RESEARCH ARTICLE

ANTICORROSIVE AND ANTIFUNGAL EFFECTS OF ETHANOLIC EXTRACT (STEM /LEAF) OF *TINOSPORA CORDIFOLIA* PLANT IN HNO$_3$ ACID USING ADDITIVE (KNO$_3$)

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ABSTRACT

Weight loss and thermometric techniques were used in the absence and presence of an additive (KNO$_3$) to test the corrosion-inhibitory effectiveness of *Tinospora Cordifolia* stem and leaf extract in various concentrations of HNO$_3$ acid (0.5, 1, 2, and 3N). The results of this study indicate that inhibition effectiveness (η%) increases with both increasing inhibitor concentration and acid strength, and that a further improvement in inhibition efficiency was observed with the addition of additives (KNO$_3$) due to a synergistic effect. Based on the research, stem extract outperforms leaf extract as a corrosion inhibitor. In the absence of an additive and using 3N HNO$_3$ acid at its maximum strength, the greatest inhibitory efficiency was seen for stem and leaf extracts at their maximum concentrations (0.8%) of 90.46% and 86.51%, whereas it was shown at 93.48% and 90.69% in the presence of an additive (KNO$_3$). The disc diffusion method was used to investigate the in vitro antifungal activity of the *Tinospora Cordifolia* stem and leaf extract against *Aspergillus niger*. Interpretations from the zone of inhibition revealed that *Tinospora Cordifolia* stem and leaf extract has good antifungal efficacy against Aspergillusniger (a fungus).

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INTRODUCTION

Corrosion is the devastation of materials brought on by a chemical or electrochemical attack from the environment. It is an unavoidable interfacial interaction between a substance and its surroundings that consumes or dissolves an environmental component into the material. The greatest issue confronting industry right now is metal corrosion. Corrosion results in annual losses of millions of dollars. Corrosion is a spontaneous and thermodynamically favorable phenomenon that may be described in a variety of ways. Since it depends largely on the local environment to which metals or other materials are exposed, understanding the process of corrosion is exceedingly challenging (1, 2). Physical and chemical interactions between a metal and its surroundings lead to corrosion, which modifies the metal's properties and frequently results in the degradation of the metal's functions, the environment, or the technological system, of which it is a part(3). Corrosion is the collapse or crumbling of a material's inherent properties as a result of a reaction in its immediate environment. Metals and alloys become unfit for their intended purposes as a result of corrosion, which erodes their metallic surface anddegrades their special properties (4). Corrosion may seriously harm metal and alloy structures, which can have an economic impact on product losses, safety, environmental pollution, and repair and replacement costs. Corrosion is an unwanted phenomenon that has to be avoided because of these adverse effects.In order to extend the lifespan of metallic and alloy materials, there are numerous approaches to avoiding corrosion and the rates at which it might spread. One of the authorized methods for reducing and/or preventing corrosion is the use of inhibitors to control corrosion in metals and alloys exposed to aggressive environments. A corrosion inhibitor is a chemical that, when introduced to an environment at modest concentrations, effectively slows down the pace at which a metal exposed to that environment corrodes (5). The two main groups of corrosion inhibitors are those that increase the production of a protective oxide coating through an oxidizing action and those that inhibit corrosion by selectively adhering to the metal surface and forming a barrier that blocks the entry of corrosive chemicals. Nearly all organic compounds with heteroatoms, including those containing oxygen, nitrogen, sulfur, and phosphorus, exhibit notable inhibitory efficiency. Plants are a source of naturally occurring substances, some of which have intricate molecular structures and unique chemical, biological, and physical characteristics. The majority of substances that exist naturally are employed because they are cheap, readily available, and ecologically friendly. These benefits are the basis for the use of plant extracts and plant-derived products as corrosion inhibitors for metals and alloys in various environments (6).

As a result, the plant *Tinospora Cordifolia was* chosen for the investigation. Various plant extracts, sometimes referred to as "green corrosion inhibitors," can be employed as corrosion inhibitors. Tin is a silvery-white metal that is soft, malleable, ductile, and highly crystalline. In group 14 of the periodic table, tin is a post-transition metal. The main source of it is the mineral cassiterite, which includes stannic oxide, SnO_2. With ten stable isotopes, tin has the highest number of stable isotopes in the periodic table and is the 49th most common element on Earth. Bronze, comprised of 1/8 tin and 7/8 copper, was the earliest tin alloy that was widely used, dating back to 3000 BC. Tin is utilized in several alloys nowadays, most notably the tin/lead soft solders, which contain 60% or more tin, and the production of transparent, electrically conductive indium tin oxide films for optoelectronic applications. Tin plating of steel for corrosion resistance is another significant use. Tin-plated steel is frequently used for food packaging, such as tin cans, due to the low toxicity of inorganic tin (7). Tin can be corroded by acids and alkalis but is resistant to corrosion by water. Tin may be highly polished and is used to cover other metals with a coating of protection from oxidation (passivation) (8–9).

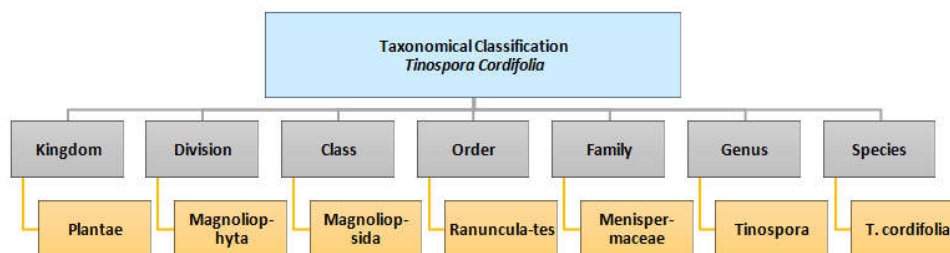## Plant Description

Classification

Fig. 1. Taxonomical Classification of *Tinospora Cordifolia* plant

Tinospora Cordifolia, commonly known as heart-leaved moonseed, guduchi, or giloy is a Menispermaceae herbaceous vine(10). It has been used in Ayurvedic medicine to treat a variety of diseases. Guduchi, an Indian medicinal plant, has long been used in Ayurvedic formulations to treat a number of ailments. Tinospora Cordifolia is a medicinal plant with remarkable therapeutic characteristics that include antioxidants, antibacterials, antidiabetics, and antiaging (11). It is widespread throughout the Asian subcontinent, including India, Nepal, Bangladesh, Malaysia, and more. This plant has been used to treat general weakness, fever, dysentery, gonorrhea, dyspepsia, secondary syphilis, viral hepatitis, impotence, gout, anemia, and skin problems. Guduchi is used in compound formulations to treat diabetes, rheumatoid arthritis, and jaundice. The root is known to be a powerful emetic and is used to alleviate intestinal obstruction (12–14).Numerous chemicals, including alkaloids, diterpenoid lactones, glycosides, steroids, sesquiterpenoids, phenolic compounds, aliphatic compounds, and polysaccharides, have been isolated from *T. cordifolia*. This plant's leaves are high in protein (11.2%), calcium, and phosphorus. From stems, the acetates of four novel clerodanefuranoditerpene glucosides (amritosides A, B, C, and D) have been identified (15–18).
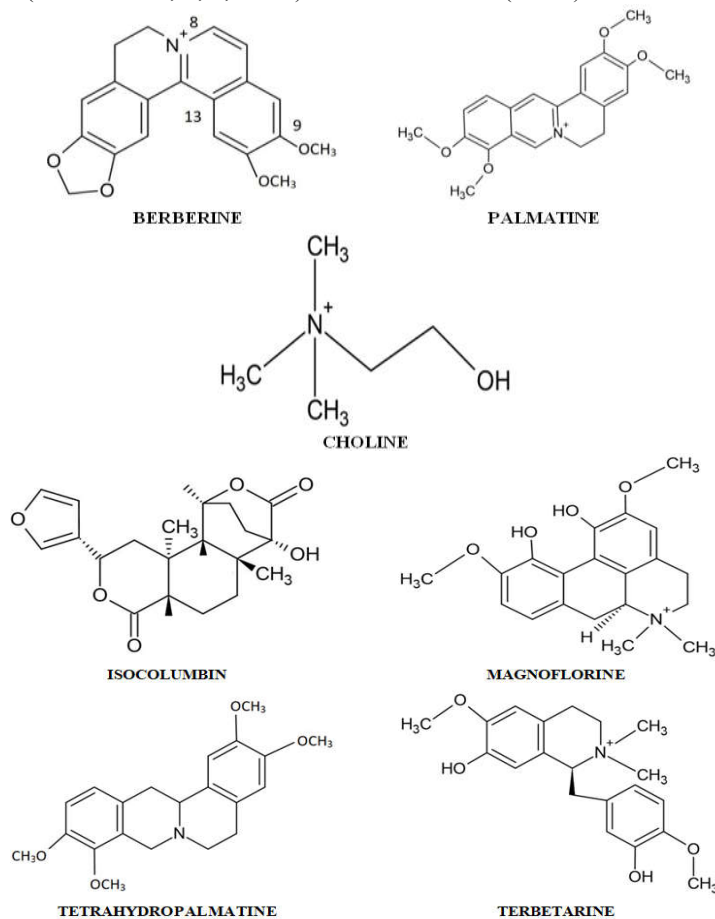

Fig. 2. Alkaloids of *Tinospora Cordifolia* plant

Experimental

Preparation of Stem and Leaves Extract: *Tinospora Cordifolia* plant stem and leaves were newly harvested from National Research Centre On Seed Spices (NRCSS) Tabiji, Ajmer (Rajasthan) India and air dried at room temperature before being processed to obtain powder. *Tinospora Cordifolia* powder stem and leaf extract was made by refluxing the dried stem and leaves in ethanol solvent in a soxhlet apparatus and heating for a suitable amount of time (a few days).

Metal Used: All of the reagents used in this study were of analytical quality, and they were prepared using double-distilled water. The tin sheet for the investigation was bought from the Central Drug House (P) Ltd. (CDH) branch in Jaipur. The sheet was mechanically cut into coupons with dimensions of 2.5 cm x 2.5 cm and a tiny hole about 2 mm in diameter drilled at the upper edge. Each coupon was cleaned and degreased before polishing to a pristine finish.

Chemicals Used: Using analytical-grade reagents, varied concentration solutions of HNO_3 (0.5N, 1N, 2N, and 3N) were made in double distillation water and utilized for corrosion investigations. The ethanol solvent was used to prepare inhibitor solutions at various concentrations, including 0.2%, 0.4%, 0.6%, and 0.8%.

Weight loss technique: Each specimen was placed into a beaker containing 50 mL of the test solution at room temperature and suspended with a V-shaped glass hook made of fine capillary. After the proper exposure, test specimens were washed with running water and dried with a hot air blower. Double trials were conducted in each instance, and the average amount of weight loss or gain was calculated. The following equation was used to compute the percentage inhibition efficiencies of inhibitors (19–24):

$$\eta\% = \left[\frac{(\Delta W_u - \Delta W_i)}{\Delta W_u}\right] \times 100$$

Where ΔW_u and ΔW_i are the weight loss of the metal in the uninhibited and inhibited solution, respectively.

The corrosion rate (CR) in mm/yr (millimeter per year) was expressed as(25-30):

$$\text{Corrosion rate (mm/yr.)} = \frac{(\Delta W \times 87.6)}{(A \times T \times d)}$$

Where ΔW is the weight loss of the specimen in mg, A is the area of exposure of the specimen in square cm^2, T is the time of exposure in hours and d is the density of the specimen in g/cm^3.

The degree of surface coverage (θ) was calculated as (31-33):

$$\theta = \left[\frac{(\Delta W_u - \Delta W_i)}{\Delta W_u}\right]$$

Where ΔW_u and ΔW_i are the weight loss of the metal in the uninhibited and inhibited solution, respectively.

Thermometric method: Thermometric method is also known as Myliusmethod (34).This method involved immersing a single specimen with a surface area of 13 cm^2 in a reaction chamber containing a 50 mL acid solution at a starting temperature of 301° K in order to measure the degree of inhibition. Nevertheless, there were no discernible temperature changes with 0.5N HNO_3. In addition to testing acid solutions of 1N, 2N, and 3N, as well as the presence and absence of inhibitors at varied concentrations of 0.2%, 0.4%, 0.6%, and 0.8%, experiments were also carried out. The test fluid in the beaker was completely filled with the specimen and thermometer bulb. The beaker was kept in a space that was thermally insulated. At intervals of five minutes, temperature variations were measured using a thermometer with a precision of 0.01^oC. The temperature increased steadily at first before increasing swiftly and reaching its highest point. Then the temperature was measured at its peak. The reaction number can be find out by the formula given below.

The formula for reaction number, RN ($K min^{-1}$), is (35-38):

$$RN = \frac{T_m - T_i}{t}$$

Where T_m = Maximum temperature of the solution.
T_i = Initial temperature of the solution.
t= time required (in minutes) to attain maximum temperature.
The percentage inhibition efficiency was calculated as (39-41):

$$\eta\% = \frac{(RN_f - RN_i)}{RN_f} \times 100$$

WhereRN_f= Reaction Number in uninhibited solution.

RN_i= Reaction Number in the inhibited solution.

RESULTS AND DISCUSSION

Weight loss technique: The corrosion rate for tin metal in nitric acid solutions of various concentrations was examined using weight loss and thermometric methods in the absence and presence of stem and leaf extracts of the*Tinospora Cordifolia* plant at 301K, and percentage inhibition

efficiencies were calculated using both the above-mentioned methods. Tables 1, 3, 5, 7, and 2, 4, 6, and 8 show the weight loss data, percentage inhibition efficiency (η%), corrosion rate, and surface coverage (θ) data for tin metal in 0.5 N, 1 N, 2 N, and 3 N nitric acid solutions with varying inhibitor concentrations (i.e., 0.2%, 0.4%, 0.6%, and 0.8%) in the absence and presence of additive (KNO₃).The related graphs for inhibition efficiency and the Langmuir adsorption isotherm are presented in Figs. 1a-b, 3a-b, 5a-b, 7a-b as well as 2a-b, 4a-b, 6a-b, 8a-b in absence and presence of additive (KNO₃) respectively.

Table 1. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage (θ) and Corrosion rate for tin in 0.5 N HNO₃ with inhibitor of stem and leaves extract

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. (η%)	$\log\left(\frac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.425		0.19588		
0.2	0.105	0.7529	0.04839	75.29	0.48386
0.4	0.095	0.7764	0.04378	77.64	0.54061
0.6	0.083	0.8047	0.03825	80.47	0.61493
0.8	0.070	0.8352	0.03226	83.52	0.70483
Leaves					
0.2	0.118	0.7223	0.05438	72.23	0.41514
0.4	0.104	0.7552	0.04793	75.52	0.48925
0.6	0.087	0.7952	0.04009	79.52	0.58914
0.8	0.078	0.8164	0.03595	81.64	0.64803

Temperature: 301K ± 0.1K;   Area of Specimen: 13 cm²; Time of Exposure : 120mins

Table 2. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage(θ) and Corrosion rate for tin in 0.5 N HNO₃ with inhibitor of stem and leaves extract in presence of Additive KNO₃

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. (η%)	$\log\left(\frac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.425		0.19588		
0.2	0.096	0.7741	0.04424	77.41	0.5344880
0.4	0.086	0.7976	0.03963	79.76	0.595574
0.6	0.074	0.8258	0.03411	82.58	0.675826
0.8	0.061	0.8564	0.02811	85.64	0.775522
Leaves					
0.2	0.103	0.7576	0.04747	75.76	0.494907
0.4	0.090	0.7882	0.04148	78.82	0.5707104
0.6	0.077	0.8188	0.03548	81.88	0.655019
0.8	0.069	0.8376	0.03180	83.76	0.712450

Temperature: 301K ± 0.1KTime of Exposure:120mins; Area of Specimen: 13 cm²Additive: 0.5N KNO₃

Table 3. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage (θ) and Corrosion rate for tin in 1N HNO₃ with inhibitor of stem and leaves extract

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. (η%)	$\log\left(\frac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.415		0.51007		
0.2	0.089	0.7855	0.10938	78.55	0.56371
0.4	0.081	0.8048	0.09955	80.48	0.61520
0.6	0.068	0.8361	0.08357	83.61	0.70767
0.8	0.056	0.8650	0.06882	86.50	0.80668
Leaves					
0.2	0.110	0.7349	0.13519	73.49	0.44281
0.4	0.098	0.7638	0.12045	76.38	0.50969
0.6	0.082	0.8024	0.10078	80.24	0.60860
0.8	0.069	0.8337	0.08480	83.37	0.70011

Temperature: 301K ± 0.1K; Area of Specimen: 13 cm; ime of Exposure: 45 mins

Table 4. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage(θ) and Corrosion rate for tin in 1N HNO₃ with inhibitor of stem and leaves extract in presence of KNO₃

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. (η%)	$\log\left(\frac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.415		0.51007		
0.2	0.080	0.8072	0.09832	80.72	0.621874
0.4	0.067	0.8385	0.08234	83.85	0.715330
0.6	0.055	0.8674	0.06759	86.74	0.815675
0.8	0.043	0.8963	0.05285	89.63	0.936674
Leaves					
0.2	0.096	0.7686	0.11799	76.86	0.521337
0.4	0.079	0.8096	0.09709	80.96	0.628603
0.6	0.064	0.8457	0.07866	84.57	0.738850
0.8	0.052	0.8746	0.06391	87.46	0.843511

Temperature: 301K ± 0.1KArea of Specimen: 13 cm² Time of Exposure: 45minsAdditive : 1N KNO₃

Table 5. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage (θ) and Corrosion rate for tin in 2 N HNO₃ with inhibitor of stem and leaves extract

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. ($\eta\%$)	$\log\left(\dfrac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.428		1.19556		
0.2	0.084	0.8037	0.23464	80.37	0.61217
0.4	0.075	0.8247	0.20950	82.47	0.67251
0.6	0.062	0.8551	0.17318	85.51	0.77094
0.8	0.050	0.8831	0.13966	88.31	0.87819
Leaves					
0.2	0.105	0.7546	0.29330	75.46	0.48784
0.4	0.092	0.7850	0.25699	78.50	0.56243
0.6	0.078	0.8177	0.21788	81.77	0.65180
0.8	0.066	0.8457	0.18436	84.57	0.73885

Temperature: 301K ± 0.1K;　Area of Specimen: 13 cm²;　Time of Exposure : 20mins

Table 6. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage (θ) and Corrosion rate for tin in 2 N HNO₃ with inhibitor of stem and leaves extract in presence of KNO₃

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. ($\eta\%$)	$\log\left(\dfrac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.428		1.19556		
0.2	0.074	0.8271	0.20670	82.71	0.679763
0.4	0.061	0.8574	0.17039	85.74	0.779063
0.6	0.049	0.8855	0.13687	88.55	0.888383
0.8	0.035	0.9182	0.09776	91.82	1.050183
Leaves					
0.2	0.091	0.7873	0.25419	78.73	0.568372
0.4	0.076	0.8224	0.21229	82.24	0.665640
0.6	0.060	0.8598	0.16760	85.98	0.787649
0.8	0.045	0.8948	0.12570	89.48	0.929710

Temperature: 301K ± 0.1K Area of Specimen : 13 cm² Time of Exposure : 20 mins　Additive : 2N KNO₃

Table 7. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage (θ) and Corrosion rate for tin in 3N HNO₃ with inhibitor of stem and leaves extract

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. ($\eta\%$)	$\log\left(\dfrac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.430		2.38782		
0.2	0.071	0.8348	0.39426	83.48	0.70357
0.4	0.063	0.8534	0.34984	85.34	0.76501
0.6	0.049	0.8860	0.27210	88.60	0.89052
0.8	0.041	0.9046	0.22767	90.46	0.97690
Leaves					
0.2	0.092	0.7860	0.51088	78.60	0.56500
0.4	0.080	0.8139	0.44424	81.39	0.64082
0.6	0.070	0.8372	0.38871	83.72	0.71117
0.8	0.058	0.8651	0.32207	86.51	0.80705

Temperature : 301K ± 0.1K;　Area of Specimen : 13 cm²;　Time of Exposure : 10 mins

Table 8. Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage (θ) and Corrosion rate for tin in 3N HNO₃ with inhibitor of stem and leaves extract in presence of Additive

Inhibitors Concentration	Δw	Surface Coverage (θ)	Corrosion Rate (mm/yr)	I.E. ($\eta\%$)	$\log\left(\dfrac{\theta}{1-\theta}\right)$
Stem					
Uninhibited	0.430		2.38782		
0.2	0.062	0.8558	0.34429	85.58	0.773407
0.4	0.048	0.8883	0.26654	88.83	0.900506
0.6	0.038	0.9116	0.21101	91.16	1.013352
0.8	0.028	0.9348	0.15548	93.48	1.156471
Leaves					
0.2	0.079	0.8162	0.43869	81.62	0.647451
0.4	0.065	0.8488	0.36095	84.88	0.749253
0.6	0.053	0.8767	0.29431	87.67	0.851887
0.8	0.040	0.9069	0.22212	90.69	0.988609

Temperature: 301K ± 0.1K Area of Specimen: 13 cm² Time of Exposure: 10 mins Additive: 3N KNO₃
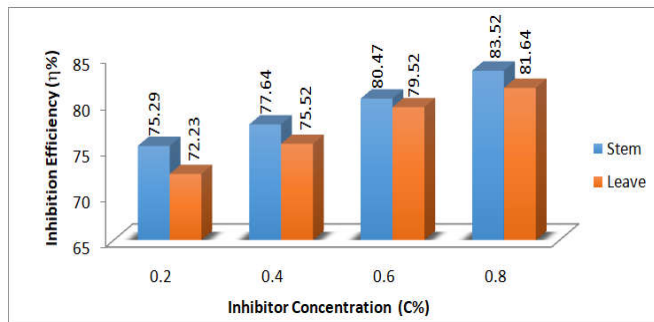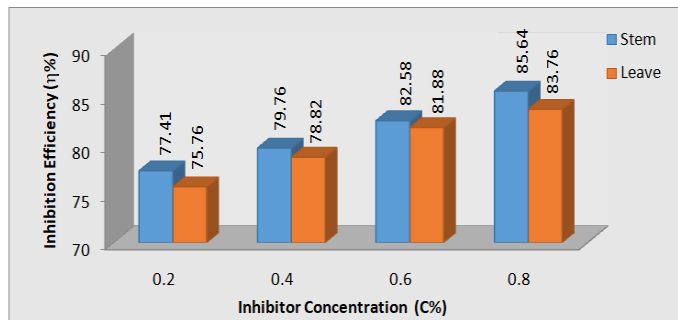
Graph 1(a). Variation of Inhibition Efficiency (η%) for tin in 0.5N HNO$_3$ with inhibitor concentration of stem and leaves extract
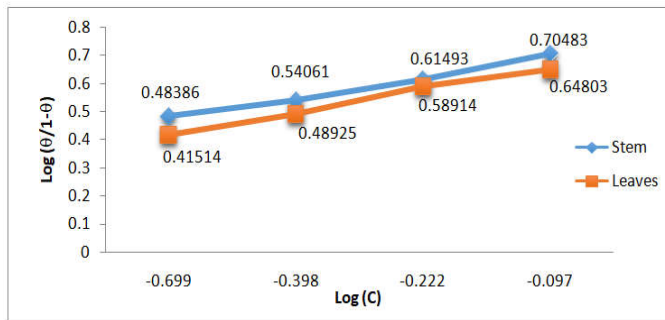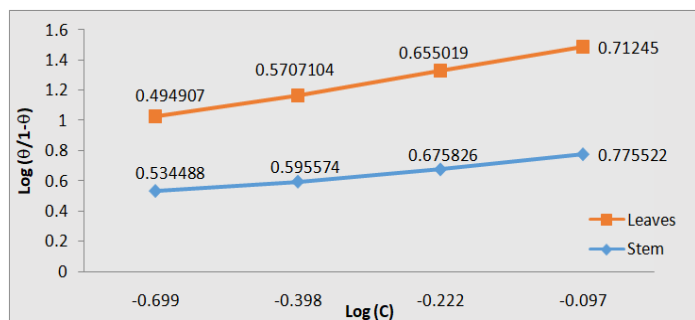

Graph 1(b). Langmuir Adsorption Isotherm for tin in 0.5N HNO3

Thermometric method: The thermometric approach uses time to calculate temperature changes. Using a thermometer, the specimen is submerged in the test solution, which is completely insulated. Because of the extremely exothermic nature of the reaction between the metal and its surroundings, the temperature of the solution first increases rapidly to its maximum value before starting to fall. The highest temperature is noted, and the temperature change is calculated.

In order to determine the reaction number and percentage of inhibition efficiency for stem and leaf extracts at different concentrations (0.2% to 0.8%) in 1N, 2N, and 3N HNO$_3$ acid solutions in the absence and presence of additives, the data represented in tables 9 and 10 were utilized. However, for 0.5N HNO$_3$, there were no appreciable temperature changes recorded. The maximum inhibition efficiency of 66.80% and 63.56% for stem and leaf extract in the absence of additive and 70.24% and 65.78% for stem and leaf extract in the presence of additive (KNO$_3$) was obtained with the highest concentrations of inhibitor (0.8%) and HNO$_3$ acid (i.e., 3N), which are represented in tables 9 and 10.
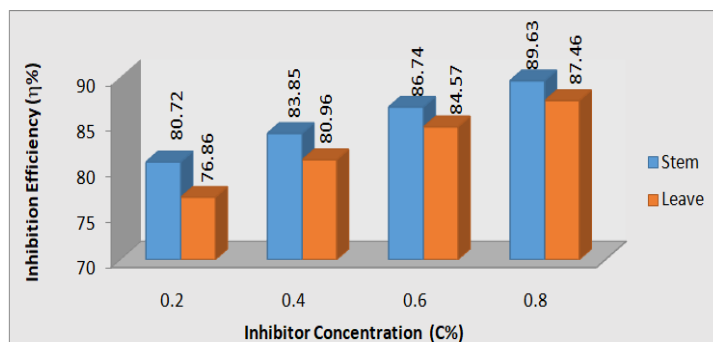

Graph 2(a). Variation of Inhibition Efficiency (η%) for tin in 0.5 N HNO$_3$ with inhibitor concentration of stem and leaves extract in presence of additive 0.5 N KNO$_3$
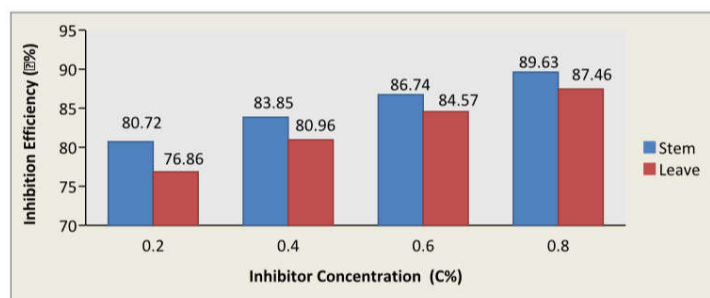

Graph 2(b). Langmuir Adsorption Isotherm for tin in 0.5N HNO$_3$ in presence of additive 0.5 N KNO$_3$
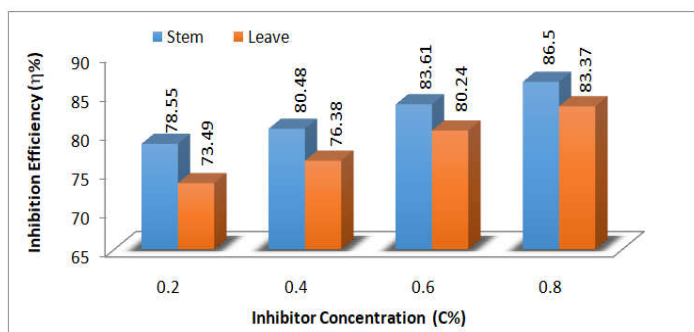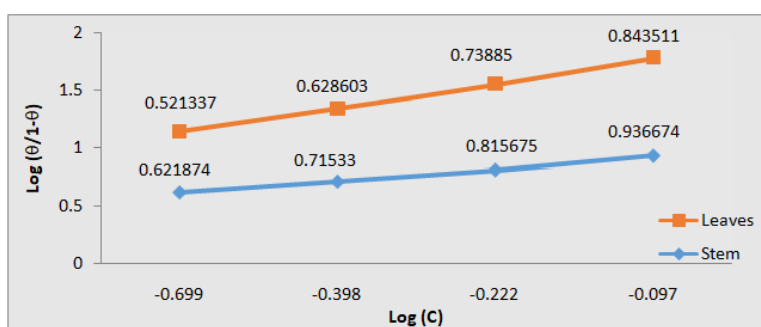
Graph 3(a). Variation of Inhibition Efficiency (η%) for tin in 1N HNO$_3$ with inhibitor concentration of stem and leaves extract
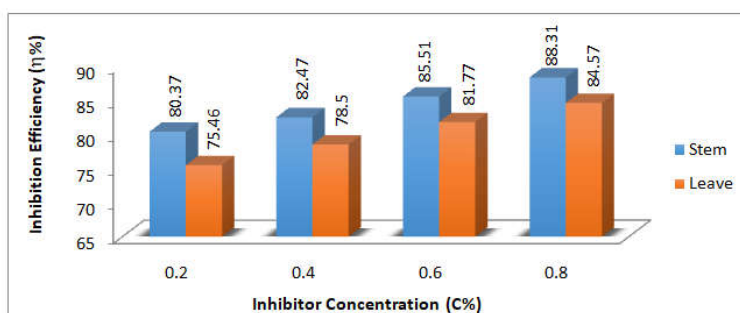

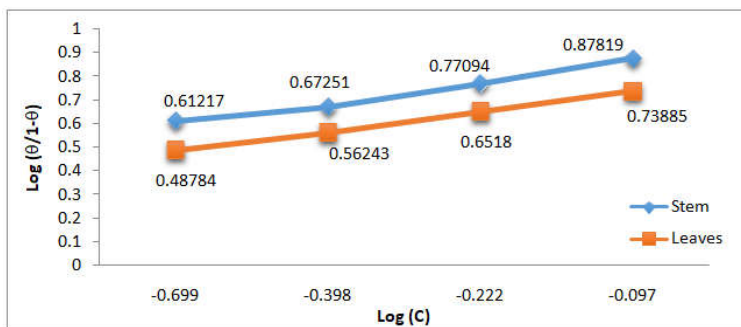**Graph 3(b). Langmuir Adsorption Isotherm for tin in 1N HNO$_3$**

Graph 4(a): Variation of Inhibition Efficiency (η%) for tin in 1 N HNO$_3$ with inhibitor concentration of stem and leaves extract in presence of additive 1 N KNO$_3$
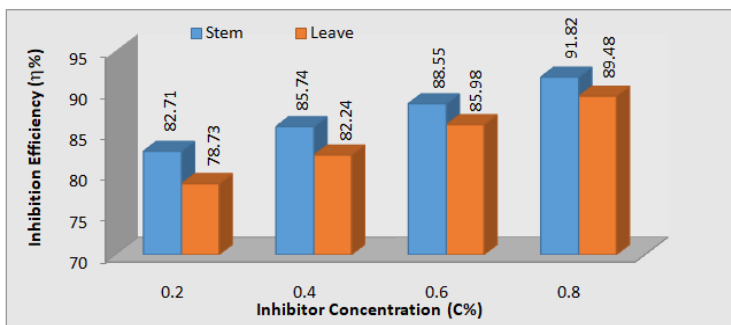

Graph 4(b): Langmuir Adsorption Isotherm for tin in 1N HNO$_3$ in presence of additive 1 N KNO$_3$
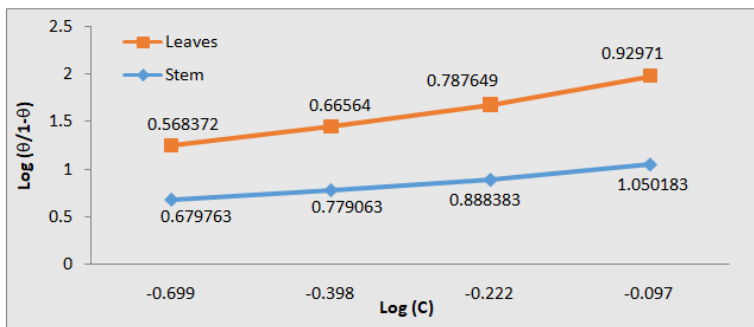

Graph 5(a): Variation of Inhibition Efficiency (η%) for tin in 2N HNO$_3$ with inhibitor concentration of stem and leaves extract.
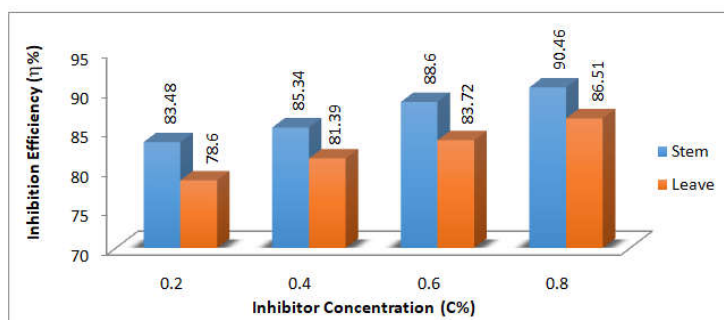
Graph 5(b). Langmuir Adsorption Isotherm for tin in 2N HNO₃

Graph 6(a). Variation of Inhibition Efficiency (η%) for tin in 2N HNO₃ with inhibitor concentration of stem and leaves extract in presence of additive 2 N KNO₃

Graph 6(b). Langmuir Adsorption Isotherm for tin in 2N HNO₃ in presence of additive 2 N KNO₃

Graph 7(a). Variation of Inhibition Efficiency (η%) for tin in 3N HNO₃ with inhibitor concentration of stem and leaves extract.

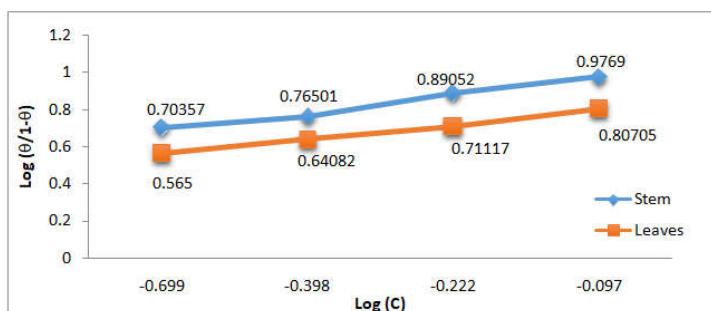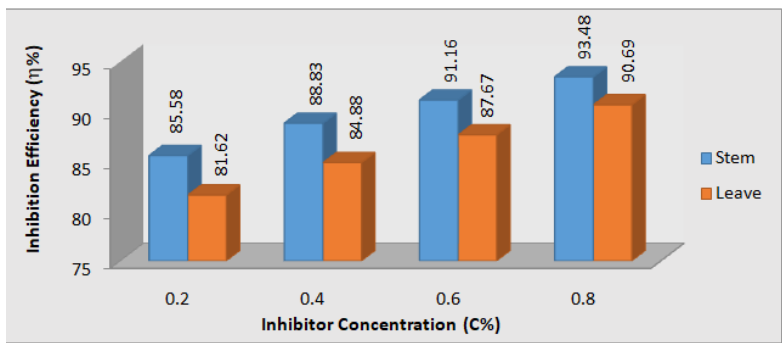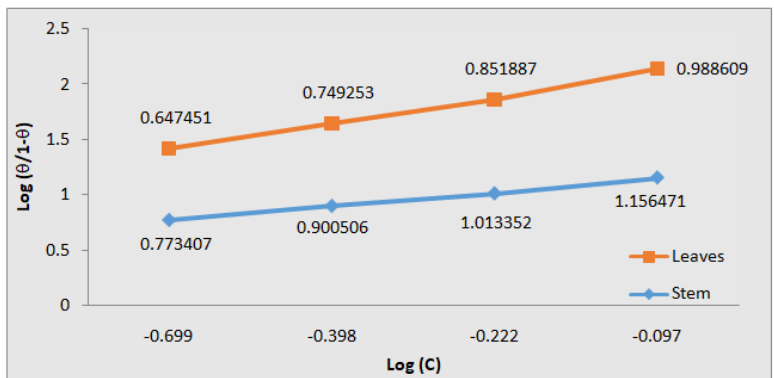**Graph 7(b). Langmuir Adsorption Isotherm for tin in 3N HNO₃**

Graph 8(a). Variation of Inhibition Efficiency (η%) for tin in 3N HNO$_3$ with inhibitor concentration of stem and leaves extract in presence of additive 3N KNO$_3$

Graph 8(b). Langmuir Adsorption Isotherm for tin in 3N HNO$_3$ in presence of additive 3N KNO$_3$

Graphical representations of the correlation between reaction number (RN) and inhibitor concentration are shown in Graphs 9 and 10. Graphs illustrate a linear relationship between reaction number and inhibitor concentration, indicating that reaction number declines as inhibitor concentration increases.

Table 9. Reaction Number (RN) and Inhibition Efficiency (η%) for tin in 1N, 2N and 3N HNO$_3$ with inhibitor of stem and leaves extract

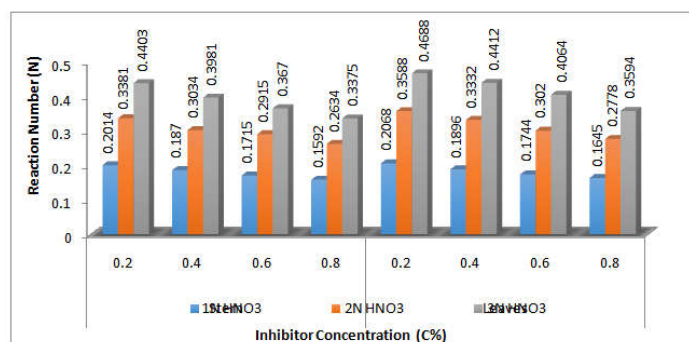| Inhibitor Concentration	3N HNO$_3$		2N HNO$_3$		1N HNO$_3$	
	RN	I.E.(η%)	RN	I.E.(η%)	RN	I.E.(η%)
Stem						
Uninhibited	0.9865		0.6852		0.3685	
0.2	0.4403	55.36	0.3381	50.65	0.2014	45.34
0.4	0.3981	59.64	0.3034	55.72	0.1870	49.25
0.6	0.3670	62.79	0.2915	57.45	0.1715	53.45
0.8	0.3375	66.80	0.2634	61.55	0.1592	56.79
Leaves						
0.2	0.4688	52.47	0.3588	47.53	0.2068	43.88
0.4	0.4412	55.27	0.3332	51.37	0.1896	48.54
0.6	0.4064	58.80	0.3020	55.92	0.1744	52.67
0.8	0.3594	63.56	0.2778	59.45	0.1645	55.35

Temperature: 301°K ± 0.1°K   Area of Specimen: 13 cm^2
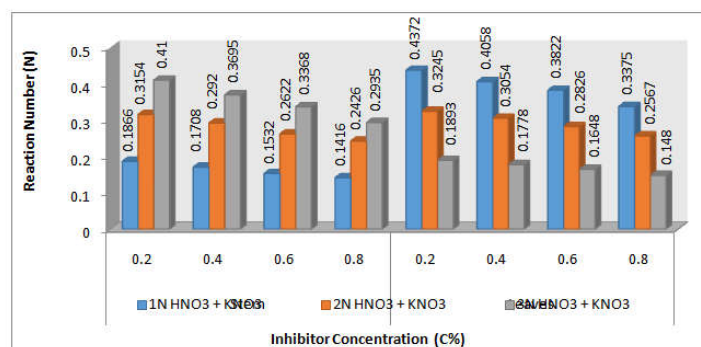
Table 10. Reaction Number (RN) and Inhibition Efficiency (η%) for tin in 1N, 2N and 3N HNO$_3$ with inhibitor of stem and leaves extract in presence of Additive

Inhibitor Concentration	3N (HNO$_3$+KNO$_3$)		2N (HNO$_3$+KNO$_3$)		1N (HNO$_3$+KNO$_3$)	
	RN	I.E.(η%)	RN	I.E.(η%)	RN	I.E.(η%)
Stem						
Uninhibited	0.9865		0.6852		0.3685	
0.2	0.4100	58.43	0.3154	53.96	0.1866	49.36
0.4	0.3695	62.54	0.2920	57.38	0.1708	53.64
0.6	0.3368	65.85	0.2622	61.72	0.1532	58.42
0.8	0.2935	70.24	0.2426	64.59	0.1416	60.57
Leaves						
0.2	0.4372	55.68	0.3245	52.64	0.1893	48.62
0.4	0.4058	58.86	0.3054	55.42	0.1778	51.75
0.6	0.3822	61.25	0.2826	58.75	0.1648	55.27
0.8	0.3375	65.78	0.2567	62.53	0.1480	59.83

Temperature: 301°K ± 0.1°K Area of Specimen: 13 cm^2

Graph 9. Variation of Reaction Number (RN) with Inhibitor Concentration of Stem and Leaves extracts for Tin in 1N, 2N and 3NHNO₃

Graph 10. Variation of Reaction Number (RN) with Inhibitor Concentration of Stem and Leaves extracts for Tin in 1N, 2N and 3N HNO₃ in presence of additive KNO₃

The data given in the above tables demonstrate that as inhibitor concentrations rise, so does their ability to inhibit. The maximal inhibitory efficacy of stem extract in 3N HNO₃ in both the absence and addition of additives (KNO₃) was 90.46% and 93.48% at maximum inhibitor concentrations of 0.8%, respectively. Similar to this, in the absence and addition of additives (KNO₃), the inhibitory effectiveness of leaf extract was 86.51% and 90.69% in 3N HNO₃ at a maximum inhibitor concentration of 0.8%, respectively. According to the findings, stem extract inhibits HNO₃ more potently than leaf extract. With an increase in inhibitor concentration (from 0.2% to 0.8%), surface coverage (θ) rises. When inhibitor concentrations increase, the values of log(θ/1-θ) increase linearly, indicating that the inhibitors follow the Langmuir adsorption isotherm or the chemisorption isotherm. The current investigation discovered that the inhibitors (stem and leaf) were more effective at inhibiting the metal tin in HNO₃ acid solution when an additive (KNO₃) was present than when the inhibitors (stem and leaf) were present alone. Synergistic effects are to blame for this. The combined action of the two chemicals is more potent on a metal surface than the combined actions of the two chemicals acting separately or concurrently. The improved inhibitory effectiveness in the presence of nitrate ions is entirely attributable to the synergism of nitrate ions. Adsorption plays an important role in the inhibition of metallic corrosion by organic inhibitors. The quantity of adsorbed inhibitors on the metal surface can be qualitatively related to the efficiencies of inhibitors, expressed as the relative reduction in corrosion rate. The active sites of the metal surface covered by adsorbed inhibitor species are thought to be where corrosion reactions are prevented from happening, while the inhibitor-free areas of the surface are supposed to be where corrosion reactions take place normally. The inhibition effectiveness is thus directly proportional to the fraction of the surface covered with adsorption inhibitors. According to Hoar and Holliday (42), the Langmuir isotherm,

$$\text{Log } (\theta/(1-\theta)) = \log A + \log C - (Q / 2.303 RT)$$

should result in a straight line with an unit gradient for the plot of log (θ/(1-θ)) against log C, where A is a constant that is independent of temperature, C is the bulk concentration of the inhibitor (percentage), and Q is the heat evolved during adsorption process.

Antifungal Activity of Stem/Leaf extract of *Tinospora Cordifolia*: Studies in the literature have been published and demonstrated that some herbs, shrubs, or plant species may prevent and regulate the growth of fungi that produce mycotoxins. Typically, they produce an abundance of secondary metabolites, including alkaloids, tannins, flavonoids, and phenolic chemicals, which are significant sources of antimicrobials, insecticides, and several pharmaceuticals (43).

The disc diffusion method was used to investigate the in vitro antifungal activity of a *Tinospora Cordifolia* stem and leaf (aerial parts) extract against *Aspergillusniger*. Also, the impact of the ethanol solvent on fungi was studied. The paper disc technique was used to examine the antifungal activity of certain aerial components (stem and leaf) of *Tinospora Cordifolia*, and the inhibition zone for each sample was identified. Higher plant extract (stem or leaf) concentrations were used since the inhibitory zone at low concentrations was too small to measure (44).

Disc diffusion Method & Procedure: The broth of the investigated fungus, Aspergillusniger, was brought from J.L.N. Medical College, Ajmer. The Aspergillusniger fungal strain was freshly cultivated aerobically on PDA slants at 35°C for 48–72 hours (or until it reached full growth). Before being used in vitro in the susceptibility tests for the antifungal activity of Tinospora Cordifolia stem and leaf extract, the fungal spores were collected with a sterile cotton-tipped applicator, suspended in sterile water, and the concentrations were adjusted to 5×10^3 to 2×10^4/ml. The tubidity of the cell suspension was adjusted by spectrophotometry to an optical density of 0.09 to 0.13 for Aspergillus spp. Lighting the UV bulb within the laminar airflow chamber sterilized the space. The autoclave was used to sterilize all the equipment, including PDA petri dishes, test tubes, a spirit lamp, a beaker, a watch glass, forceps, etc.

Additionally, the plant extract and the fungal solution were also autoclaved for 20 minutes at 121°C before analysis. Using Whatsmann filter paper no. 1, paper discs of 6 mm diameter impregnated with stem/leaf extract (0.8%) were prepared. Following the sterilizing procedure, all items were brought into a laminar airflow chamber. Firstly, inoculate the potato dextrose agar (PDA) petri dish with fungus suspension (Aspergillusniger) with the help of a sterilized cotton swab or loop. After making the fungus lawn, paper discs impregnated with plant extracts (stem and leaf) were placed on the surface of the inoculated PDA plate. The plates were incubated at 27 °C for 7 days, and the zone of inhibition was measured. Both plant extracts were shown to have excellent inhibitory activity at 1000 µg/mL during the investigation. According to the findings on zones of inhibition presented in Table 11, stem extract exhibits stronger antifungal activities than leaf extract (45-47). Tinospora Cordifolia extract's wider zones of inhibition of Aspergillusniger may be attributable to the presence of a number of active chemicals. Based on the findings, Tinospora Cordifolia stem and leaf extract exhibited antifungal effectiveness against the Aspergillusniger fungus. This shows that Tinospora Cordifolia has a high potency and contains more of the active ingredients that are responsible for its antifungal properties.

CONCLUSION

Tinospora Cordifolia stem and leaf extracts have been shown to be efficient corrosion inhibitors on metal tin in the absence and presence of additives (KNO$_3$) at varied nitric acid concentrations (HNO$_3$). The inhibitory efficacy of stem and leaf inhibitors improved with increasing inhibitor concentrations from 0.2% to 0.8%, as well as with increasing acid strength from 0.5N to 3N for HNO$_3$. The findings of this study reveal that stem extract is a more efficient corrosion inhibitor in HNO$_3$ than leaf extract. The findings of thermometric and weight reduction techniques are highly correlated. The adsorption mechanism in this phenomenon is dependent on the heterocyclic compounds contained in the inhibitors, which include more electronegative atoms like N, O, and S and possess lone pair electrons. These atoms combine with the metal to form a coordination connection that limits H+ ion release and metal ion dissolution in acidic conditions. As a result, the presence of inhibitors prevents metal corrosion. Interpretations from the zone of inhibition revealed that Tinospora Cordifolia stem and leaf extract has good antifungal efficacy against *Aspergillusniger* (fungus). The zone of inhibition data for stem and leaf extract against *Aspergillusniger* is shown in Table 11. The zones of inhibition against Aspergillusniger in the presence of stem extract were measured to be 17 mm and 14 mm for leaf extract, respectively. The antifungal activity results showed that *Tinospora Cordifolia* stem extract had more potent antifungal properties than leaf extract.

Acknowledgment

Key Points

- Anticorrosive
- Antifungal
- *Tinospora Cordifolia*
- Additive

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