^2 of foliar area.However, *T. diversifolia* is an excellent biostimulationtool on induction of plant defense. It improved defense responses against phytopathogens such as *Mycospharellafijiensis* in terms of severity of the black sigatoka disease.The level of the protection rate for the plantainbanana achieved 83% when the plant has been amended with mulch of dry form *T. diversifolia*, according toMeshuneke*et al.* (2020). Comparatively, this level reached 87% with the liquid extract obtained, according toTatsegouock*et al.* (2020). So, the reinforcement of the plant cell wall, which is the first mechanism started during plant attack, can be quick observed when the cultivated plant is watering with the extract (Ewané*et al.*, 2020).Indeed, specific information about the action mechanism of liquid extracts, their implication to this protection and the compounds responsible for their pesticidal effects are not yet known. Treatment applications based on fermented liquid extracts do not yet fully demonstrate the phytochemicals activities of the constituents and the effectiveness in BSD biocontrol. The phytochemical knowledge of this aqueous and fermented liquid extract against *M. fijiensis* or other several phytopathogenes is therefore still mulch wanting. However, the same metabolites or biomarkers are sometimesinvolved in the growth promotion and defense induction on plantain banana seedlings.

4. Conclusion

*T. diversifolia*works asabiostimulant product for increasing crop productivity. Thecurrent review highlights the stimulatory effect of this product as a biofertilizer anda pesticide.It has antioxidant activities and some plant protections.The health-related aspects of someextractsare linked to theirphytochemical constituents. Recently, most published biostimulantapplications have shown that extracts from fresh material,are more widely used than pure isolated compounds for some biological activities. Molecules such as phenolic compounds, terpenoids, alkaloids and essentials oils are mobilized secondary metabolites involved in the plant defense mechanisms against pathogens and in growth promotion. These compounds are also involved in the defense responses of the banana tree, although their mechanisms of action joined to their properties are not yet known and well understand. The action mechanism of these extracts or phytochemical constituents are not fully demonstrated.Thus, there is still a lack oftheir stimulatory activityknowledge too. The challenges for identifying and characterizing fermented liquid extracts that comprise a multitude of compounds, should be solved by high-performance liquid chromatography coupled to mass spectrometry analysis. The major bioactive compound with the greater stimulatory potential of the *T. diversifolia*fermentedliquid extract, and the mechanism of action should be comprehended further.By the way, these points need to be understood for the global acceptance of this product in eco-agriculture and later inhuman health, before labeling.

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