

Eco-Friendly Natural Corrosion Inhibitors of *Asparagus racemosus* for Mild Steel in 8% H₂SO₄

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Research Article

Received date: 16/03/2017

Accepted date: 04/03/2017

Published date: 08/03/2017

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Keywords: *Asparagus racemosus*, Mild steel, Weight loss, SEM, Polarization measurement

ABSTRACT

By means of polarization measurements UV, IR, and weight loss study, it has been detected that the extract of *Asparagus racemosus* leaves can act as corrosion inhibitor for the sake of mild steel in 8% H₂SO₄ solution. These plants show good inhibition efficiency at particular concentrations of the acid. It is observed that plants extract act as better inhibitor on increasing their concentration. Here we have focused on the corrosion inhibition action of different plant extracts in H₂SO₄ medium.

INTRODUCTION

From last few decades, corrosion inhibitor has been a colorable field of research. Acids are being used widely in the field of mild steel machinery in industries for different applications for e.g. cleaning, descaling, pickling etc.^[1]. To prevent the corrosion of mild steel by using plant extracts is one of the most enterprising methods. Several organic inhibitors are dynamically used to prevent corrosion and it is the most provident method. The inhibition action of organic inhibitors relies on their adsorption capability on metal by replacing water molecules^[2]. Organic compounds also show corrosion inhibition efficiency and there are several organic compounds which are notified to prevent corrosion^[3-7]. But the problem with them is that they are extremely poisonous to both humanitarian as well as surroundings. Because of the poisonous effects of these organic inhibitors, natural nontoxic inhibitors are the requirement of our environment^[1]. Compounds which contain oxygen and nitrogen inhibit the corrosion of mild steel most effectually^[8]. In green inhibitors, secondary metabolize O and N are usually present and they are the active centers for adsorption^[9,10]. The adsorption of green inhibitors on the steel surface can be either in the form of physisorption or chemisorptions or it may also be as a combined effect of both^[11]. Therefore, to overcome the toxic effect of commercial inhibitors, the development of natural nontoxic inhibitors to prevent the metallic corrosion is necessary and seductive^[12]. Extract of naturalistic products contain many compounds which are biodegradable in nature. Here we have used the extracts of *Asparagus racemosus* with H₂SO₄ which play an effective role to prevent corrosion of mild steel. The extract of *Asparagus racemosus* consists of Saponins alkaloid (**Figure 1**). The inhibition effect of this plant extract on the corrosion rate of mild steel in 8% H₂SO₄ was studied by using weight loss study, IR, UV and polarization measurements.

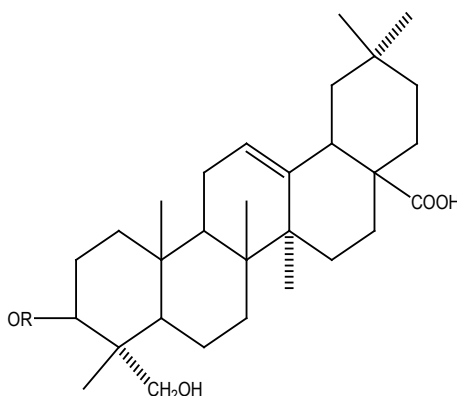


Figure 1. Saponins: Chemical constituent of *Asparagus racemosus*.

EXPERIMENTAL

Preparation of Plant Extract

The very first, we collected the plants mentioned above for our study, then dried and powdered. The powder was soaked into 500 ml deionized water and then refluxed for 5 h. In this manner, we obtained the aqueous solution which was then filtered and concentrated to 100 ml with the help of soxhlet apparatus. Then we prepared the solutions of particular concentrations with the help of this concentrated solution.

4.2. Weight Loss Measurements

With the help of weight loss study, we measured the loss in weight of mild steel strips when they were placed in saturated solution of H_2SO_4 with extract. For this purpose, we took rectangular pieces of mild steel which composed of (wt %) Fe 97.60%, C 0.083%, Si 0.39%, Mn 0.43%, P 0.12%, Cr 0.45%, Ni 0.27% and Cu 0.43% [13]. These strips were then squeezed with fine grade emery paper (120, 600, 800, and 1000), washed with distilled water and dried. Then the mild steel strips were weighted accurately before inserting them into the saturated solution of H_2SO_4 with extract. The mild steel strips were then dipped into H_2SO_4 without extract and saturated with varied concentrations of extract. Then we left the set up for 5 hours and after the elapsed time, the mild steel strips were excluded, cleansed, drained and weighed. A difference in weight was noted between the mild steel strips dipped in H_2SO_4 solution without extract and with varied concentrations of extract. Here we have used 8% H_2SO_4 in the experiment. All the concentrations of inhibitors for weight loss are taken in mgL^{-1} by weight. The inhibition efficiency and surface coverage (θ) can be determined by using following equation:

$$\theta = \frac{w_0 - w_i}{w_0} \quad (1)$$

$$\eta(\%) = \frac{w_0 - w_i}{w_0} \times 100 \quad (2)$$

Where, w_i and w_0 are the weight loss values in presence and absence of inhibitor, respectively.

Electrochemical Measurements

Electrochemical studies were conducted by using a Gamry interface Potentiostat/Galvanostat/ZRA0300. All techniques were useful. Polarization with Potentiostat measures current while on the other hand polarization with Galvanostat measures potential. The corrosion cell consists of three electrodes. We used saturated calomel electrode in the form of reference electrode, a platinum foil in the form of counter electrode and mild steel was used in the form of a working electrode. Here, we immersed the working electrode in the test solution and stabilized it for 30 minutes. With the help of such studies, we obtained Tafel polarization curves which helped us to get information about corrosion inhibition of mild steel. These slopes provided us the value of corrosion current densities (I_{corr}), we used this value in the following formula and found the inhibition efficiency.

$$\eta(\%) = \frac{I_{0corr} - I_{icorr}}{I_{0corr}} \times 100 \quad (3)$$

Where I_{icorr} and I_{0corr} represent the corrosion current density values without and with inhibitor, respectively.

UV-Visible Spectroscopy

We subjected the 8% H_2SO_4 solution saturated with extract before and after dipping the mild steel strips to UV-Visible spectrophotometer. We obtained the UV-visible absorption spectra for various concentrations of extracts before and after dipping the mild steel strips. The spectra of extract before dipping the mild steel strip showed some smaller peaks which were not found in the spectra of extract after dipping the mild steel strip. It means that when we dip mild steel strip in the extract, some molecules get adsorbed on the mild steel surface. They form a protective film on the surface and prevent the corrosion of mild steel.

IR Spectroscopy

The IR spectroscopy tells us about different types of functional groups, heteroatoms present in the extract.

Surface Analysis

The SEM micrographs of mild steel samples were immersed in 8% H_2SO_4 solution for 3 h in the absence and presence of extract. A rough surface can be seen for the mild steel immersed in H_2SO_4 without inhibitor which indicates the corrosion on mild steel surface in acidic medium. In the presence of inhibitor, a smooth surface can be observed, which indicates that inhibitor covers the mild steel surface.

RESULTS AND DISCUSSION

IR Study

IR study tells about the functional groups present in the extract. From the IR spectra of *Asparagus racemosus*, the peak at 3454 cm^{-1} suggests O-H stretching of alcohol, the peak at 1639 cm^{-1} suggests C=O stretching of amide. Further peak at 1057 cm^{-1} suggests C-O stretching of alcohol. The IR spectra of *Asparagus racemosus* are shown in **Figure 2**.

UV-Visible Spectroscopy

The UV spectra of *Asparagus racemosus* extract saturated with 8% H_2SO_4 before and after dipping the mild steel strips are shown in the **Figures 3 and 4**.

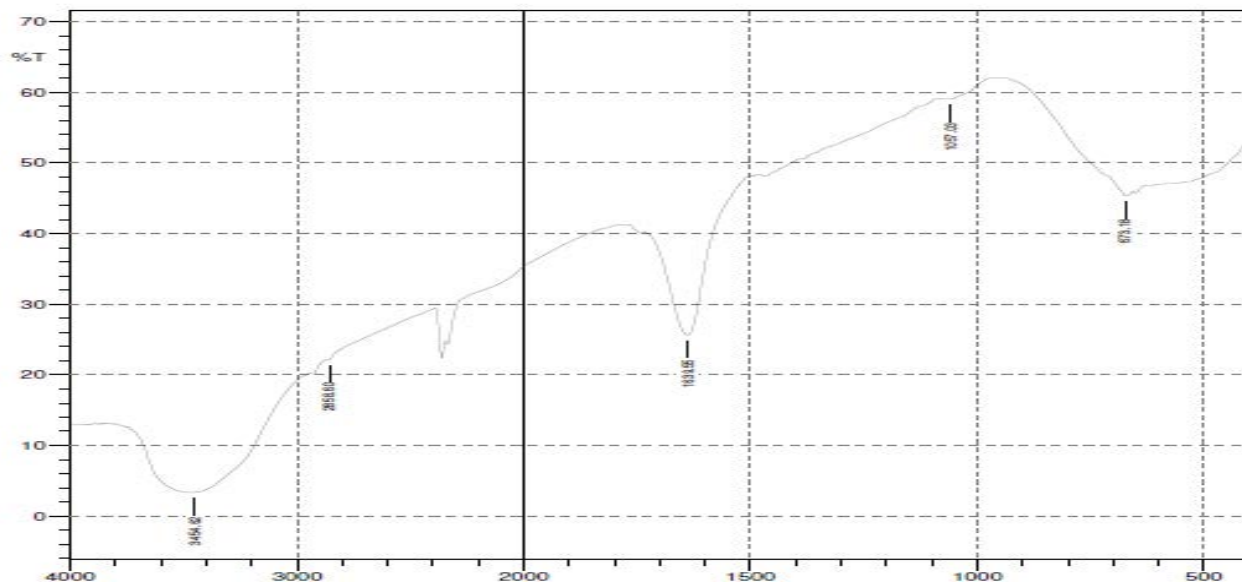


Figure 2. IR spectra of *Asparagus racemosus*.

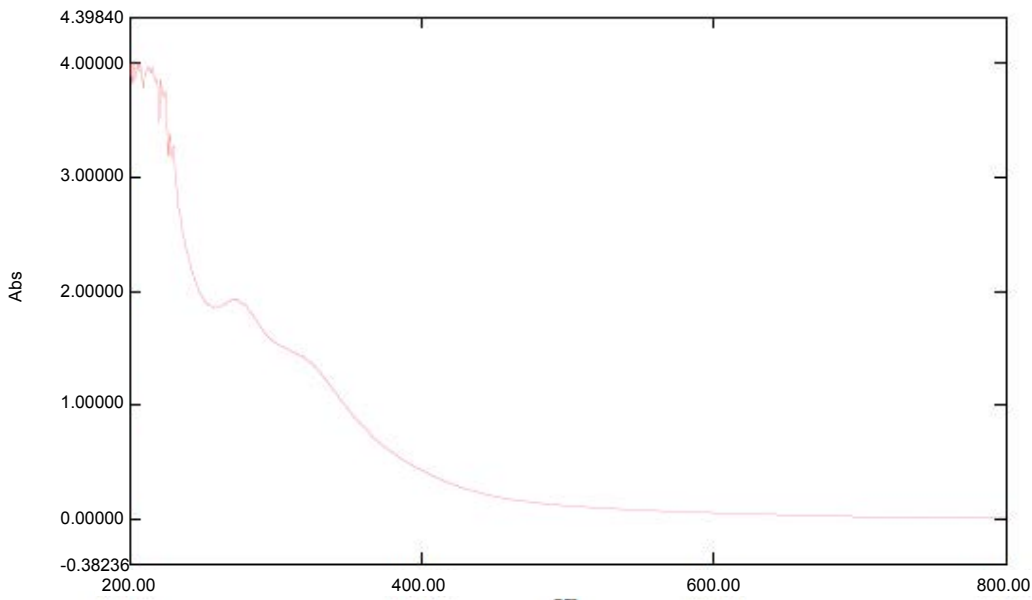


Figure 3. UV spectra of *Asparagus racemosus* extract before immersion of mild steel strip.

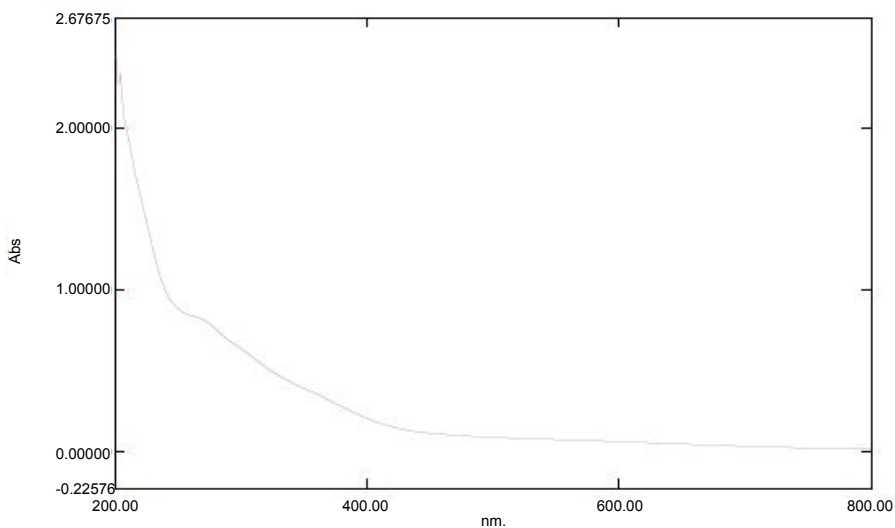


Figure 4. UV spectra of *Asparagus racemosus* extract after immersion of mild steel strip.

Weight Loss Study

For mild steel, the weight loss results in the absence and presence of different concentration of *Asparagus racemosus* extract saturated with H₂SO₄ are summarized in **Table 1**. The **Table 1** clearly indicates that when concentrations of the *Murraya koenigii* extract increases, the inhibition efficiency also enhances. The *Asparagus racemosus* extract gives maximum inhibition efficiency of 77% at 300 ppm. *Asparagus racemosus* consist of heteroatoms (O, N) which form the metal complex bond with the metal surface thereby reducing corrosion.

Polarization Measurements

Weight loss study was verified by polarization measurement. The polarization measurement for *Asparagus racemosus* provided the values of corrosion current density (I_{0corr}) which has been shown in **Table 2**.

We used these values in the following formula and will find inhibition efficiency.

$$\eta(\%) = \frac{I_{0corr} - I_{icorr}}{I_{0corr}} \times 100 \tag{4}$$

Where I_{icorr} and I_{0corr} represents the corrosion current density values without and with inhibitor, respectively. **Figures 5** and **6** represent the polarization curves of mild steel in 8% H₂SO₄ without and with various concentrations of *Asparagus racemosus* extract respectively.

Surface Analysis

The **Figure 7** shows the SEM micrographs of mild steel strips immersed in 8% H₂SO₄ without and with *Asparagus racemosus* inhibitor respectively.

Table 1. Corrosion parameters for mild steel in 8% H₂SO₄ without and with various concentrations of *Asparagus racemosus*.

Acid solution	Inhibitor concentration (mgL ⁻¹)	Weight loss (mgcm ⁻²)	η (%)	θ
8% H ₂ SO ₄	0	36.06	0	0
	60	11.23	68.87	0.6887
	90	9.87	72.63	0.7263
	120	9.23	74.4	0.744
	180	8.85	75.45	0.7545
	240	8.42	76.65	0.7665
	300	8.14	77.43	0.7743

Table 2. Potentiodynamic polarization parameters for the corrosion of mild steel in 8% H₂SO₄ without and with different concentrations of extract.

Con.(ppm)	E _{corr} (V)	I _{corr} (A)	Beta _a (V/decade)	Beta _b (V/decade)	CR (mpy)	E%
0	-0.44	0.0355	0.2742	0.7565	20687	-
30	-0.42	0.0159	0.1469	0.3335	9237	55
90	-0.42	0.0095	0.1202	0.2987	5545	73
180	-0.42	0.0084	0.1216	0.2936	4916	76
300	-0.42	0.0079	0.1092	0.2647	4585	78

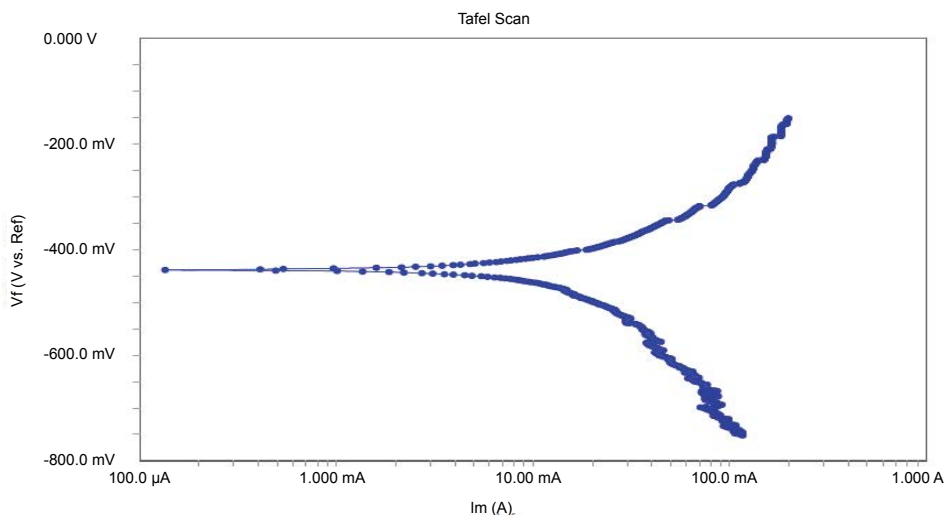


Figure 5. Tafel polarization curves for mild steel in 8% H₂SO₄ without *Asparagus racemosus* extract.

MECHANISM OF ACTION

In the present study, the plant extracts which we used to determine the corrosion inhibition action of plant extracts for mild steel, contain alkaloids. These alkaloids are rich in heteroatoms like N, O. From the IR study of plant extracts, it has been shown that they contain functional groups like hydroxyl group, amide group, carbonyl group etc. Hence, the IR study also verifies the presence of heteroatoms N, O in the extract. These heteroatoms donate their lone pair of electron to the empty d-orbital of Fe. Similarly, there is also the interaction between the π electrons of C=O and empty d-orbital of Fe. In such a way, the inhibitor gets adsorbed on the mild steel surface and forms a protective thin film by the combination of inhibitor and mild steel surface. This protective film prevents the corrosion of mild steel (Figure 8).

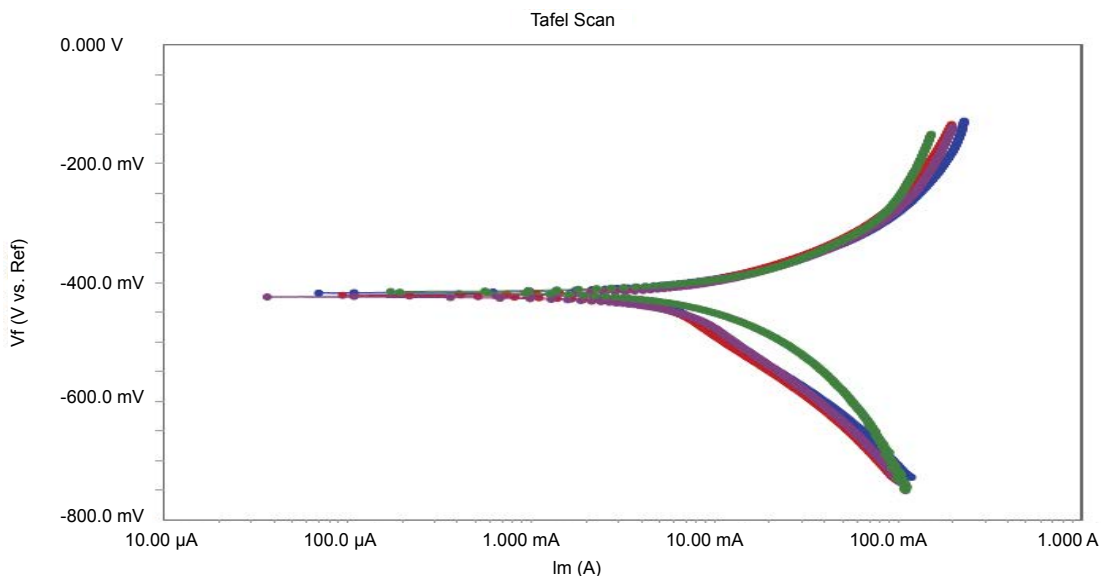


Figure 6. Tafel polarization curves for mild steel in 8% H₂SO₄ with various concentrations of *Asparagus racemosus* extract.

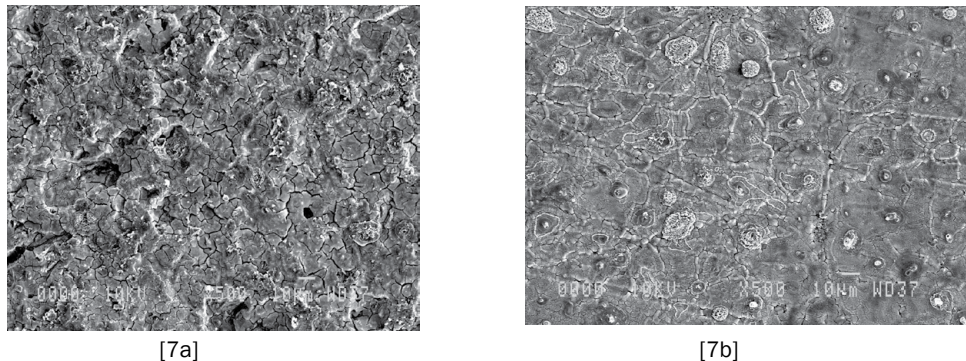


Figure 7. SEM images of mild steel in 8% H₂SO₄ without [a] and with *Asparagus racemosus* and inhibitor [b].

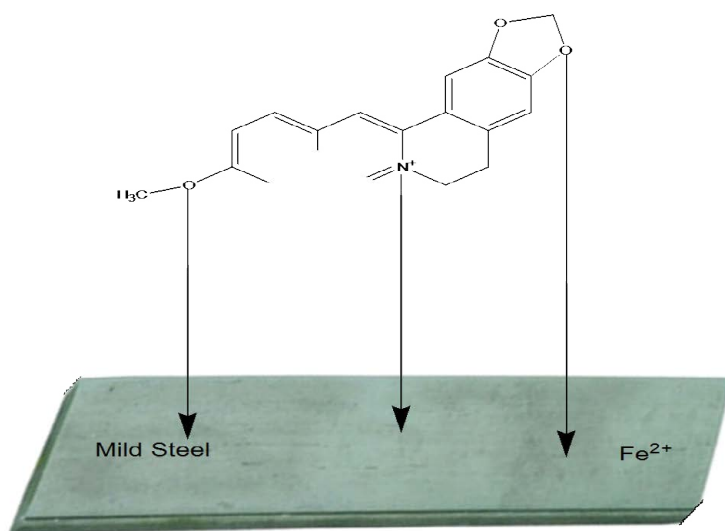


Figure 8. Mechanism of action.

CONCLUSION

In the present study, we have used the plant extracts of *Asparagus racemosus*, *Tinospora Cardifolia* and *Voila odorata*. We have determined the corrosion inhibition rate of plant extracts for mild steel in 8% H₂SO₄. The examined plant extract prevent the corrosion of mild steel in 8% H₂SO₄ by adsorbing on the mild steel surface. Enhancement of inhibition efficiency was observed on account of the concentration of inhibitors. We observed 78% inhibition efficiency for *Asparagus racemosus* extract at 300 ppm inhibitor concentration, 88% inhibition efficiency for the plant extract of *Voila odorata* at 300 ppm inhibitor concentration and 89% for *Tinospora Cardifolia* at 120 ppm inhibitor concentration with 8% H₂SO₄. Therefore, it is clear that *Tinospora Cardifolia* extract shows maximum inhibition efficiency of 89% with 120 ppm inhibitor concentration and 8% H₂SO₄, hence it can be a better corrosion inhibitor. Present study may be useful for all those areas where mild steel meets acidic medium or wherever mild steel corrosion occurs.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge Dr. R. Jayaganthan, Department of Metallurgical and Materials Engineering, IIT Roorkee, Uttarakhand, India for provide lab facility for our study.

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