Thunbergia Fragrans extract as green inhibitor for mild steel in acidic medium

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Abstract

The present study focuses on the formulation of a green inhibitor against the corrosion of mild steel in 1 M H_2SO_4. At first, the ethanolic extract of *Thunbergia fragrans* was prepared. Then the inhibitor solution was formulated at different concentrations such as 100, 200, 300, 400, and 500 ppm. The inhibitory effect on the corrosion of the mild steel and the effect of concentration was studied using weight loss measurements at 303 K. The green inhibitor inhibited about 82% of corrosion of mild steel in acid medium. Also, the results indicated that inhibitor concentration and inhibition efficiency are directly proportional to each other. The mechanism of inhibition was analysed through an adsorption isotherm. Langmuir and Temkin adsorption isotherm plots revealed the nature of adsorption behaviour. The data obeyed Langmuir adsorption isotherm as the correlation coefficient value was 0.98. The adsorption process was spontaneous in nature. Furthermore, the thermodynamic behaviour (ΔG_{ads}) confirms that the inhibitor was adsorbed on the steel surface in 1 M H_2SO_4 through physisorption processes. The metal surface protection was also observed under a scanning electron microscope. The results indicated adsorption of inhibitor on the metal surface.

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Introduction

Mild steel is extensively utilized in a variety of industrial settings. Mild steel corrosion is unavoidable in various industrial operations [1–3]. Many techniques are being successfully used to reduce mild steel corrosion. The usage of green inhibitors is one such technique of corrosion prevention. As a result, much study has been focused on developing green inhibitors that have been shown to have significantly better environmental characteristics [4–15]. Green inhibitors have the highest concentration of components responsible for efficient corrosion inhibition, such as alkaloids, carbohydrates, flavonoids, glycosides, phenolic compounds, *etc*. Nitrogen, phosphorus, oxygen, sulphur and selenium are also present in the green inhibitors. The polar function of these molecules creates adsorption reaction sites. Extracts of plants have been demonstrated as corrosion inhibitors for metals during pickling and cleaning operations due to the presence of electronegative atoms and other functional groups. Furthermore, compared to synthetic organic inhibitors, the cost of employing green inhibitors is much lower [15–22]. In this view, the current study focuses on determining the adsorption and inhibition capability of the green inhibitor *Thunbergia fragrans* on mild steel in 1 M H_2SO_4, with the findings presented in the sections below.

Experimental

Thunbergia fragrans was gathered from the Yallagiri Hills in the Vellore area, identified, and verified by the Rapinat Herbarium at St. Joseph's College in Tiruchirappalli, Tamil Nadu, India. The fresh plant was collected and dried for two weeks in the shade before being ground into powder in a blender. For six hours, 200 g of powdered plant material was steeped in 600 mL of ethanol. The extract was then produced by refluxing. The resultant solution was filtered and concentrated on producing the crude extract after it was refluxed. In 1 M H_2SO_4, inhibitor solutions with various concentrations of crude extract (100, 200, 300, 400, and 500 ppm) were produced.

MS coupons were selected with the following specifications: C = 0.07%, Mn = 0.34%, P = 0.08%, and remainder Fe. For the weight loss research, specimens measuring 1.5 cm×4.0 cm×0.28 cm were utilised. Before usage, these MS coupons were mechanically polished with various grades of emery paper, degreased with acetone, rinsed with distilled water, and allowed to dry at room temperature.

Weight loss method

In the presence and absence of inhibitor, pre-weighed MS specimens were submerged for 2 hours in a 100 mL beaker containing 1 M H_2SO_4 solution with five different inhibitor concentrations ranging from 100 ppm to 500 ppm. The weights of specimens were determined after two hours of immersion. The data from this method was used to compute inhibitory efficiency (*IE*%) and surface coverage (θ) using Equations 1 and 2. Adsorption isotherms were also fitted using the surface coverage (θ).

$$IE(\%) = \frac{(W_2 - W_1)}{W_2} \cdot 100 \quad (1)$$

$$\theta = \frac{(W_2 - W_1)}{W_2} \quad (2)$$

where, W_1 and W_2 are the weights of the MS coupons in the presence and absence of inhibitor, respectively [16–21]. Equation 2 is applied based on the assumption of a blocking mechanism of action of the inhibitor.

Adsorption isotherm

Using the corrosion parameter of surface coverage (θ) [22–23], the adsorption behaviour of inhibitor *Thunbergia fragrans* on mild steel in 1 M H_2SO_4 acidic medium was studied using Langmuir and Temkin isotherms plots. Below is the mathematical Equations 3 and 4 for the Langmuir and Temkin isotherms,

$$K = \frac{\theta}{1-\theta} \cdot \frac{1}{C} \tag{3}$$

$$K_{ads} \cdot C = \exp(f\theta) \tag{4}$$

Surface morphology

CARL ZEISS Model EVO18 scanning electron microscope was used for the surface morphological investigations. Mild steel coupons with dimensions of 1×1×0.1 cm were polished to a mirror surface. They were dipped in a blank solution and a 500 ppm inhibitor solution for 2 hours at 303 K. Images were reviewed once the experiment was completed [24].

Results and Discussion

In 1 M H_2SO_4 medium, the corrosion inhibition activity of the ethanolic extract in *Thunbergia fragrans* was investigated using different concentrations of inhibitor. Table 1 depicts the percentage of inhibitory efficiency and surface coverage (θ) and visually in Figure 1. The inhibition effectiveness was improved with increasing inhibitor concentrations, as shown in Table 1 and Figure 1. Furthermore, surface coverage improves. The inclusion of the inhibitor was thought to cause surface changes in the metal, favouring higher adsorption of inhibitor molecules and therefore improved prevention of the mild steel surface corrosion process. It was due to presence of a wide range of phytochemical compounds. The polar function of these molecules creates adsorption reaction sites. This indicates that even at low concentrations, the green inhibitor *Thunbergia fragrans* effectively prevented corrosion. As a result, at 500 ppm concentration, the tested inhibitors had the most significant inhibition effectiveness of about 82.37%.

The free energy of adsorption (ΔG_{ads}) adsorption parameter provides crucial information regarding the interaction between inhibitor compounds and metal surfaces. Figures 2 and 3 show the ΔG_{ads} values derived from Equation 5 utilising Langmuir and Temkin isotherm plots.

$$\Delta G_{ads} = -RT\ln(55.5 \cdot K_{ads}) \tag{5}$$

Table 1. Corrosion parameters obtained from weight loss method.

***C**, (ppm)**	***IE* %**	**θ**
Blank	–	–
100	70.24	0.7024
200	75.97	0.7597
300	77.26	0.7726
400	81.76	0.8176
500	82.37	0.8237

*****Concentration of inhibitor

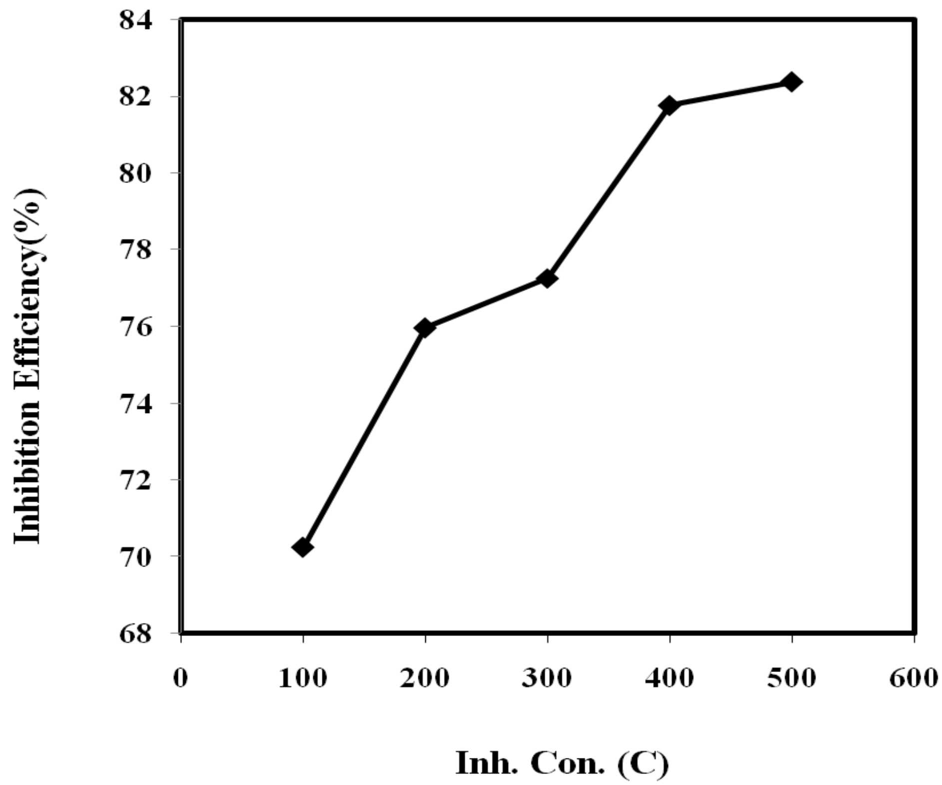

Figure 1. Effect of *Thunbergia fragrans* on mild steel in 1 M H_2SO_4.

Table 2. Adsorption parameters obtained from isotherm plots.

Isotherms	R^2	**Slope**	$-\Delta G_{ads}$, **(kJ·mol^{-1})**
Langmuir	0.998	1.155	–18.81
Temkin	0.969	0.175	–10.27

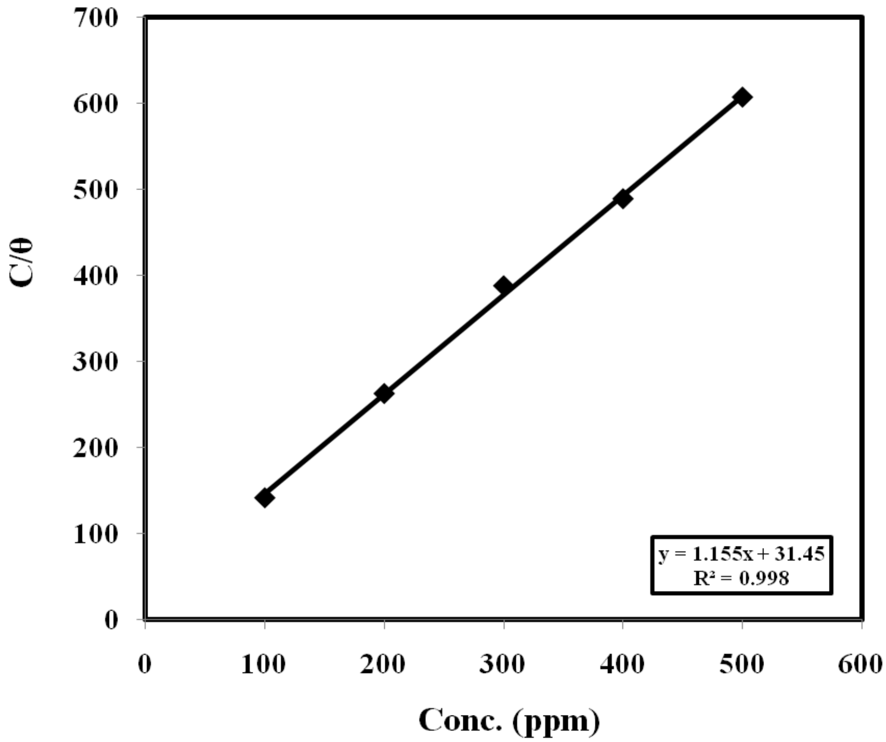

Figure 2. Langmuir adsorption of *Thunbergia fragrans* on mild steel in 1 M H_2SO_4.

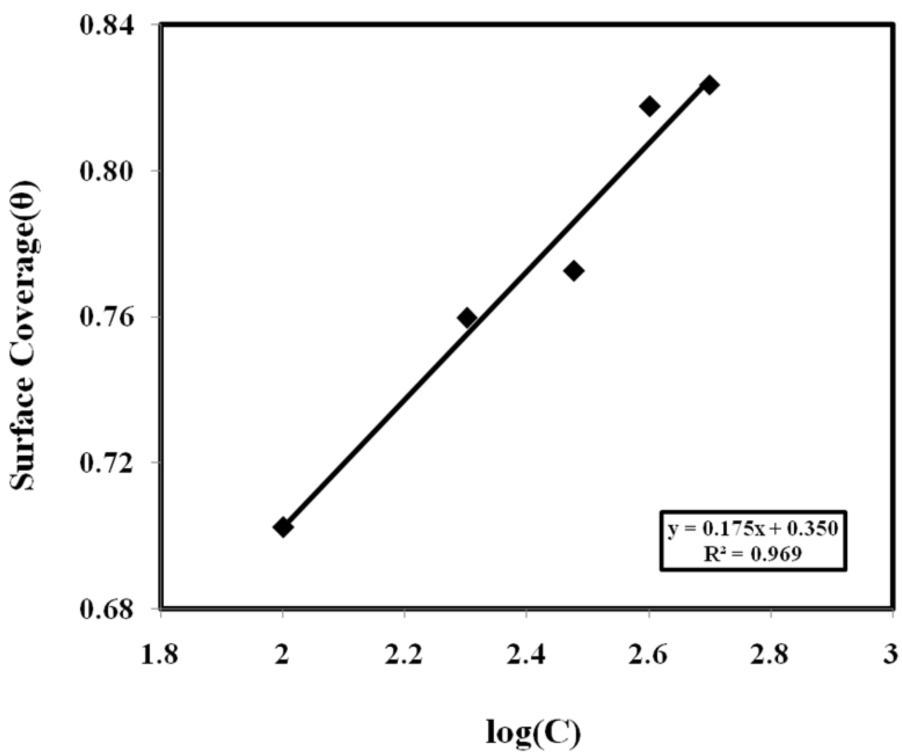

Figure 3. Temkin adsorption of *Thunbergia fragrans* on mild steel in 1 M H_2SO_4.

The Langmuir plot yielded a straight line, whereas the Temkin plot yielded a slightly deviated line. As a result, the correlation coefficient (R^2) values for Langmuir and Temkin isotherms are 0.998 and 0.969, respectively. Langmuir and Temkin's ΔG_{ads} values were also –18.81 and –10.27 kJ·mol^{-1}, respectively. The adsorption was determined to be of the physisorption type [25–27]. The adsorption of the inhibitors *Thunbergia fragrans* on the mild steel surface was a spontaneous process, as evidenced by the negative values of free energy of adsorption ΔG_{ads} [28]. The strong contact between inhibitor molecules and the metal surface was to blame. This adds to the evidence that excellent anticorrosion action is due to the adsorption of inhibitor compounds from the plant extract.

Figure 4 shows SEM images of polished MS coupons with and without inhibitors in 1 M H_2SO_4 for corrosive medium. Because of the strong attack by the corrosive medium in 1 M H_2SO_4 (Figure 4b), it is evident that the mild steel surface was severely damaged. The addition of an inhibitor successfully shields the surface, limiting the amount of damage (Figure 4c). This indicated that inhibitor molecules formed an adsorption layer that inhibited the active site on the metal corrosion. These findings show that a *Thunbergia fragrans* extract significantly reduced mild steel corrosion in 1 M H_2SO_4 acidic solution.

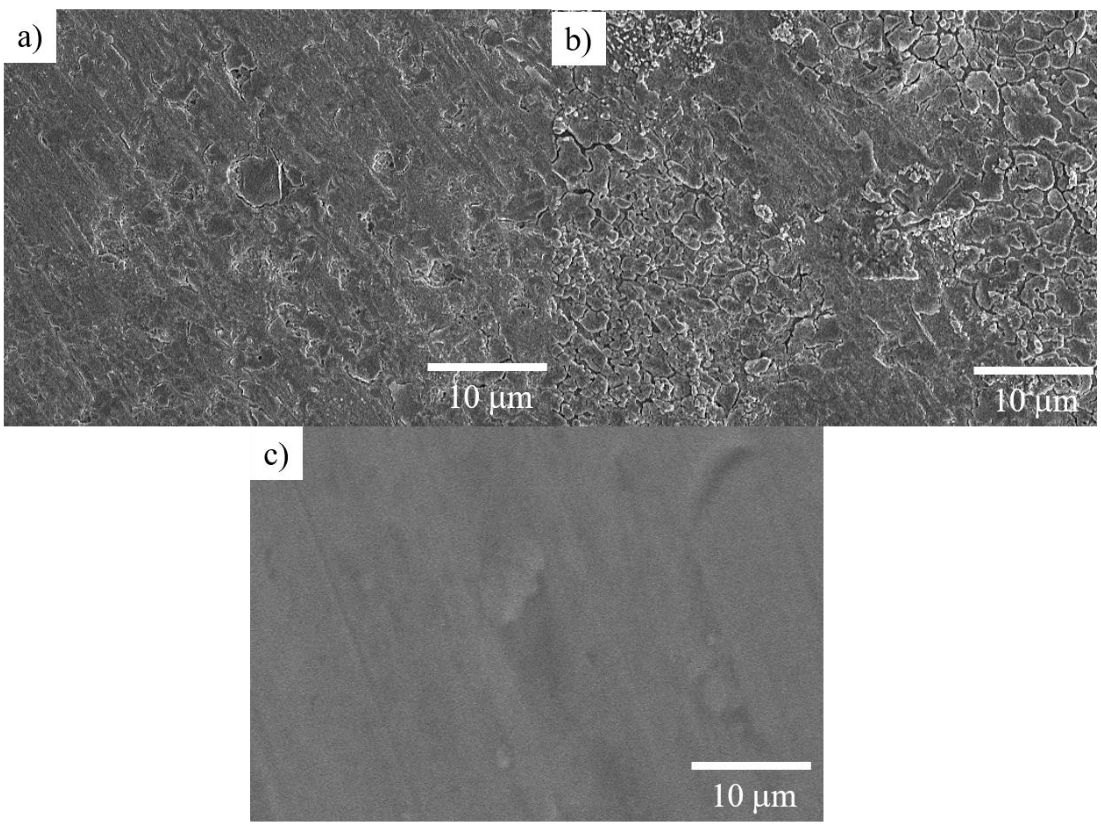

Figure 4. SEM image of (a) mild steel, (b) mild steel in 1 M H_2SO_4, and (c) mild steel treated with inhibitor.

Conclusions

Thunbergia fragrans adsorption and inhibition potential on mild steel in 1 M H_2SO_4 revealed considerable corrosion inhibition activity. The inhibition effectiveness improves with increasing concentration in this research, and the optimal inhibitor concentration was determined to be 500 ppm utilising the weight loss technique. The adsorptions of *Thunbergia fragrans* extract on mild steel followed the Langmuir and Temkin isotherms. The negative sign of the thermodynamic parameter, free energy of adsorption (ΔG_{ads}), revealed that the inhibitors' adsorption on mild steel surfaces was spontaneous. The magnitude of ΔG_{ads} values also suggests that the inhibitors were adsorbed on the mild steel surface in 1 M H_2SO_4 *via* physisorption processes. This adds to the evidence that excellent anticorrosion action is due to the adsorption of inhibitor compounds from the plant extract.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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