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RESEARCH ARTICLE

ETHNOBOTANY AND ANTIMICROBIAL POTENTIAL OF ETHANOLIC EXTRACTS OF PLANTS SOLD IN THE MARKETS OF BOUNDIALI (NORTHERN IVORY COAST)

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Abstract

The vegetation of northern Côte d'Ivoire is renowned for its floristic diversity, particularly its medicinal plants commonly used traditionally to treat infectious diseases. However, rapid urbanization and the resulting human pressures threaten the disappearance of numerous species, creating an imbalance in its biodiversity. The objective of this study was to evaluate the antibacterial activity of ethanolic extracts from 10 medicinal plants from this flora against bacteria of the genera Staphylococcus and Pseudomonas, as well as enterobacteria (Escherich ia coli, Salmonella typhimurium, and Proteus mirabilis), which are responsible for opportunistic infections. These bacteria include both wild-type and multidrug-resistant strains. Ten ethanolic extracts from 10 plant species belonging to 9 botanical families were prepared for diffusion tests in agar plates. Based on their activity against germs, the extract of Funtumia africana Stapf (Apocynaceae) was selected to determine antibacterial parameters (MIC and MBC) using the macrodilution method in liquid medium. The largest inhibition zone diameter (28 ± 1.2 mm) was obtained with the extract of this plant at a concentration of 50 mg/mL. This extract also yielded the best MIC (0.04 ± 0.0 mg/mL) and MBC (0.39 ± 0.2 mg/mL). Furthermore, phytochemical sorting by thin-layer chromatography detected the presence of several phytoconstituents, including saponins, tannins, flavonoids, polyphenols, alkaloids, and sesquiterpenes, which are likely responsible for the observed activity.

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The results obtained would support scientific validation of the traditional use of these plants in the treatment of pathologies, primarily of bacterial origin. Furthermore, the range of protections for medicinal plants must be broadened to better safeguard plant biodiversity.

Introduction:-

Despite the spectacular development of the pharmaceutical industry, herbal medicine remains crucial, especially in developing countries where over 80% of the population relies exclusively on medicinal plants to meet their primary healthcare needs (Traoré, 2013). In Côte d'Ivoire, numerous researchers have conducted and continue to conduct antimicrobial tests with many of these plants (Zirihi et al., 2003 ; Tra Bi, 2008). For a large number of ailments, these plants represent an essential alternative to pharmaceutical drugs, which themselves largely derive from plant secondary metabolites (N'Gaman et al., 2009). However, this abundance of medicinal plants does not prevent the numerous deaths from various diseases observed each year. Given this situation, the floral diversity of Côte d'Ivoire should inspire further contributions to provide the population with more accessible remedies capable of overcoming bacterial resistance. Indeed, diseases caused by microbes remain the leading cause of death worldwide, killing more than 50,000 people every day globally (Ahmad & Beg, 2001).

Bacteria are responsible for 70% of these deaths (Gangoué, 2007). To combat bacteria, modern medicine has developed antibiotics, which have proven effective in significantly reducing the spread of these diseases. However, many conventional antibiotics are increasingly encountering resistance against bacteria (Ben et al., 2007). In Côte d'Ivoire, numerous cases of multidrug-resistant bacteria have been reported (Guessennd, 2013). This bacterial resistance, linked to the continuous or even uncontrolled use of antibiotics (Ben et al., 2007), is a criterion in the selection of bacteria used in this research. Furthermore, these germs are responsible for common diseases in tropical regions. These include typhoid fever caused by Salmonella Typhimurium; Escherichia coli, responsible for purulent meningitis and diarrhea in newborns; Pseudomonas aeruginosa, responsible for meningitis in adults; Staphylococcus aureus, found in furunculosis, sinusitis, otitis, urinary tract infections, and diarrhea in children; and Proteus mirabilis, causing urinary tract infections, meningitis in infants, and diarrhea due to intestinal dysbiosis.The overall objective of this study is to evaluate the antibacterial properties of ethanolic extracts from 10 plants used in traditional medicine in Côte d'Ivoire in order to contribute to the development of Ivorian pharmacopoeia. This development could lead the population to understand the urgency and necessity of the rational and sustainable use of these plants.

Materials and Methods:-

Plant material :-

It is essentially composed of plant organs such as the leaves of six (6) species [Spondias mombin (Desr.) A. Juss. (Anacardiaceae), Nauclea latifolia Sm. (Rubiaceae), Lawsonia inermis L. (Lytraceae), Carica papaya L. (Caricaceae), Diospyros mespiliformis Hochst. (Ebenaceae), Funtumia africana Stapf (Apocynaceae)], the stem barks of three (3) species [Ficus iteophylla Miq. (Moraceae), Pterocarpus erinaceus Pear. (Fabaceae), Lannea microcarpa Engl et Kr. (Anacardiaceae)] and the roots of one species [Fagara xanthoxyloids Lam. (Rutaceae)].

Bacterial material :-

It consists of eleven (11) microorganisms, including three reference strains (E. coli ATCC 25922; Pseudomonas aeruginosa ATCC 27853 and Staphylococcus aureus ATCC 25923) for quality control and eight clinical isolates categorized as resistant or wild-type phenotypes (Table 1). These microorganisms originate from the Pasteur Institute of Côte d'Ivoire and the University Hospital Centers of Cocody and Yopougon (Abidjan).

Table 1: List of different bacterial strains.

Bacterial strains	Code	Biological origins	Phenotypes
Escherichia coli	CIP7624 (ATCC 25922)		
Pseudomonas aeruginosa	CIP 76110 (ATCC 27853)		
Staphylococcus aureus	CIP 7625 (ATCC 25923)		
Escherichia coli	1218 (BLSE)	Urine	Resistant
Proteus mirabilis	1048 (BLSE)	Stools	Resistant

Pseudomonas aeruginosa	261 (IMP^R)	Pus	Resistant
Staphylococcus aureus	926 (MET^R)	Blood	Resistant
Salmonella typhimurium	1176	Blood	Resistant
Salmonella typhimurium	1938	Blood	Savage
Pseudomonas aeruginosa	872	Ascite	Savage
Staphylococcus aureus	1227	Blood	Savage

BLSE : Extended Spectrum Beta-Lactamase ; IPM^R : Imipenem-resistant strain; MET^R : Methicillin-resistant strain ; ATCC : American Type Collection Culture.

Methods:-

Ethnobotanical survey:-

The meticulously conducted ethnobotanical survey in the Boundiali department, involving traditional medicine practitioners, identified thirty-eight (38) plants. An initial courtesy visit was made to these practitioners (traditional health practitioners, traditional healers, herbalists, and households) to get acquainted, establish a foundation of trust, and define a work plan. After obtaining their consent, a date was set for the main survey. This consisted of a semi-structured interview using an interview guide. The questions concerned the names of the plants, the diseases treated (primarily those of microbial origin), the local name of each plant, the parts used, and the methods of preparation and administration of the remedies. This led to the identification of 38 plants traditionally used to treat bacterial infections. A literature review identified 10 of these plants, which are well-known to the local population.

Calculation of the proportions of organs used and methods of prescription :-

Since the preparation method is decoction, only the percentages of use of each organ and the methods of prescription were calculated according to the following formulas :

% of organ usage =

$$\text{\% of prescription methods} = \frac{\text{Number of uses of the organ}}{\text{Total}} \frac{\text{Number of uses of the prescription method}}{\text{Total number of recipes}} \times 100$$

Sample collection and packaging :-

The selected plant samples were harvested during the dry season in the savannas of northern Côte d'Ivoire. Harvesting took place at dusk, when the plants had time to secrete sufficient active compounds to combat the stresses of the day. The harvested plant parts were cleaned, cut into small fragments, and then dried in a well-ventilated shed at ambient temperature, away from direct sunlight to prevent the loss of any substances sensitive to ultraviolet rays. After drying, they were ground into a powder and stored in glass jars for extraction.

Preparation of the alcoholic extract :-

The plant samples underwent several extractions according to a method described by Zirihi et al. (2003), adapted for this study. To do this, 25 g of plant powder were macerated in 250 ml of hexane for 24 h under magnetic stirring to degrease the powder. The residue was dried on blotting paper and weighed, then added to 250 ml of ethanol. After 24 h of maceration under stirring, the filtrate was evaporated using a rotary evaporator at 40 °C to remove the alcohol and dried under a fume hood to obtain the ethanolic extract.

Antibacterial study :-

Preparation of inoculum for solid-state tests :-

The inoculum was prepared from a 24-hour-old colony. These were emulsified in 2 ml of 85% NaCl suspension. The optical density was then adjusted to 0.5 mcFarland using a densimat. The volume collected was 100 µl for Enterobacteriaceae, 1000 µl for S. aureus, and 10 µl for P. aeruginosa. This suspension was diluted in 10 ml of physiological saline (0.9% NaCl), thus constituting the bacterial inoculum estimated at 10^6 bacteria/ml.

Germ susceptibility testing :-

Before evaluating any activity, the extracts underwent a sterility test to verify whether or not they were contaminated by a germ.The well diffusion method in agar plates and the macrodilution method in liquid medium were used to perform the tests (Koné et al., 2004). Petri dishes containing Muller-Hinton agar were inoculated by swabbing with the prepared inoculum. Wells were then created by inserting the large end of a Pasteur pipette into

the agar and filled with 50 µl of the different extracts. The plates were incubated at 37 °C for 24 hours. After this time, the inhibition zone diameter around each well was measured using calipers. The effectiveness of the extracts was assessed according to the criteria of Poncé et al. (2003). A substance is considered ineffective if the inhibition diameter is less than 8 mm, while it is considered effective if the diameter is between 9 and 14 mm. Conversely, it is judged very effective when the diameter is between 15 and 19 mm, and extremely effective if the diameter is greater than 20 mm. This test is followed by the determination of antibacterial parameters.

Preparation of the inoculum for liquid-based tests :-
Two 24-hour bacterial colonies were collected using a Pasteur pipette and emulsified in a test tube containing 10 ml of sterile Muller-Hinton broth. The mixture was incubated at 37 °C for 3 hours. After this incubation, a 0.3 ml suspension of this pre-culture was taken and diluted in 10 ml of sterile Muller-Hinton broth, then homogenized.

Preparation of the concentration range :-
The concentration range was obtained by the double dilution method. To do this, the solution of each extract with a concentration of 50 mg/ml underwent a series of dilutions with a ratio of 2, in order to obtain concentration ranges from 50 to 0.02 mg/ml.

Determination of antibacterial parameters :-
The determination of antibacterial parameters was performed by dilution in liquid medium according to the method used by Kouadio et al. (2015). Thus, in 10 experimental hemolysis tubes, 1 ml of each concentration range was mixed with 1 ml of bacterial inoculum. The growth control tube received 1 ml of sterile distilled water in addition to the inoculum, while the sterility control received only 2 ml of sterile Muller-Hinton broth (MHB). The tubes were incubated for 24 hours at 37°C. After this incubation time, visual observation was performed, and the lowest concentration at which no bacterial growth was observed corresponds to the Minimum Inhibitory Concentration (MIC). The Minimum Bactericidal Concentration (MBC) yields 0.01% viable bacteria after 24 hours of incubation at 37°C. Its determination began with enumeration. This consisted of diluting the initial inoculum from 10^{-1} to 10^{-4} and inoculating these different dilutions using a 2 µl calibrated loop in 5 cm streaks onto Muller-Hinton agar, then incubating for 24 hours.

These Petri dishes were designated A. After reading the MICs, the contents of the tubes in which no visible growth was observed were used to inoculate the GMH in 5 cm streaks. This series of Petri dishes is designated B. The MBC was determined by comparing the bacterial growth of dishes A and B. Thus, the lowest concentration in the tube that has less than 0.01% viable bacteria relative to the initial inoculum is the MBC. This part of the study was conducted using the ethanolic extract of Funtumia africana, which proved to be the most active against the majority of bacteria and germs exhibiting an inhibition zone diameter greater than or equal to 10 mm.
The MBC/MIC ratio was used to determine the substance's mode of action (Fauchere, 2002). According to Kamanzi (2002), the extract is bactericidal when its MBC is equal to its MIC or if the MBC/MIC ratio is less than or equal to 4. It is considered bacteriostatic when its MBC is greater than its MIC or if the MBC/MIC ratio is greater than 4. When this ratio is equal to 32, the strain is considered tolerant.

Statistical analysis of the results :-
Analysis of variance (one-way ANOVA) followed by Tukey's test was used to compare the variations in MICs and MBCs, and to determine whether the activity of the extracts was statistically influenced by the phenotypes (wild-type and resistant) of the bacteria. The results are expressed as means ± standard deviation. P-values < 0.05 were considered statistically significant. The R software (R CORE TEAM, 2013) was used to perform these statistical tests.

Phytochemical screening :-
The identification of the different chemical compounds in the solutions was performed by thin-layer chromatography (TLC), according to the method used by Kouadio et al. (2015). This method allows the detection of several groups of secondary metabolites by specific colorations, either in the visible spectrum or at a given wavelength (N'gaman et al., 2009). Ten milligrams of extracts were dissolved in 1 mL of absolute methanol to obtain a solution with a concentration of 10 mg/mL. Ten microliters (10 µL), or 100 µg of this solution, were spot-applied onto an F254 silica gel plate (stationary phase) using a microcapillary tube. The chromatograms were developed in tanks previously saturated with the eluent or mobile phase CHCl3-MeOH-H2O (65:35:5 v/v/v), and

then dried. These plates were observed before and after development either in the visible spectrum or under a UV lamp.

Detection of Terpenoids and Saponins :-
These compounds are detected using Godin's reagent. After spraying the plate with Godin's reagent and heating it at 100 °C for 10 minutes, various colors appear. In the visible spectrum, violet and red spots indicate the presence of monoterpenes, while blue spots indicate saponins.

Detection of Alkaloids :-
After spraying with Dragendorff's reagent and heating the chromatogram at 100 °C for 10 minutes, alkaloids appear as orange spots in the visible spectrum.

Detection of Polyphenols :-
After spraying the chromatogram with 10% Folin-Ciocalteu reagent and heating it at 100 °C for 10 min, the blue spots observed in the visible spectrum indicate the presence of polyphenols.

Detection of Flavonoids and Sesquiterpene Lactones :-
After spraying the chromatogram with 5% (w/v) aluminum chloride (AlCl3) and heating it, the presence of flavonoids is indicated by the yellow spots observable in the visible spectrum or under UV light at 366 nm. Sesquiterpene lactones are indicated by fluorescence of various colors at 366 nm.

Detection of Coumarins :-
5% (w/v) basic lead acetate (CH3COO)2 Pb was used for sputtering the chromatogram. Green and blue fluorescence spots under UV light at 366 nm indicate the presence of coumarins.

Detection of Tannins :-
The appearance of spots of various colors (blue, green, black), observable in the visible spectrum, after sputtering the chromatogram with a 10% FeCl3 solution, indicates the presence of tannins.

Detection of Anthraquinones and Anthrones :-
A 5% ethanolic solution of KOH was sprayed onto the chromatogram. The red spots visible in the visible range and at 366 nm confirm the presence of anthraquinones. Anthrones, on the other hand, are visible at 366 nm as yellow spots. After heating the plate, terpenes appear in purple and saponins in blue.

Results :-

Plants and Recipes :-
These plants are used in the treatment of conditions such as urinary tract infections, headaches, diarrhea, gonorrhea, wounds, ulcers, ringworm, pimples, coughs, fever, itching, Buruli ulcer, chronic wounds, and tuberculosis. They belong to nine (9) botanical families. These results indicate that the leaves and stem bark are the most commonly used plant parts in the preparation of medicinal recipes. Decoction is the method of preparation used. It is generally administered orally (Table 2).

Table 2: List of selected plants and their uses in traditional medicine

Scientific names	Families	Parts used	Preparation method	Method of administration	Traditional therapeutic indications
Funtumia africana	Apocynaceae	Leaves	Decoction	Drink, Bath	Tuberculosis, urinary tract infection
Spondias mombin	Anacadiaceae	Leaves	Decoction	Drink, Bath	Buruli ulcer, urinary tract infection
Carica papaya	Caricaceae	Leaves	Decoction	Drink	Headaches
Diospyros mespiliformis	Ebenaceae	Leaves	Decoction	Drink	Swelling in pregnant women
Fagara	Rutaceae	Root bark	Decoction	Mouthwash	Tooth decay

xanthoxyloïdes					
Ficus iteophylla	Moraceae	stem bark	Decoction	Drink, Bath	Ringworm, pimple
Lannea microcarpa	Anacardiaceae	stem bark	Decoction	Drink	Ulcers
Lawsonia inermis	Lytraceae	Leaves	Decoction	Mouthwash	Mouth sore
Nauclea latifolia	Rubiaceae	Leaves	Decoction	Drink, Bath	Cough, fever
Pterocarpus erinaceus	Fabaceae	stem bark	Décoction	Mouthwash	Gonorrhea, sore, itching

Calculation of the proportions of organs used and methods of prescription :-

Organs used :-

The most used part consists of the leaves with 55%, followed by stem bark (36%) and finally root bark with 9% (Figure 1).

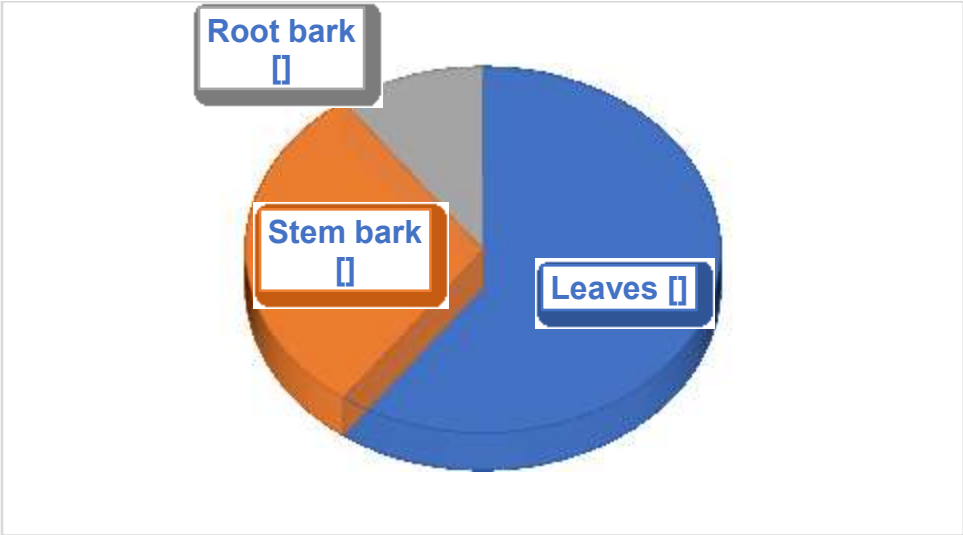

Figure 1: Proportion of organs used

Methods of prescription :-

The most frequently prescribed method was oral administration (50%), followed by oral administration (31%). Mouthwash, on the other hand, was less frequently prescribed, representing only 15% (Figure 2).

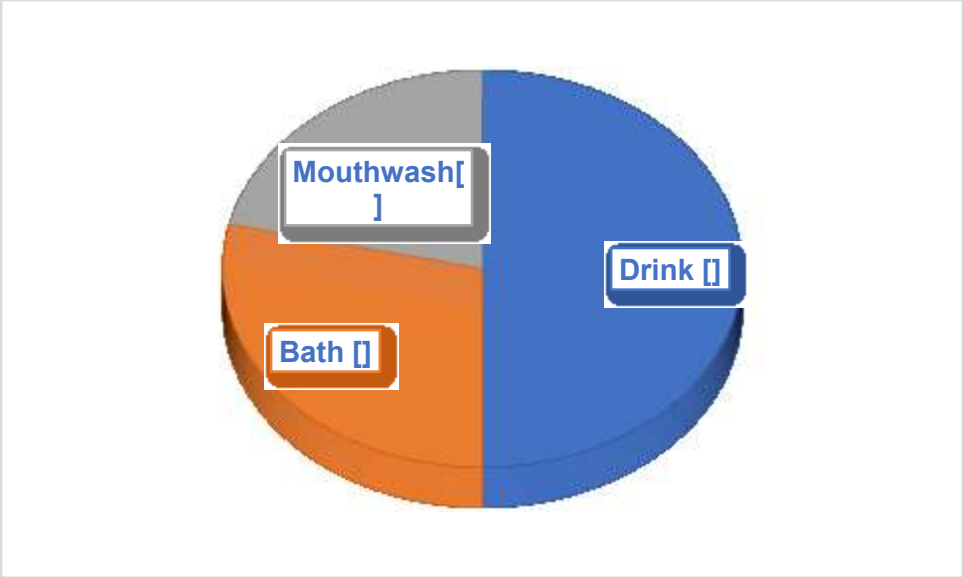

Figure 2: Proportion of prescription methods

Phytochemical screening :-

The results of the tests for the groups of chemical compounds in the ethanolic extracts of the different organs are recorded in Table 3. Thirteen (13) groups of phytochemical compounds were identified. These include polyterpenes, saponins, polyphenols, flavonoids, xanthones, naphthoquinones, alkaloids, anthrones, coumarins, and tannins, several of which are known for their antibacterial potential.

Table 3: Chemical compounds identified in different plant organs

Plant species	Chemical compounds detected
Funtumia africana Stapf (Apocynaceae)	Saponins, catechins, flavonoids, polyterpenes, polyphenols
Spondias mombin (Desr.) A. Juss. (Anacardiaceae)	Saponins, catechins, flavonoids, polyphenols, coumarins, sesquiterpene lactones, terpenes, anthrones
Carica papaya L. (Caricaceae)	Catetechic and gallic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, anthocyanins, flavonoids, alkaloids, polyterpenes
Diospyros mespiliformis Hochst. (Ebenaceae)	Saponins, catechins and gallic tannins, polyphenols, anthocyanins, polyterpenes
Fagara xanthoxyloïdes Lam. (Rutaceae)	Catetechic tannins, alkaloids, polyphenols, anthocyanins, flavonoids, polyterpenes
Ficus iteophylla Miq. (Moraceae)	Saponins, catechins and gallic tannins, anthraquinone glycosides, polyphenols, anthocyanins, polyterpenes, alkaloids
Lannea microcarpa Engl et Kr. (Anacardiaceae)	Catetechic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, polyterpenes, anthocyanins
Lawsonia inermis L. (Lytraceae)	Gallic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, polyterpenes, anthocyanins
Nauclea latifolia Sm. (Rubiaceae)	Saponins, catechins and gallic acid tannins, anthraquinone glycosides, free anthraquinones, polyphenols, flavonoids, polyterpenes
Pterocarpus erinaceus Poir. (Fabaceae)	Saponins, catechins and gallic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, flavonoids, anthocyanins

Antibacterial activity :-

Sensitivity of germs :-

The extracts were active, to varying degrees, against all bacterial strains. Of the ten ethanolic extracts tested, with the exception of that of Carica papaya, the other nine produced inhibition zone diameters ranging from 9 ± 0.1 to 28 ± 1.2 mm against the majority of bacterial strains (Figure 3). Among these extracts, the most active was that of Funtumia africana, which produced the largest inhibition zone diameter (28 ± 1.2 mm) against the bacterial strain Staphylococcus aureus 1227. This strain, of the wild-type phenotype, was obtained from the blood of a superinfected patient.

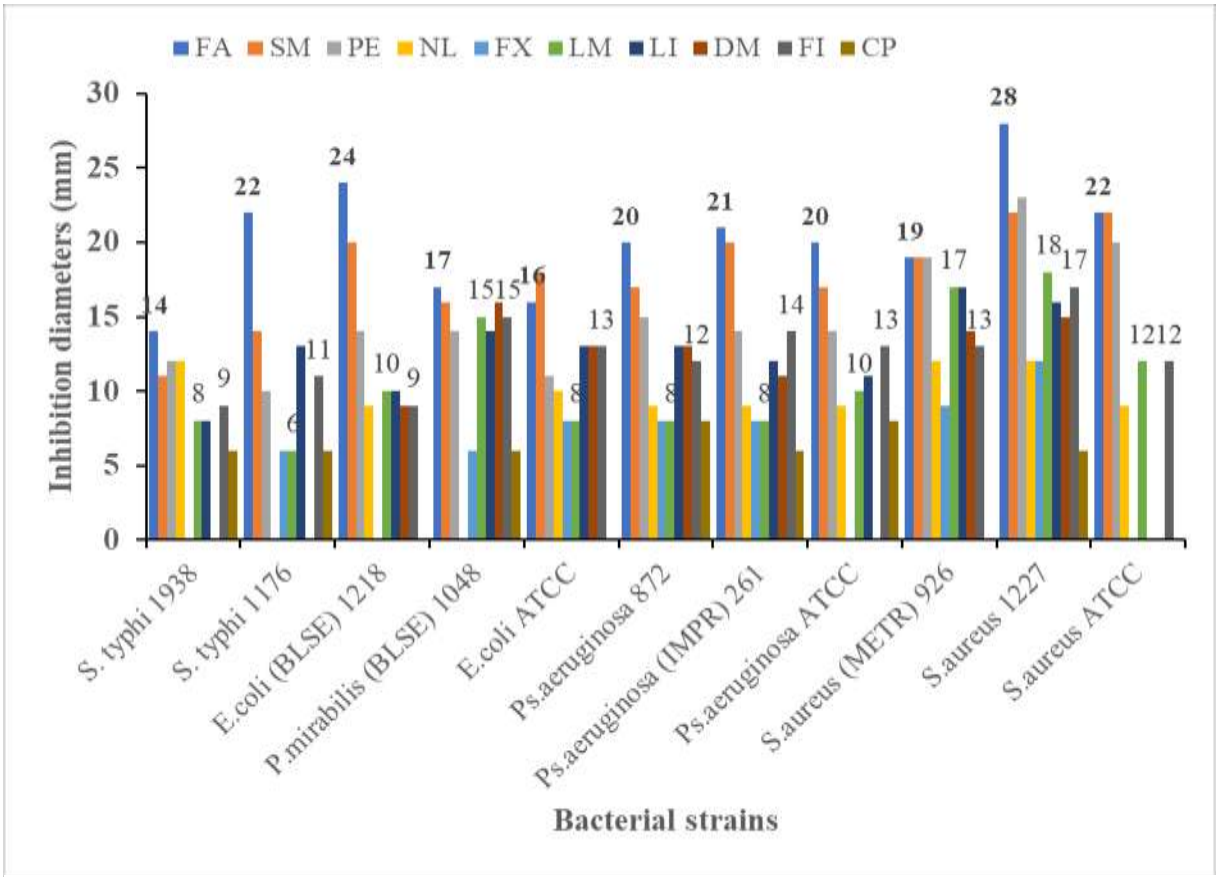

Figure 3: Activity (mean ± SD) of ethanolic extracts from plant organs at 50 mg/mL on selected bacterial strains.

S. typhi: Salmonella typhimurium; E. coli: Escherichia coli; P. mirabilis: Prateus mirabilis; Ps.aeruginosa: Pseudomonas aeruginosa; S. aureus: Staphylococcus aureus; ESBL: expanded spectrum beta lactamase; ATCC: American type culture collection; IMPR: strain resistant to the antibiotic imipenem. PE: Pterocarpus erinaceus; NL: Nauclea latifolia; FX: Fagara xanthoxyloids; LM: Lannea microcarpa; LI: Lawsonia inermis; DM: Diospyros mespiliformis; FI: Ficus iteophylla; FA: Funtumia africana; SM: Spondias mombin.

Antibacterial parameters :-

Tests revealed that turbidity induced by bacterial growth decreased inversely with the concentration of extracts in the test tubes. Overall, the extracts exerted a bactericidal effect on all selected bacteria. MICs ranged from 0.04 ± 0.0 mg/mL to 3.12 ± 3.0 mg/mL. The lowest MIC (0.04 ± 0.0 mg/mL) was observed for Staphylococcus aureus (METR) 926. This methicillin-resistant strain also exhibits cross-resistance to fluoroquinolones. It was collected from the blood of a patient with a urinary tract infection. MBCs ranged from 0.39 ± 0.2 mg/mL to 6.24 ± 4.1 mg/mL. Low MBC values were generally observed in bacterial strains exhibiting low MIC values (Table 4).

Analysis of variance showed a non-significant difference between the MICs of wild-type and resistant bacterial strains and the MBCs of these strains (Table 5; P > 0.05).

Table 4 : Antibacterial parameters of the ethanolic extract of Funtumia africana

Bacterial strains	Antibacterial parameters (mg/mL)			
	MIC	MBC	$\frac{MBC}{MIC}$	Antibacterial power
S. typhi 1176	1,56 ± 1,1	3,12 ± 0,2	2	Bactericide
P. mirabilis (BLSE) 1048	3,12 ± 3,0	6,24 ± 1,4	2	Bactericide
E. coli (BLSE) 1218	1,56 ± 1,0	3,12 ± 0,2	2	Bactericide
S. typhi 1938	0,78 ± 0,1	1,56 ± 0,2	2	Bactericide
S. aureus ATCC	3,12 ± 1,2	6,24 ± 0,1	2	Bactericide
Ps. Aeruginosa ATCC	3,12 ± 0,0	6,24 ± 0,2	2	Bactericide
E. coli ATCC	0,97 ± 0,0	0,39 ± 0,2	2	Bactericide
Ps. aeruginosa 872	1,56 ± 7,2	3,12 ± 2,4	2	Bactericide
Ps. aeruginosa (IMP^R) 261	1,56 ± 0,0	6,24 ± 4,1	4	Bactericide
S. aureus (MET^R) 926	0,04 ± 0,0	0,97 ± 0,0	1	Bactericide
S. aureus 1227	0,97 ± 0,0	0,97 ± 0,0	1	Bactericide

Table 5: Comparison of mean MIC and MBC values of the ethanolic extract of Funtumia africana according to bacterial phenotypes

Antibacterial parameters	Wild bacterial strains	Resistant bacterial strains	P-value
MIC (mg/mL)	2,575 ± 2,0	2,92 ± 3,1	**P** (0,2365) > 0,05
MBC (mg/mL)	2,785 ± 2,1	3,478 ± 4,2	**P** (0,3008) > 0,05

Discussion:-

Ethnobotanical survey ;-

Investigations into the treatment of bacterial infections using traditional medicine in the Boundiali department identified 38 medicinal plants. A literature review highlighted ten (10) plants that require further investigation. These readily available plants are regularly harvested and sold in the markets of Boundiali and the surrounding area. They belong to nine (9) botanical families, including the Combretaceae. The use of Combretaceae in treating microbial infections is mentioned by other authors, such as Koné (2005), in a survey conducted in the Ferkessédougou region. This can be explained by the fact that these two study areas share similar vegetation (wooded savannas and shrub savannas). Furthermore, the Combretaceae family is abundant in all Sahelian-Sudanian savannas (the type of vegetation found in northern Côte d'Ivoire).

In traditional remedies, leaves are the most frequently used part of the plant in various medicinal preparations, accounting for 60% of cases. Several authors agree on the increased use of this part of the plant. Koffi et al. (2009) found a usage rate of 63.52% in an ethnopharmacological survey in Krobou country. Similarly, in other West African countries, particularly Nigeria, leaves remain the most commonly used component. This high usage of leaves can be explained by their abundance, availability, and relatively easy handling (Tra Bi, 2008). Remedies are prepared as decoctions. Generally, among neighboring populations, recipes vary very little from one traditional healer to another, as the same recipes are often used to alleviate the ailments of a patient suffering from a given condition. This would explain the similarity of our results with those of Koné (2005), who also conducted his research in the far north. Similarly, the decoction, prepared at a high temperature, has the advantage of neutralizing pathogenic germs and ensuring the preparation is safe, thus preventing any contamination. The primary method of

administration is oral administration at a concentration of 50%. This result is similar to that of Jean (2000) in his work on plants used as anthelmintics in traditional medicine in the Dja Biosphere Reserve in Cameroon.

From a phytochemical perspective :-

Plants identified as effective against microbial infections are often prescribed for the treatment of several other common ailments. They therefore have multiple uses, explained by the presence of numerous groups of biologically active chemical compounds they contain (Tra Bi, 2008). Indeed, phytochemical investigations have identified thirteen (13) groups of chemical compounds, including alkaloids, quinones, flavonoids, terpenes, saponins, and tannins. These phytoconstituents are responsible for the pharmacological effects observed with the use of the plants and, consequently, determine their therapeutic value. Among these compounds, many are recognized for their antibacterial effects; alkaloids play an important role in biological structures and appear to be potent anticholinergics (Muster, 2004). Their presence in the various selected organs could explain the use of these species in treating headaches, tooth decay, colds, and coughs, since, according to Jacques (2000), certain alkaloids have a direct effect on the body, reducing spasms and relieving pain. Similarly, the presence of funtumine, an alkaloid extracted from F. africana, has been indicated, in addition to flavonoids, coumarins, tannins, and terpenes, proving that this plant possesses bactericidal and fungicidal properties (Thanyani, 2010).

Anthraquinone-containing drugs are very often used in the treatment of itching and dermatological conditions (Sanogo et al., 2016). These compounds are present in almost all of these plant species, which would justify their use in the treatment of acne, itching, gonorrhea, and wounds. Similarly, flavonoids (flavones and flavonols) are also present in most plant species. These secondary metabolites are known for their protective properties against hormone-dependent diseases (Cimanga et al., 2006), which would explain their anti-edematous effects (in pregnant women) in the leaves of D. mespiliformis. Polyterpenes possess anti-allergic and anti-inflammatory properties. The anti-inflammatory effects of these plants in the treatment of wounds, fevers, and headaches could be linked to these compounds, as these various ailments can trigger inflammatory processes. This would particularly explain the anti-inflammatory capacity of F. africana leaves (Thanyani, 2010).Saponins are also recognized for their anti-inflammatory, anti-edematous, analgesic, and antibacterial properties (Sanogo et al., 2016). They are present in almost all plants and justify their use in relieving pathologies such as ulcers, tooth decay, headaches, and gonorrhea, which cause excruciating pain.According to this author, tannins are known for their antiseptic, bactericidal, and astringent properties. The treatment of skin blemishes with the stem bark of Ficus iteophylla, itching with the same part of Pterocarpus erinaceus, and mouth sores with the leaves of Lawsonia inermis, could be due to tannins, both catecholic and gallic.

Antibacterial activity:-

Tests showed that the extracts are active to varying degrees against bacteria. This is reflected in the differences observed in inhibition zone diameters. Of all the plant species, Funtumia africana was the most active, yielding the highest inhibition zone diameters. Its activity was particularly evident against Staphylococcus aureus (MET^R) 926. This methicillin- and fluoroquinolone-resistant strain was collected from the blood of a patient with a urinary tract infection. This result corroborates the findings of several authors, including Koudio et al. (2015), who have reported the use of this plant in the treatment of bacterial infections.

Regarding antibacterial parameters, the lowest value at which the inhibitory action of the Funtumia africana extract begins to be exerted is 0.04 mg/ml against Staphylococcus aureus (MET^R) 926. This reflects the efficacy of this extract against this strain. These results are comparable to those of Baba-Moussa et al. (2013), who, in their work with a decoction of F. africana leaves, demonstrated significant antibacterial activity against susceptible strains of E. coli, P. aeruginosa, and S. aureus, responsible for opportunistic infections. These same authors highlighted the fungicidal properties of this plant. The one-way ANOVA test indicated that the differences observed in the MICs and MBCs of the two strain categories were not significant. We can therefore conclude that the activity of the extracts was not statistically influenced by the bacterial phenotype.Furthermore, the CMB/CMI ratios being all less than or equal to 4, indicate bactericidal activity on all germs subjected to this study.

Conclusion:-

Research conducted in northern Côte d'Ivoire on medicinal plants used to treat bacterial infections and many other pathologies identified 38 plants, 10 of which were selected following a literature review. Ethnobotanical surveys confirmed their traditional therapeutic uses. Phytochemical screening of these plants revealed the presence of several major groups of secondary metabolites, including alkaloids, quinones, flavonoids, terpenes, saponins, and tannins,

all of which have known antimicrobial activity.Furthermore, the evaluation of their antibacterial potential confirmed that all these plants have an antibacterial effect. The species *F. africana* was the most active, and its extract was selected to determine the MICs and MBCs.
This research demonstrates that these plants offer hope for alleviating microbial infections, a significant public health threat. Therefore, the range of protection for endangered species will need to be broadened in order to guarantee the preservation and safeguarding of plant biodiversity, a true wealth of Ivorian flora.

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Authors' contributions:-
This work was carried out in collaboration with all the authors listed. They participated in every stage of the manuscript development, up to and including the final version. They have therefore read and approved the final manuscript.

Competing Interests:-
Authors have declared that no competing interests exist.

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