
SPATHODEA CAMPANULATA LEAF AS A GREEN CORROSION INHIBITOR FOR MILD STEEL IN H₂SO₄ SOLUTION

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Abstract: The corrosion inhibition behavior of *Spathodea Campanulata* (SC) leaves on mild steel in 1N H₂SO₄ medium was investigated by gravimetric, polarization, electrochemical impedance measurements and temperature studies. Effect of temperature (35-75°C) on the corrosion behavior of mild steel in the presence of plant extract was studied. The surface adsorbed film was analyzed by scanning electron microscope technology (SEM). The inhibition efficiency of SC showed an improvement with increasing concentration of the extract. The results obtained prove that the leaves of *Spathodea Campanulata* act as a good corrosion inhibitor having efficiency of 75% at 1.5% inhibitor concentration.

Keywords Corrosion, H₂SO₄ medium, mild steel, *Spathodea Campanulata*

Introduction: Mild steel finds a lot of application in industries like metal finishing, boiler scale removal, pickling baths etc. It gets rusted when it comes in contact with any acid. Corrosion inhibitors are used to prevent the effect of corrosion in such cases. Chromates, phosphates, molybdates etc. and a variety of organic compounds containing heteroatoms like nitrogen, sulphur and oxygen have been investigated as corrosion inhibitors [1-6]. Current research trend is towards the development of nontoxic, economical and more environmentally safe green chemicals as corrosion inhibitors [7-11]. Plant extracts are mostly preferred because they are cheap, easily available, non-toxic and renewable. They are also eco friendly. Several leaf extracts have been studied as corrosion inhibitors. Extracts of natural products like *Murraya koenigii*, *Nypa fruticans wurmb*, *Emblia officinalis*, *Phyllanthus amarus*, *Michelia champaca*, *khillah seeds*, *Ficus carica*, *piper guinensis*, *fenugreek seeds and leaves*, *Nyctanthes arbortristis*, *Caffeic acid*, etc. [12-22] have been reported to act as good corrosion inhibitors for mild steel in acid medium.

Experimental: Mild steel coupons were mechanically polished with emery sheet of fine quality, washed with double distilled water, degreased with alcohol and finally dried at room temperature before being immersed in the acid solution. Weight loss experiments were performed using an electronic balance. For polarization studies mild steel coupons with 1 cm² exposed area were used as the working electrode. A 5% stock solution of *Spathodea Campanulata* inhibitor was prepared and taken as the stock solution. From this different concentration of inhibitor solutions ranging from 0.1% to 1.5% were diluted. The initial weight of the specimen was recorded using an analytical balance. After the corrosion test in 1N H₂SO₄ with and without the inhibitor in different concentration (0.1% to

1.5%), the specimens were carefully washed in double distilled water, dried and then weighed. The weight loss was determined after different immersion periods (1 hr, 3 hr, 5 hr, 7 hr, 12 hr and 24 hr) at 303 K. The weight loss experiments were conducted at different temperatures (308, 318, 328, 338 and 348 K). A conventional three electrode glass cell consisting of a working electrode (mild steel sample), a pure platinum counter electrode and a saturated calomel reference electrode was used for the measurements. The AC impedance measurements are shown as Nyquist plots and polarization data as Tafel plots. The surface morphology of the mild steel specimen was evaluated by SEM analysis.

Results and Discussion: Based on weight loss measurements, the values of % IE for various concentrations of SC at different temperatures are given in Table I. From the values in Table 1 it is clear that the % IE increases with the increase of concentration reaching a maximum value of 75% at an inhibitor concentration of 1.5% at 308 K. The graph in Fig.1 depicts that as the temperature increases the inhibition efficiency decreases. At elevated temperature as time lag between adsorption and desorption of inhibitor over metal surface becomes shorter the IE decreases. Metal surface remaining exposed to acid environment for a longer period increases the rate of corrosion and thus decreases the inhibition efficiency.

Corrosion rate (CR) of mild steel in the absence and presence of SC extract was calculated and the data obtained for different immersion timings is shown in Table II. The result obtained shows that the rate of corrosion of mild steel decreases with increase in the concentration of SC extract but increases with increase in temperature. This confirms the inhibitive action of the extract in H₂SO₄ medium.

Table I
% IE of SC in H₂SO₄ at different concentrations and different temperatures

T in K	%IE							
	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5
308	32.63	42.37	49.47	52.89	59.74	63.42	69.74	75.26
318	31.59	40.43	48.94	50.74	57.12	61.05	67.92	74.14
328	30.26	39.65	47.86	49.21	56.36	59.47	66.80	73.26
338	28.63	37.83	45.84	47.78	54.97	57.39	64.85	71.07
348	26.47	35.15	43.47	45.83	52.99	55.87	62.26	69.09

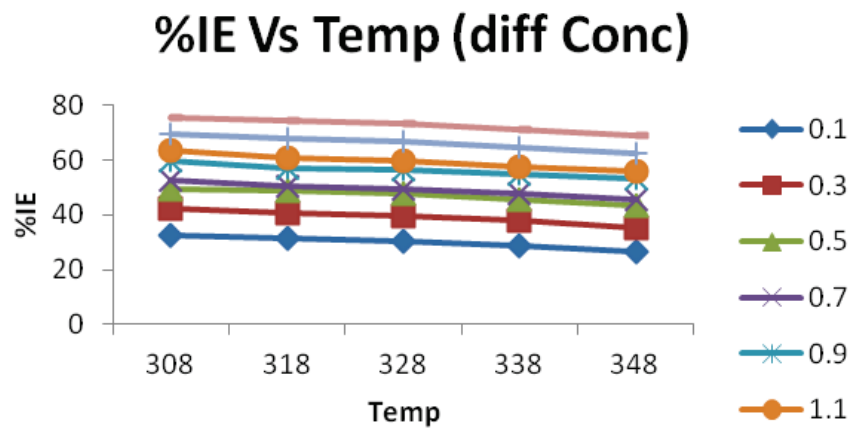


Fig. 1: Plot of % IE Vs Temp at different concentrations

Table II
CR of SC in H₂SO₄ at different concentrations and different immersion periods

Ext Conc. (%v/v)	CR					
	1 hr	2 hr	5 hr	7 hr	12 hr	24 hr
Blank	859.1072	728.277	831.1971	487.8012	890.7179	843.407
0.1	619.2549	505.869	552.0963	316.4789	532.3957	447.0066
0.3	597.4502	486.2448	520.6974	272.2466	480.0646	438.1028
0.5	514.5921	409.9284	416.0346	234.2442	427.3702	379.2288
0.7	427.3731	324.89	349.7482	193.7499	310.3521	283.6493
0.9	379.4027	307.4463	318.3494	169.4533	272.1941	241.4926
1.1	318.3494	235.4908	242.4688	130.8279	214.7753	200.2444
1.3	281.2813	213.6861	232.0025	119.6141	193.3341	173.3513
1.5	257.2961	191.8814	202.3481	111.5152	174.8002	145.5497

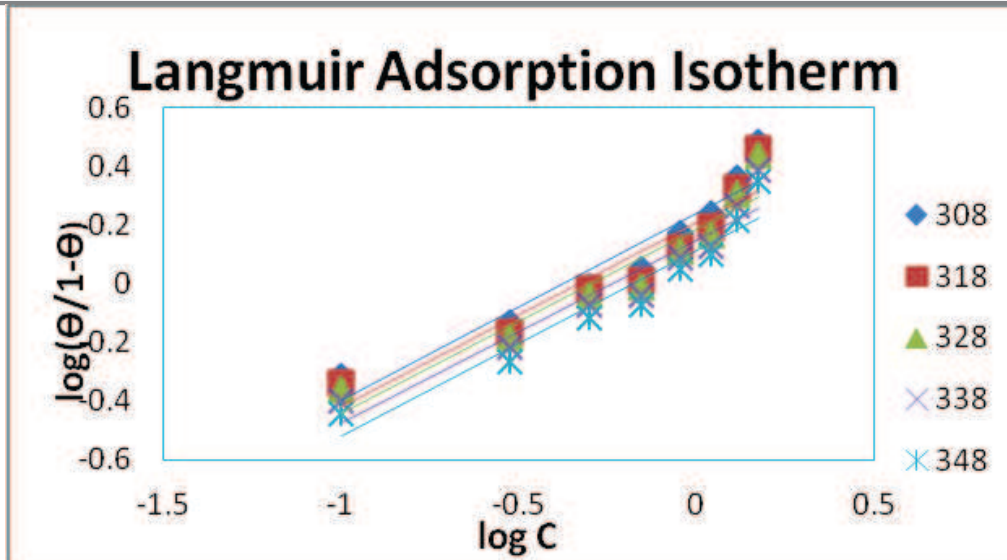


Fig.2 Langmuir isotherm of SC in H₂SO₄

The interaction between inhibitor and mild steel surface can be understood from the adsorption isotherms. The values of surface coverage (θ) were evaluated using CR values obtained from the weight loss method. The θ values for different concentration of inhibitors from the acid were tested graphically by fitting to various isotherms. It was observed that the data fitted the Langmuir adsorption isotherms with correlation coefficients >0.9 . The plots of $\log(\theta / 1 - \theta)$ vs. $\log C$ yielded a straight line as shown in Fig.2, where C is the inhibitor concentration, proving that the inhibition is due to the adsorption of the active compounds onto the metal surface and obeys the Langmuir isotherm.

The Potentiodynamic polarization data are shown as the Tafel plots for mild steel in 1N H₂SO₄ with the

addition of various concentrations of the inhibitor in Fig.3. The corrosion kinetic parameters such as corrosion potential (E_{corr}), corrosion current density (I_{corr}), anodic and cathodic Tafel slopes (b_a and b_c) were derived from these curves and are given in Table III. The values given in the Table III shows that corrosion current (I_{corr}) decreases markedly in the presence of extract, which confirms the inhibitive action of SC extract in H₂SO₄ medium. The anodic and cathodic Tafel slopes b_a and b_c are changed markedly in the presence of the extract, which confirms that the extract contained the active molecules which behaved as mixed-type of acid corrosion inhibitors. The inhibitive properties of the extract have also been evaluated by the determination of the polarization resistance R_p .

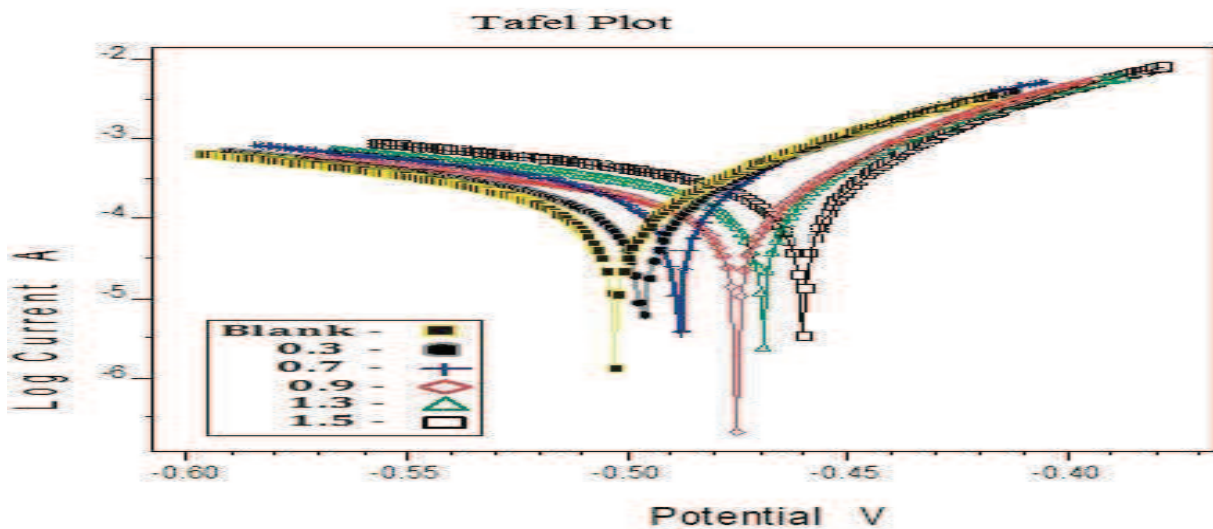


Fig. 3: Potentiodynamic polarization of mild steel in 1N H₂SO₄ with and without SC extract

Table III
Potentiodynamic Polarization and Impedance parameter for Mild Steel In 1N H₂SO₄ in presence of SC Extract.

Conc	E _{corr} V	I _{corr} μAmp/cm ²	b _a 1/v	b _c 1/v	R _p Ohm/cm ²	% IE		C _{dl} μ farads	R _{ct} ohms	Inhibitor Efficiency Linear
						Tafel	Linear			
Blank	-0.46	0.30	50	154	69.13	—	—	36.6	25.28	-----
0.3	-0.48	0.27	54	152	81.81	11.14	15.49	35.4	51.33	50.75
0.7	-0.47	0.26	52	162	83.10	14.42	16.81	33.0	57.49	56.02
0.9	-0.47	0.19	47	149	108.20	36.39	36.10	32.0	66.52	61.99
1.3	-0.49	0.18	55	138	111.70	39.67	38.11	28.0	75.30	66.42
1.5	-0.50	0.17	56	133	122.90	41.96	43.75	26.0	99.37	74.55

The linear polarization values R_p in the absence and presence of different concentrations of inhibitor are given in the Table III. From the results, R_p values gradually increased with increase in the concentration of inhibitor confirming that the extracts of SC acted as a good corrosion inhibitor.

The corrosion behavior of mild steel in 1N H₂SO₄ in the absence and presence of different concentrations of SC extract were also investigated by Electrochemical Impedance Spectroscopy (EIS) technique. The resultant Nyquist plots are shown in Fig.4. The existence of single semicircle in each plot shows that there was only single charge transfer process during the anodic dissolution of MS. There was a gradual increase in the diameter of each semicircle of the Nyquist plot due to increase in the

number of inhibitive molecules in the extract when the concentration was raised from 0.3 to 1.5 % v/v. From the values obtained in Table III the R_{ct} values increased with the increasing concentration of the inhibitor indicating that more inhibitor molecule adsorb on the metal surface at higher concentration and form a protective film on the metal-solution interface [23-24]. The values of C_{dl} decreased with increasing inhibitor concentration. Decrease of C_{dl} indicates a reduction in local dielectric constant by increase in thickness of the electrical double layer. Thus the results obtained indicate that the extract of SC function by adsorption on the metal surface causing a decrease in the C_{dl} values and an increase in the R_{ct} values.

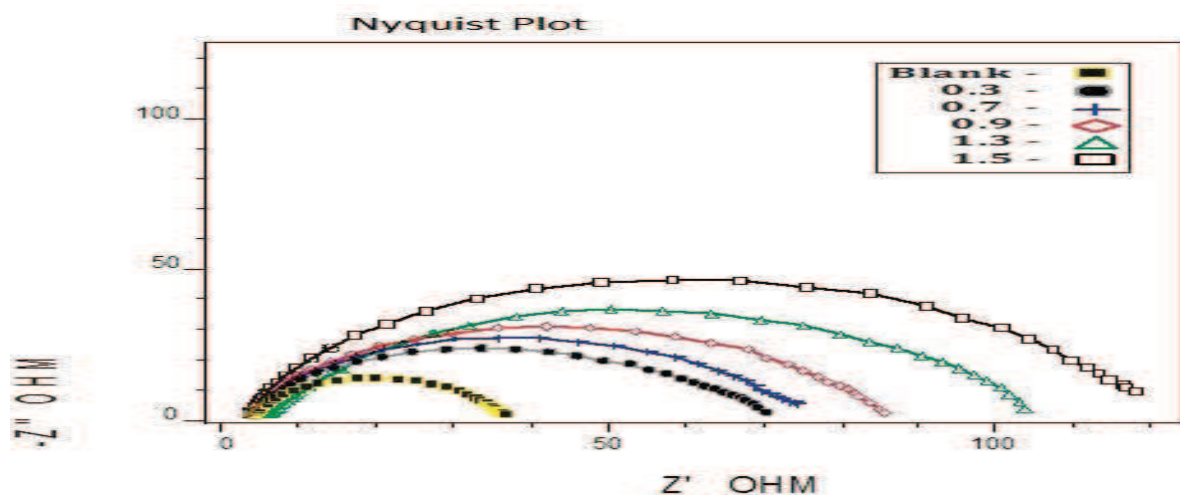


Fig.4: Nyquist plots showing inhibitive effect of SC extract on corrosion of mild steel in 1N H₂SO₄.

The SEM micrographs of different slides of mild steel after immersion in the aqueous solution with the absence and presence of the inhibitor are shown in Fig.5 and Fig.6. The SEM images in Fig.5 shows that the surface of mild steel was extremely damaged in the absence of the extract while Fig.6 shows the formation of a film by the constituents present in leaf

extract of *Spathodea Campanulata* (SC) on the mild steel surface which was responsible for corrosion inhibition.

Conclusion: The molecules present in the extract of *Spathodea Campanulata* leaves effectively inhibited the corrosion of mild by forming a protective barrier layer. The inhibition efficiency increased gradually

with increase in the concentration. Potentiodynamic polarization measurements have shown that the extract of SC leaves acted as a mixed type inhibitor inhibiting both anodic and cathodic reactions. The results of the weight loss, electrochemical

polarization and AC impedance were all in good agreement as a support to the above conclusions. Thus acid extract of SC leaves is considered to be a cheap, eco-friendly and effective corrosion inhibitor.

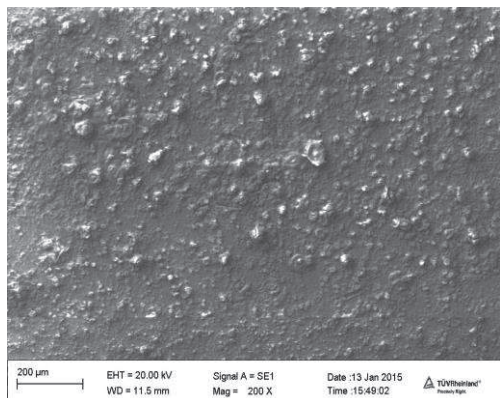


Fig. 5: SEM images of MS in 1 N H₂SO₄

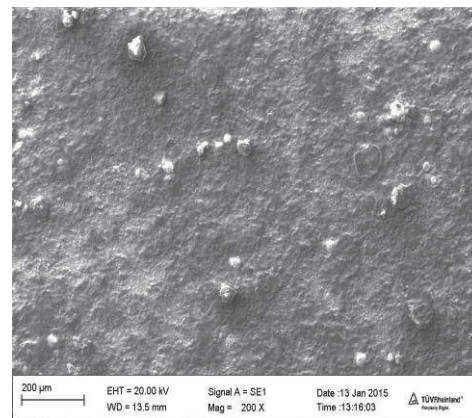


Fig. 6 SEM images of MS with 1.5% (v/v) SC extract.

References:

1. Refaey S.A.M., Appl Surf Sci., 240(1-4) (2005), 396-404. steel in 1N H₂SO₄ at various concentrations
2. Quraishi M.A, Sharma H.K, J Appl Electrochem, 35(1) (2005), 33-39.
3. Ashassi-Sorkhabi A., Shaabani .B, Seifzadeh .D, Appl Surf Sci., 239(2)(2005), 154-164
4. Bouklah .M.Ouassini A, Hammouti .B,El Idrissi .A. Appl Surf Sci., 252(6)(2006), 2178-2185.
5. Oguzie E. E., Okolue B. N., Ebenso E. E., Onuoha G. N, Onuchukwu A. I., Mater Chem Phy. 87(2-3) (2004), 394-401.
6. Ali SK A., Saeed M. T, Rahman S. U., Corros Sci., 45(2) (2003), 253-266.
7. A.K. Singh, M.A. Quraishi, Corros. Sci., 52 (2010), 152.
8. M.S. Morad, Corros. Sci., 50 (2008), 436.
9. O.K. Abiola, A.O. James, Corros. Sci., 52 (2010), 661.
10. F.S. de Souza, A. Spinelli, Corros. Sci., 51 (2009), 642.
11. S.A. Umoren, I.B. Obot, N.O Obi-Egbedi, J. Mater. Sci., 44 (2009), 274.
12. Quraishi M. A., Singh A., Singh V. K, Yadav D. K., Singh A. K., Materials Chemistry and Physics, 122(1) (2010), 114- 122.
13. Orubite K. O., Oforka N. C., Materials Letters, 58 (11) (2004), 1768-1772.14. Saratha R., Vasudha V.G., E-Journal of Chemistry, 7(3) (2010), 677-684.
15. Okafor P. C., Ikpi M. E., Uwah I. E., Ebenso E. E., Ekpe U. J., Umoren S. A.,Corrosion Science, 50(8) (2008), 2310-2317.
16. Saratha R, Savitha R, Sivakamasundari S, J Electrochem Soc India., 52(2) (2003), 59-63.
17. El-Etre A.Y., Appl Surf Sci., 252 (2006), 8521.
18. Abdel-Gaber A M., Abd-El-Nabey B A, Khamis E, Abd-El-Khalek E, Desalination, 230(1-3) (2008), 314-328.
19. Ebenso E E, Eddy N O , Odiongenyi A O, Afr J Pure Appl Chem., 2(11)
20. Noor E. A., Journal of Engineering and Applied Sciences, 3(1) (2008), 23-30.
21. Saratha R., Vasudha V.G., E-Journal of Chemistry, 6(4) (2009), 1003-1008.
22. De Souza F. S., Spinelli A., Corrosion Science, 51(3) (2009), 642-649.
23. F. Bentiss, M. Traisnel and M. Lagrenee: Corros. Sci., 2000, 42, 127.
24. S. Muralidharan, K.L.N. Phani, S. Pitchumani and S.Ravichandran: J.Electrochem. Soc., 1995, 142, 1478.

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