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# Investigating Inhibitive Properties Of Green Inhibitors On Mild Steel In Acidic Medium

Okporie Ndifreke Brown, Patrick Akata Nwofe, Nweke Friday Ukpai

*Department Of Industrial And Medical Physics, Faculty Of Natural Sciences, David Umahi Federal University Of Health Sciences, Uburu, P.M.B. 211, Ebonyi State, Nigeria*
*Department Of Industrial Physics, Faculty Of Science, Ebonyi State University, P.M.B. 53, Abakaliki, Ebonyi State, Nigeria*
*Department Of Physics And Astronomy, Faculty Of Science, Ebonyi State University Of Aeronautics And Aerospace Engineering, Ezza, P.M.B. 035, Ebonyi State, Nigeria.*

***Abstract***
*The present study investigated the potentials of green inhibitors (leaf extracts of Heinsiacrinita (atama) and Editan (Clasianthera Africana)) for the prevention of corrosion of mild steel in an acidic media. The experiment was tested in a control environment and in an acidic environment under different concentrations of the green inhibitors and with fixed exposure time. The concentration of the acidic environment was fixed at 0.5 M while the concentration of the green inhibitors was varied between 0 g/mol (control) to 50 g/mol. The incremental steps were maintained at 10 g/mol. The exposure time was fixed at 360 hours. All the experiments were carried out at room temperature and the weight loss technique was applied in all the measurements, enabling to deduce the corrosion rate-CR (mpy), surface coverage (θ), and inhibition efficiency (%). The coupons were then subjected to different characterisation techniques. In particular, X-ray diffractometry (XRD) was used to study the structural properties, and Scanning Electron Microscopy (SEM) was used to investigate the morphological properties of the coupons, and phytochemical investigations to understand the functional groups present. The findings indicated that the leaf extracts of Heinsiacrinita (atama) exhibited better corrosion inhibition efficiency under the test conditions. To the best of our knowledge, the use of leaf extracts of Heinsiacrinita (atama) and Editan (Clasianthera Africana) as corrosion inhibitor of mild steel in an acidic medium is a pioneering report.*

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## I. Introduction

Rapid interest in the use of green inhibitors as corrosion inhibitors is increasing widely globally, due to the need to use more ecofriendly materials that will solve corrosion problems and simultaneously preserve the environment. Generally, inhibitors are commonly classified into organic or inorganic groups depending on their composition and source of origin. The recent paradigm shift from utilising inorganic and non-degradable products for corrosion inhibition to using green inhibitors of plant extracts which are organic, bioactive and biodegradable is because of their friendliness to the environment and rich content of antioxidants amongst others (Zeng *et al.*, 2021). The existence of different bioactive extracts that were sieved out from the whole plant or its parts which contain high concentrations of active ingredients, and phytochemicals have been established (Umoren *et al.*, 2024) wherein high antioxidant concentrations exist in natural forms (Agarry *et al*., 2019).

Different researchers (El-Hashemy & Almehmadi, 2025) have established the potentials of the various parts of plants, including the extracts of leaves have shown high potency for corrosion inhibition due to their presence of phytochemicals content (Jabbar *et al.,* 2023). The phytochemicals are rich in lone-pair electron donor sites, active, or adsorption sites and these electron-rich sites are mostly polar functional groups with multiple bonds. This helps to facilitate strong adhesion to metallic surfaces through hydrogen and coordinate bonding including physical adsorption and chemisorptions mode, enabling to exhibit the corrosion inhibitive characteristics on the metal surface. Inhibitors are chemical compounds or mixture of compounds which when present at certain concentrations in a corrosive medium typically induce effective prevention of corrosion or lowers the corrosion potential, through reduction of the substantial interaction of the metal substrate with the environment's components of moisture and oxygen (Idu *et al.,* 2016). The inhibitors behave as barrier-thin coating on the metal surfaces as evidenced in the use of plant extracts as corrosion inhibitors for metals and alloys in different environment (Jabbar *et al.,* 2023).

Mild steel generally corrodes easily in everyday situations because they are very reactive and mostly oxidises to iron oxide (rust) in the presence of water, oxygen, and free ions (Kadhim *et al.,* 2021). The ability of mild steel to oxidize on slight exposure to the environment requires that it should be given adequate protection in order to prevent self-oxidation and thus retain its aesthetic, structure, quality and design integrity. Mild steel is mostly utilised as a structural material in various industries including: structure, chemical, petrochemical, and in the oil and gas industries amongst others (Jabbar *et al.,* 2023). Mild steel has outstanding mechanical qualities and are generally cost-effective but possess the weakness that it dissolves in acidic conditions. One of the major practical ways to reduce corrosion of mild steel or metals from corrosion generally, especially in acid environments is by use of inhibitors. The application of green inhibitors to reduce corrosion in mild steel in acidic media has yielded a significant improvement as detailed in the literature (Okungbowa *et al.,* 2017). For instance, the use of moringa oliefera leaf extracts has been reported by Idenyi*et al.,* (2015), Robinia pseudoacacia leaves extract (Yüce, 2020), Azadirachta indica (Peter & Sharma, 2017), soybean leaves extract (Pepe *et al.,* 2024), extracts of Musa paradisiaca peels, Moringa oleifera leaves, and Carica papaya peels (Agarry *et al.,* 2019), and Glebionis coronaria L. flower extract (El-Hashemy & Almehmadi, 2025) amongst others. Since different industrial operations including acid cleaning, oil-well acidizing, and acid descaling amongst others, expose the mild steel to corrosion attacks, it is pertinent to devise preventive approach to reduce the menace. It is in this light that this research is aimed at, by studying the potentials of the green leaf extracts of *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) for use as a corrosion inhibitor of mild steel in an acidic environment.

## II. Materials And Methods

**Materials**

The mild steel used for the investigation was sourced from Scientific Equipment Development Centre (SEDI), Enugu, Nigeria. The composition percentage by weight of the mild steel is: Iron-Fe (98.82), Carbon-C (0.1041), Silicon-Si (0.0441), Manganese-Mn (0.2553), Phosphorus-P (0.0078), Sulphur-S (0.0332), Copper-Cu (0.0482), Cobalt-Co (0.0313), Nickel-Ni (0.2202), Chromium-Cr (0.0518), Molybdenum-Mo (0.0351), Tungsten-W (0.0420), and Titanium-Ti (0.000). The 0.5 M $H_2SO_4$ electrolyte solution was prepared with 95% analytical grade sulfuric acid (BDH Chemicals) with double distilled water. The leaves of *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) were sourced from local forests in Ebonyi State, Nigeria and the extracts were obtained using standard methods.

**Methodology**

Preparation of the green inhibitors (leaves of *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*)). The leaves of *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) were collected and carefully cleaned to remove dust and other unwanted particles. They were then dried in a shadowy area for one week and finally crushed into a fine powdered form. A 15 g powder of each of *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) was extracted with ethanol as a solvent, using a soxhlet apparatus. The set-up was allowed for 1 day.

**Mild steel sample preparation**

The Mild steel coupons were cut into dimensions of 1.55mm x 1.99mm and was then polished with the help of sandpaper that possess different grit sizes in order to obtain a smooth surfaced mild steel coupon. The coupons were further mechanically abraded sequentially with silicon carbide papers so as to remove fine metal or dust particles deposited on the surface. The purpose of abrasion was to: i) ensure uniformity on the surface of the mild steel coupons, ii) be sure that the coupons attain the same weight, and iii) limit the influence of rough surfaces on the corrosion monitoring process. After the abrasion process, each sample was individually degreased in methanol, rinsed with acetone, air dried and stored at room temperature in the desiccators to prevent oxidation prior to the commencement of the experiment.

**Weight Loss Measurements**

The leaf extracts of the *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) were prepared at varying concentrations from 10 g/mol to 50 g/mol, where 0 g/mol was used as the control (no inhibitor). To measure the weight loss of the Mild steel coupons, the exposure time was fixed for 360 hours and the pre-cleaned and dried Mild steel coupons were weighed before and after being immersed with or without the *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) leaf extract at the various concentrations in 0.5 M $H_2SO_4$. Silicon carbide papers of different grades were used for polishing, followed with successive washing with distilled water and acetone. Further drying of the coupons were done in a moisture-free desiccator. Following submerging of the Mild steel coupons again, it was washed and removed with distilled water and

kept in a vacuum oven for about 60 minutes to dry. According to the literature (Idenyi *et al.*, 2015), the weight loss data was deduced by using the equations given hereunder.

$$IE\ (\%) = \frac{W_o - W_i}{W_o} x\,100 \quad (1)$$

$$\theta = \frac{W_o - W_i}{W_o} \quad (2)$$

$$CR\ (mpy) = \frac{k\ x\ \Delta W}{D\ x\ A\ x\ T} \quad (3)$$

where $W_0 - W_i = \Delta W$ is weight loss (g), $W_0$ and $W_i$ is weight loss with and without plant inhibitor, k represents the corrosion constant and was used as 87600 (Olanrewaju & Olaseinde, 2025; Ogunleye *et al.*, 2020), D represents the density of coupon (g $cm^{-3}$), A is the Mild Steel coupon total area ($cm^2$), θ is the surface coverage and T represents corrosion exposure time (hours).

**Phytochemical investigation**

The leaf extracts of the *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) were subjected to phytochemical studies in order to ascertain the presence of phytochemicals in the extract. Standard assays were conducted and the presence of bioactive compounds were targeted and correlated with the literature. In lieu, the tests were fashioned to detect specific groups of phytochemicals, such as glycosides, alkaloids, flavonoids, tannins, phenols, saponins, and terpenoids, depending on their peculiar characteristic reactions and color changes that resulted when interacted with some specific reagents. In this light, the leaf extracts of the *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*) were subjected to Mayer's test, Salkowski's test, Keller–Kiliani test, copper acetate test, lead acetate test, alcoholic NaOH test, and sodium hydroxide test as indicated in the literature (Kadhim *et al.*, 2021; Pepe *et al.*, 2024). Table 1 show the summary of the findings, confirming the presence of glycosides, terpenoids, tannins, alkaloids, steroids, flavonoids, and phenols. The concentrations of leaf extracts of the *Heinsiacrinita* (atama) is represented as $A_{inh}$ while that of Editan (*Clasianthera Africana*) is represented as $E_{inh}$ as indicated in Figures 1-4 and in subsequent pages.

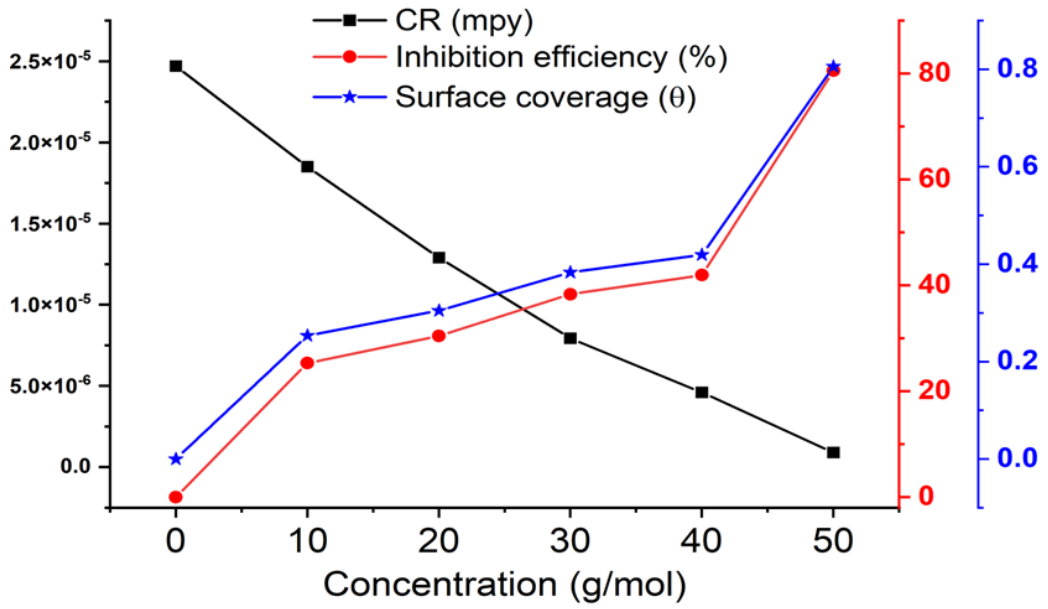


**Figure 1. Corrosion Rate (Cr), Surface Coverage (Θ) And Inhibition Efficiency (%) Against Varying Concentration Of Ainh (G/Mol) In 360 Hrs.**

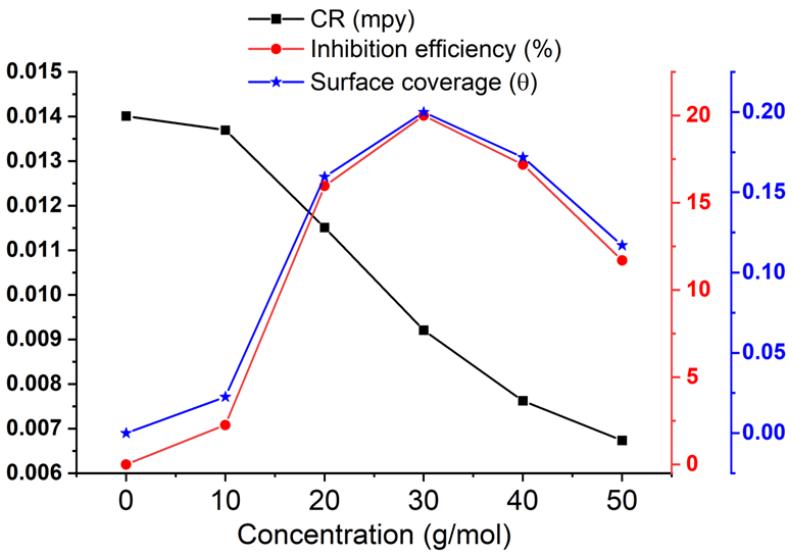


**Figure 2. Corrosion Rate (CR), Surface Coverage (Θ) And Inhibition Efficiency (%) Against Varying Concentration Of Einh (G/Mol) In 360 Hrs.**

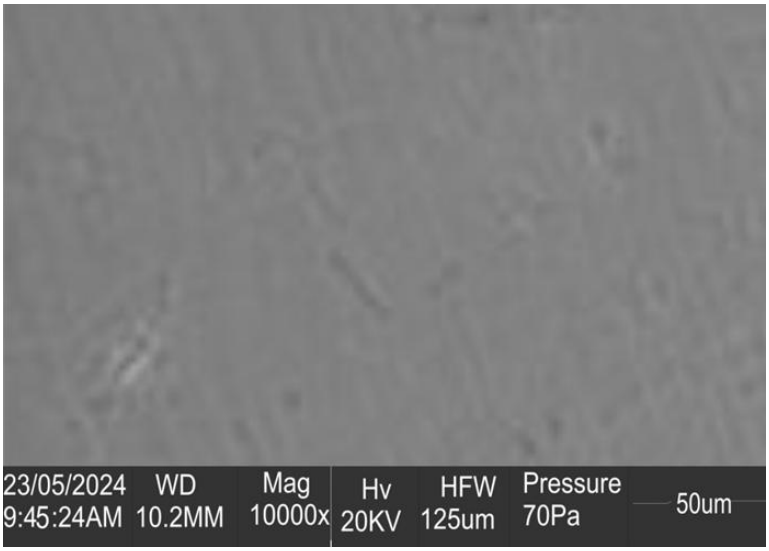


**Figure 3. Typical SEM Micrograph At 50 G/Mol Concentration Of Ainh In 360 Hrs.**

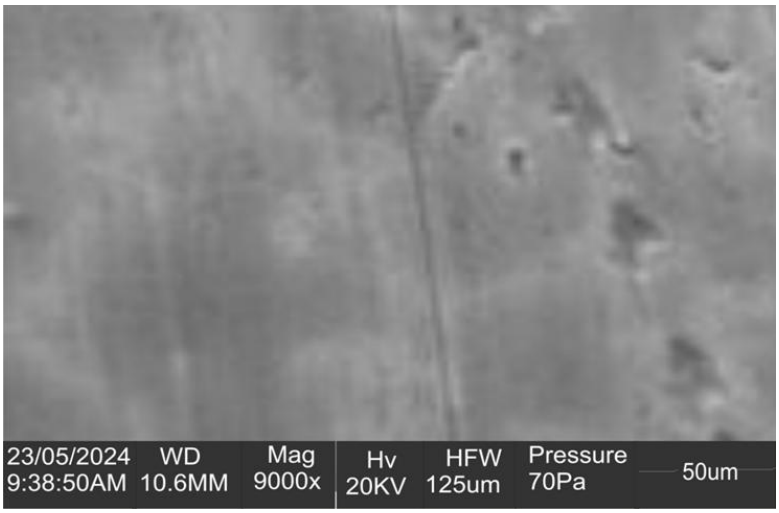


**Figure 4. Typical SEM Micrograph At 50 G/Mol Concentration Of Einh In 360 Hrs.**

**Table 1. Phytochemical composition of $A_{inh}$and$E_{inh.}$**

| Compound | Test | This Study | Compared Study | References |
|---|---|---|---|---|
| Glycosides | Keller–Kiliani test | +ve | +ve | Bhardwaj *et al.*, 2024 |
| Steroids | Salkowaski's test | +ve | +ve | Kale, 2020 |
| Flavonoids | Sodium hydroxide | +ve | +ve | Mir *et al.*, 2016 |
| Tannins | Lead acetate | +ve | +ve | Santhi & Sengottuvel 2016 |
| Terpenoids | Copper acetate test | +ve | +ve | Nongalleima *et al.*, 2017 |
| Phenols | Mayer's test | +ve | +ve | Maigoda *et al.*, 2022 |

## III. Results And Discussion

**Weight Loss Analysis**

Figure 1 show the Corrosion rate (CR), Surface coverage (θ) and Inhibition efficiency (%) against varying Concentration of $A_{inh}$ (g/mol) in 360 hrs. The findings indicated that there was serious corrosion of the mild steel coupon in the acidic medium since the weight loss was optimum in the absence of the inhibitor. In particular, the corrosion rate of the mild steel coupon was 2.5 x $10^{-5}$mpy at the absence of inhibitor. However, as the concentration of the inhibitor increased, the corrosion rate decreased, indicating the ability of the $A_{inh}$ inhibitor to reduce corrosion. The decrease in the corrosion rate of the mild steel coupon was optimum at the highest concentration of $A_{inh}$ inhibitor, exhibiting a value of 0.15 x $10^{-6}$ mpy. This consistent decrease in the CR of the mild steel coupon could be attributed to the possible degradation of the bioactive compounds in the acidic medium over time, especially considering the fact that the $A_{inh}$ inhibitor biological and acidic nature as given from the phytochemical results (see Table 1). This findings show that the $A_{inh}$ inhibitor is quite efficient in preventing the mild steel coupons from corroding in the acidic environments, especially at concentrations of 50 g/mol. The $A_{inh}$ inhibitor exhibited both short-term and long-term corrosion protection potential at all the test concentrations of the $A_{inh}$ inhibitor. The drop from CR of 2.5 x $10^{-5}$mpy at the control to CR of 1.8 x $10^{-5}$mpy at 10 g/mol, and to a CR value of 0.15 x $10^{-6}$ mpy at 50 g/mol indicates clearly that the inhibitor, especially at the highest concentration offered a near total protection by offering an effective protective barrier on the mild steel coupon surface. This consistent decrease of the corrosion rate equally affirms the persistent efficacy of the $A_{inh}$ inhibitor under the test conditions. A similar finding on decrease of corrosion rate of mild steel in acidic environment, with increasing concentration of extracts of green leaves have been reported by other authors (El-Hashemy & Almehmadi, 2025). Further, the surface coverage (θ) was relatively at zero for the control experiment. This is an indication that the mild steel coupon had no protection and was aggressively attacked in the acidic environment, resulting to the high CR for the control. However, as the $A_{inh}$ inhibitor concentration increased, the surface coverage increased consistently as well from 0.2 at 10 g/mol to 0.8 at 50 g/mol of the $A_{inh}$ inhibitor. This indicates that the $A_{inh}$ inhibitor adsorbed onto the mild steel coupon surface and successfully blocked the corrosion sites thereby offering increased protection to the coupon. This also reflected in the trend exhibited by the inhibition efficiency which show negative value of inhibition efficiency at the control, and increased consistently from 20% at 10 g/mol to 80 % at 50 g/mol of the $A_{inh}$ inhibitor. Additionally, the ability of the $A_{inh}$ inhibitor to shield the mild steel coupon against severe corrosion is evidenced by the sharp decrease in corrosion rate in the acidic environment, added with the exponential increase in the inhibition efficiency as the concentration of the $A_{inh}$ inhibitor increases. This change from negative value of inhibition efficiency at control to 20% at 10 g/mol and to 80 % at 50 g/mol indicates that the $A_{inh}$ inhibitor offers substantial protection even at lower concentrations and that at higher concentrations, the protection efficiency is very excellent. This points to the exceptional efficacy of the $A_{inh}$ inhibitor in the specified environment. In summary, this is a clear evidence which indicates that the $A_{inh}$ inhibitor is quite successful in lowering the rate of corrosion of mild steel in a 0.5 M $H_2SO_4$ solution under room temperature conditions.

For the $E_{inh}$ inhibitor (see Figure 2), relatively similar behaviour was observed for the corrosion rates. The corrosion rate decreased from 0.014 mpy for the control to 0.065 mpy at the optimum concentration of 30 g/mol of the $E_{inh}$ inhibitor. The higher values of the corrosion rate values compared to that of the $A_{inh}$ inhibitor was attributed to the difference in the surfaces of the mild steel coupons as exhibited in the SEM micrographs shown on Figure 3 and Figure 4 respectively.

The inhibition efficiency of the $E_{inh}$ inhibitor increased from the inhibitor concentration of 10 g/mol to 30 g/mol and then decreased sharply. The decrease in the inhibition efficiency at the higher concentrations (40 g/mol to 50 g/mol) may suggest that some inhibitor components experienced hydrolysis or oxidation under the test acidic conditions and the impact of the crevices shown on the SEM micrograph (Figure 4). Such pitting effect could induce reactions that will deter the active functional groups (such as phenolic or carboxylic groups) that are mostly responsible for adsorption onto the mild steel coupon surface from performing effectively. The surface coverage (θ) increased from 0.007 to 0.014 from the control, up to an optimum concentration of 30 g/mol and also decreased sharply at the higher concentrations of the $E_{inh}$ inhibitor. The protection efficiency

increased by increasing the inhibitor concentration, and a decrease in the corrosion rate was shown at all studied concentrations for the $A_{inh}$ inhibitor, as indicated in Figure 1, implying that the inhibition efficiency was concentration-dependent for the $A_{inh}$ inhibitor. This is because with increasing inhibitor concentration, considerable inhibitor molecules numbers are adsorbed on the tested coupon surface, resulting in the increased protection efficiency. The adsorbed inhibitor molecules control and/or block the reaction sites and hence protect the coupon surface from the corrosive solution. However for the $E_{inh}$ inhibitor at the highest concentrations, the significant ion pairs of electrons, such as ion pairs on sulphur, and nitrogen atoms, and the pi-electrons, that are co-ordinately bonded with iron atoms on the coupon surface are altered by the impact of the pits and crevices, resulting to an imbalance in the ionic distribution at the surface of the mild steel coupon. Therefore instead of slowing down corrosion, the surface coverage was reduced, resulting to a decrease in the inhibition efficiency as observed in Figure 2. Similar findings have been observed in the literature (Rahal *et al.*, 2024; Santhi & Sengottuvel, 2016). Further, the excess electrons on the surface of the mild steel coupons are created by various adsorbents, and thus instead of paving way for cationic particles to be adsorbed on the mild steel surface, there was a completion of ion-to-ion interaction within the excess electrons, resulting to a destructive pair interaction and thus diminish the protective layer at that higher concentrations of the $E_{inh}$ inhibitor, as observed in the literature (Yadav *et al.*, 2024).

**SEM Micrograph Analysis**

Figure 3 show a typical SEM micrograph at 50 g/mol Concentration of $A_{inh}$ in exposure time of 360 hrs. SEM analysis helps to explain and to understand the surface morphology of mild steel coupons under various conditions. A close inspection of the SEM micrograph depicts uniformly formed film on the surface of the mild steel coupon. In Figure 4, the SEM micrograph at 50 g/mol Concentration of $E_{inh}$ in exposure time of 360 hrs show the non-uniform film formation, which possibly yielded the differences observed previously. This could be attributed to the differences in the chemical constituents of the leaf extracts.

**Phytochemical Analysis**

The phytochemical composition of extracts of green plants makes it to be readily available for use as sustainable source of green corrosion inhibitors. Although the presence of glycosides, terpenoids, tannins, alkaloids, steroids, flavonoids, and phenols were observed in the two leaf extracts investigated in the study, the standard deviation values were higher in the $E_{inh}$ inhibitor compared to the $A_{inh}$ inhibitor. This was the possible reason for the better corrosion inhibition performance of the $A_{inh}$ inhibitor compared to the $E_{inh}$ inhibitor.

## IV. Conclusion

In the present investigation, leaf extracts of *Heinsiacrinita* (atama) and Editan (*Clasianthera Africana*), prepared under vary concentrations was investigated for use as a green corrosion inhibitor for mild steel in 0.5 M $H_2SO_4$ environment. Weight loss technique, SEM study and phytochemical studies were used for analysis. The findings show that leaf extracts of *Heinsiacrinita* (atama) exhibits excellent corrosion inhibition characteristics at all the test conditions. The inhibition efficiency was greater than 80% for the highest concentration of the $A_{inh}$ inhibitor. Also the inhibition efficiency was found to be dependent on the concentration of the $A_{inh}$ inhibitor. However such uniform trend was not observed for the $E_{inh}$ inhibitor. This method of preventing corrosion has proved to be more advantageous because of the low cost, readily available, and being more environmental friendly compared to inorganic corrosion inhibitors. The widescale deployment of the $A_{inh}$ inhibitor for protection of mild steel against corrosion in acidic media should be given attention in industrial scale.

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**Authors' Note**

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. Authors confirmed that the data and the paper are free of plagiarism.

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