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Investigation of Green Corrosion Inhibitors of *Musa* on Mild Steel

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ABSTRACT **Original Research Article**

The study investigated green corrosion inhibitors of *musa* on mild steel. The ever present threat to the integrity of a metals' structure called corrosion has led to the heavy use of preventive measures in order to slow down its' progression. One of such preventive measures is the use of corrosion inhibitors. The use of corrosion inhibitors has proven to be very successful making their application one of the most used measures against corrosion. However, despite the successful use of corrosion inhibitors, having high corrosion inhibition efficiencies; some corrosion inhibitors have been found to be moderately to highly toxic to man and the environment. A call for alternative inhibitors to the toxic inorganic corrosion inhibitors was made and the answers arrived at by researchers, were the use of "Green Inhibitors". This research focused on the use of DNA extracted from two varieties of plants from the *Musa* species and a hybrid of the two as corrosion inhibitors of mild steel with the corrosive medium being HCl. Experiments were undertaken at varying temperatures of the corrosive medium and at varying concentrations of DNA in order to determine the optimal temperatures and concentrations that give the highest corrosion inhibition efficiencies of the two Musa varieties and the hybrid. The highest corrosion inhibition for *Musa acuminate* DNA was 58.1818% at the conditions, 55˚C and 5 **mg/L** while for *Musa paradisiaca* DNA, the highest corrosion inhibition was 55.0720% at the conditions, 10˚C and 20 **mg/L** and for the hybrid, the highest corrosion inhibition efficiency was 60.8697% at the conditions, 10˚C and 20 mg/L.

Keywords: Inhibitors, *Musa*, Mild Steel, Metals, Green, Corrosion.

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Introduction

Metals play a large role in modern society, they can be found in almost everything from the simple things like spoons and pens to more complicated things like heavy machinery and airplanes. Corrosion is the inevitable degeneration of the properties possessed by a material due to interactions with their surrounding (Shaw et al., 2006). Corrosion eats away at metals causing them to be weakened. Unfortunately, corrosion cannot be stopped but its progression can be slowed down. Several techniques can be adopted in order to decelerate or hinder corrosion of structures made of metal. The most frequently used procedures are protective coatings on metals using organic molecules, plastics, polymers; and cathodic and/or anodic protection using organic or inorganic inhibitors (Devarayan, 2012). The word "inhibitor" refers to materials whose presence in minute concentrations in a corrosive domain can cause a reduction in the rate of corrosion.

Passivating inhibitors are oxidizing substances that can give corrosion protection under definite conditions because of one (or more) of the following mechanisms: (i) Enhancement of the passive ability by incorporation of species into the passive layer; (ii) stabilization of passive oxide layers; (iii) decrease of the probability of absorption of aggressive ions, such as chloride ions; (iv) ability to shift the corrosion potential to more positive values, forcing the metallic surface to the passive range. Chromates and nitrites are the classic examples of passivating inhibitors. The inhibitors are stable in several pH ranges and are particularly efficient in near neutral solutions. They create sparingly soluble corrosion products such as oxides, hydroxides or salts which are protective in different surfaces (Montomer, 2016).

Cathodic inhibitors will precipitate at cathodic sites or slow down the cathodic process, as the pH rises owing to hydroxyl release, thus raising the local impedance and preventing the diffusion of reducible species to these sites. These inhibitors work by multiple ways including: (i) selective precipitation on the cathodic areas (cathodic precipitators); (ii) decrease of the reduction reaction rates (cathodic poisons). Montomer (2016) usually adds oxygen scavengers in the family of cathodic inhibitors. Rare earths are popular examples, notably the cerium cation able to generate stable oxides or hydroxides on the cathodic regions (Mishra, 2007).

Mixed corrosion inhibitors are among the most commonly used inhibitors and are mainly compounds that are organic and can be neither classified as cathodic nor as anodic inhibitors (Montomer, 2016). Mixed inhibitors form a thin protecting layer by suppressing the cathodic and anodic corrosion reactions, generally by adsorption on the metal surface (Richardson, 2008). Due to this, these inhibitors are also called ‘film-forming inhibitors’ (Elsener, 2002), or ‘adsorption inhibitors’ (Kondratova, 2003). This process depends strongly on the metallic surface morphology, roughness and composition, structure of the inhibitor and chemical composition. Organic substances with polar groups containing sulphur (S), nitrogen (N) and hydroxyl (OH) are usually effective mixed inhibitors (Soeda, 2003). Volatile corrosion inhibitors (VCIs) are material molecules that are adsorbed on the surface of the metal after vaporizing at a significant pressure and form a thin corrosion protection layer (Saini, 2013). Aminocarboxylates (products of reaction between amine or amine derivatives and organic acids) are usually volatile corrosion inhibitors. VCIs can protect metals in enclosed spaces by condensing on the metal surface without being directly in contact with the metal because their vapor pressure is sufficient (Gangopadhyay, 2018). Compounds that are nonvolatile but release volatile components on hydrolysis can also be called

VCI. VCIs can be used in the form of porous emitters (VCI desiccants), inhibited air and packaging materials (VCI films and VCI papers) to provide temporary protection (Valdez, 2006).

Corrosion inhibitors were developed from inexpensive raw materials or synthesized from compounds with heteroatoms in an aromatic ring and aliphatic carbon structures of a long chain. While most of these inhibitors exhibit good corrosion protection, their use is sometimes limited due to negative environmental and ecological impacts (Kumar, 2016). In view thereof, significant efforts are undertaken to develop novel green surface protection technologies. Hybrid organic–inorganic sol-gel coatings have emerged as one of the most significant defenses due to their superior protective properties. Such coatings have interesting properties like flexibility, hydrophobicity, corrosion resistance, transparency and strong adherence on metallic substrates. Hybrid coatings are usually created through polysiloxane, past siloxane and polymeric elements to offer camouflage as an active protecting layer that may reasonably inhibit corrosive processes. The hottest role of these such investments is to provide a thin, even layer that limits the diffusion of other corrosive agents and oxygen at a surface that answers. By applying a dual-network structure, in which inorganic parts are chemically bonded to polymer chains, sol-gel-derived hybrid coatings combine both inorganic and organic properties. Moreover, introducing active corrosion inhibitors into the coating matrix significantly improves the corrosion resistance of paint systems, especially in areas where defects/discontinuities (due to mechanical damage or environmental factors) may arise during service life, providing higher performance final material over time (Khoshkhou et al., 2018).

Mild steel, also known as plain-carbon steel and low-carbon steel, is the most prevalent embodiment of steel due to its cost being comparatively low and its material characteristics being tolerable for many applications. 0.05–0.21% carbon is contained by mild steel, giving it properties of malleability and ductility (Baker, 2018).

Acknowledging the environmental and health hazard factors of many synthetic corrosion inhibitors, researchers try to find natural and sustainable resources for corrosion control. Consequently, much attention has recently been directed towards green inhibitors which are eco-friendly substances obtained from natural resources like plant extracts. This paper investigates two Musa varieties as the new candidates for organic corrosion inhibitors. Musa is the genus of flowering plants in the family Musaceae, which also includes the genus Ensete, and is comprised of the familiar bananas and plantains. It comprises about 70 recognized species with different economic, nutritional and industrial importance; it was first described by Carl Linnaeus in 1753 (Hai, 2015). Bananas and plantains collectively rank within the top 5 most essential food crops globally, with rice, wheat and maize being regarded as the next three important human foods. Musa species are widely adaptable and can grow in several environments for different purposes (food, fiber extraction, ornamental/single purpose plantations/production systems, etc) [3]. People have relied on these plants for thousands of years as an essential part of their diets and livelihoods. Musa species are also of great cultural and socioeconomic significance especially in many Pacific communities, serving as food, beverages, fermentable sugars, medicinal products, aroma agents and cooked meals (Nelson et al., 2006) and ceremonial/religious materials. Due to their availability, renewability and bioactive component composition, Musa species can be considered as a promising green corrosion inhibitors for sustainable industrial application as well.

Statement of Problem

Corrosion is the detrimental attack of a material by electro/chemical contact with its environment. The severe consequences of the corrosion process are now clear internationally. The overall annual evaluations in the U.S. were expected to exceed $1 trillion in 2013. But the cost of rusting isn't merely economic. Corrosion causes plant shutdowns, loss of precious resources, product loss or contamination, reduced inefficiency, maintenance expense and expensive overdesign (Dikici et al., 2014).

The toxicity levels of inorganic inhibitors such as chromates and chromium compounds caused them to be deemed unsuitable for use. The term 'green inhibitors' refers to the materials that are compatibility with the natural world. The inhibitors like plant extracts doubtlessly possess biocompatibility because of their natural origins (Devarayan et al., 2012).

Aim and Objectives of the Study

Aim

The aim of this study is to research the impact of hybrid impact of SEM and FTIR of Tafel polarization on mild steel.

Objectives

The objective of this study is:

- To study the structural features of the hybrid films by SEM and FTIR.
- To compare the gravimetric analysis results with the Tafel polarization results.
- To determine the adsorption thermodynamic parameters (i.e., ΔH °, ΔS ° and ΔG °)

Plant Extracts

Plants extracts such as seeds, natural oils, leaves, bark etc. are green inhibitors which have an extensive research portfolio as research has been carried out on them since the 1960s starting with Baldvin et al. who used vegetable oil and molasses as inhibitors for steel sheets in the pickling process (Solmaz, 2005). In order to discover the corrosion inhibition efficiency of the inhibitors, gravimetric measurements and electrochemical impedance spectroscopy were used. It was observed that the extract from the barks and leaves of plant matter had a significant effect on the rate of corrosion and this effect was amplified when they were used together.

Methanol extract from the leaves of the Willow-leaved justicia (*Justicia gendarussa*) that grows in India and Indonesia were researched to determine if they could inhibit corrosion of mild steel in hydrochloric acid by (Satapathy, 2009). The organic compounds in the methanol extract were characterized by the authors using gas chromatography-mass spectrometric technique. From the results gotten, the authors found that due to the retention times of the compounds present in the metanol extract being close to each other, separating them would be difficult. Film formation analysis on the metal surface was done using electron spectroscopy and atomic force microscopy.

(El-Etre, 2003) used extracts from the stem of Paddle cactus (*Opuntia)*, which grows in Mexico, India and North Africa, as an inhibitor for the corrosion of aluminum in HCl acid solution. No solvent was used in the extraction, instead the stems were squeezed and the juice gotten was applied directly as the inhibitor.

Oil extracted from Pennyroyal Mint (*Mentha pulegium)* has been researched as an inhibitor of the corrosion of steel with HCl as the corrosive medium by (Bouyanzer, 2006). The oil was classified as a cathodic type inhibitor after it was observed that the corrosion inhibition efficiency experienced increments with increasing temperature which indicated that chemisorption of the inhibitor was occurring on the surface of the steel.

The corrosion inhibition property of an extract of *Lupinous albus L.* (White Lupine), which is found in Sudan, Western Europe, Ethiopia and Egypt, on steel in $\boldsymbol{H_2SO_4}$ and HCl was studied by (Adbel-Gaber, 2009). A kinetic-thermodynamic model was used to analyse the data gotten and it was revealed that the inhibitor efficiency was greater in HCl than $\boldsymbol{H_2SO_4}$.

(Okafor, 2008) reported the inhibitive action of the seeds, leaves and a combination of seeds and leaves of Stonebreaker (*Phyllanthus amarus*), which grows in India and other tropical regions, used as inhibitors of the corrosion of mild steel with $\boldsymbol{H_2SO_4}$ and HCl used as the corrosive mediums. Increased resistance of the half-life time of the mild steel in the electrolyte solution that had a combined extract of leaves and seeds was observed in both corrosive mediums. Chemical adsorption of the inhibitors on the surface of the metal was revealed due the heat of adsorption being positive.

Leaf and seed extracts of *Gossipium hirsutum L.* (Upland Cotton) were used by (Abiola, 2009) as inhibitors of the corrosion of aluminum in the corrosive medium, NaOH. It was observed that the seed extract (94%) had a lower inhibition efficiency than that of the leaf extract (97%). In a similar experiment, the extracts from the seeds, leaves, bark and heartwood of Carica papaya were used as inhibitors of the corrosion of mild steel in $\boldsymbol{H_2SO_4}$. Here, the extract with the highest efficiency was also obtained from the leaves (Okafor, 2007).

An extract of *Gongronema latifolium* was used as inhibitor for aluminum in both an acidic and a basic environment. It was observed that the inhibitor exhibited higher inhibition efficiency in the acidic environment (HCl) than in the basic environment (NaOH). In the HCl solution, the suggested mechanism of inhibition was chemisorption while the suggested mechanism of inhibition in the NaOH solution was physisorption (Oguzie, 2007)

Inorganic Green Corrosion Inhibitors

When present in trace amounts, inorganic metals or elements play a vital role in living organisms. The toxicity of many metals increases with their concentration. Chromium compounds, for example, were used as corrosion inhibitors due to their high corrosion inhibition efficiencies but then it was discovered that chromium compound exhibit high levels of toxicity and because of this chromium compounds were banned from being used for industrial purposes. Table 2.1 shows a few inorganic green inhibitors, the metals and corrosive mediums used.

Table 2.1: Inorganic Green Inhibitors

Inorganic Green Inhibitor	**Material**	**Corrosive Medium**	**Reference**
$CeCl_3$, $7H_2O$	Tinned Iron	NaCl	(Arenas, 2002)
$CeCl_3$	AA5083, galvanized steel	NaCl	(Arenas, 2001)
$La(NO_3)_3$, $Sm(NO_3)_3$ $LaCl_3$, and $SmCl_3$	AISI 434 SS	NaCl	(Bernal, 1995)

Lanthanide salts were observed to possess high corrosion inhibition characteristics and as such were used as a replacement for the toxic chromium compounds, mainly chromates, that were being used (Twite, 1998). The toxicity of lanthanide salts is comparable to that of sodium chloride and because of this lanthanide salts are also classified as green corrosion inhibitors.

(Arenas, 2001) used $CeCl_3$ as an inhibitor for galvanized steel and aluminum alloy (AA5083) with the corrosive medium being NaCl. The creation of a protective layer on the surface of both the aluminum alloy and galvanized steel was observed during the study. Arenas et al in 2002 conducted another experiment using $CeCl_3$ and $7H_2O$ as corrosion inhibitors for tinned iron with the corrosive medium being NaCl. The nature of the inhibitor was revealed to be cathodic by coulometric studies.

The inhibitive effects of lanthanium chloride ($LaCl_3$), lanthanium nitrate ($La(NO_3)_3$), samarium chloride ($SmCl_3$) and samarium nitrate ($Sm(NO_3)_3$) on AISI 434 SS with the corrosive medium being NaCl were reported by (Bernal, 1995).

Characteristics of Green Corrosion Inhibitors

The general characteristics of green corrosion inhibitors is similar to those of the 'non-green corrosion inhibitors'. Adsorption onto the surface of the metal by both chemical and physical adsorption is done by many green corrosion inhibitors at room temperature. When temperature is elevated, chemisorption is usually how inhibition occurs. A green inhibitor will either lose or gain effectiveness after being exposed to a corrosive medium for an extended period of time. Usually, an inhibitor losses effectiveness with time but there have been some cases where the inhibitor becomes more effective as time passes. Extracts from the leaf of *Clematis gouriana* were used as an inhibitor for mild steel and it was observed that the efficiency of the inhibition increased with an increase of the time immersed in the corrosive medium (Gopiraman, 2011).

Methodology

Procedures

8 hours or 3 days.

Extraction of Plant Genomic DNA Using CTAB (Hexadecyl Trimethyl-Ammonium Bromide)

4.8 g of plant extract was put into a clean centrifuge tube and approximately 12 ml of CTAB Buffer, preparation of which is detailed in Table 3.1, was added to it. The CTAB/Plant material mixture was then shaken vigorously to ensure proper mixture. The CTAB/plant extract mixture was then left for 15 minutes at 55˚C in a CO_2 incubator (Plate 3.2) to incubate.

After incubation had concluded, the CTAB/plant extract mixture was spun in a centrifuge (Plate 3.1) at 12000 rpm for 5 minutes to push down the cell debris. The supernatant was then transferred to clean centrifuge tubes using a micropipette (Plate 3.3).

3 ml of Chloroform: Iso Amyl Alcohol (24:1) was then inserted to each centrifuge tube and the solution mixed by inverting the tubes. The tubes were then spun again at 13000 rpm for 1 minute. After spinning, the supernatant of the solution was transferred to clean tubes and 0.6 ml of 7.5 M Ammonium Acetate was inserted to each tube followed by 12 ml of ice cold absolute ethanol. The tubes were inverted slowly and kept in a freezer for a few hours in order to precipitate the DNA (appears white and stringy). After the DNA has precipitated, the Ammonium Acetate/Absolute ethanol mixture was decanted out and 70% ice cold ethanol was added to the DNA to clean it.

Preparation of CTAB Buffer

Table 3.1: Materials and their quantities' needed to make 100ml CTAB Buffer

Materials	**Quantity**
CTAB (Hexadecyl trimethyl-ammonium bromide)	2.0 g
1 M Tris pH 8.0	10.0 ml
0.5 M EDTA pH 8.0 (Ethylenediaminetera Acetic acid Di-sodium salt)	4.0 ml
5 M NaCl	28.0 ml
H_2O	40.0 ml
PVP 40 (polyvinyl pyrrolidone)	1 g

Adjust all to pH 5.0 with HCl and make up to 100 ml with H_2O

Results

Results of Gravimetric Analysis

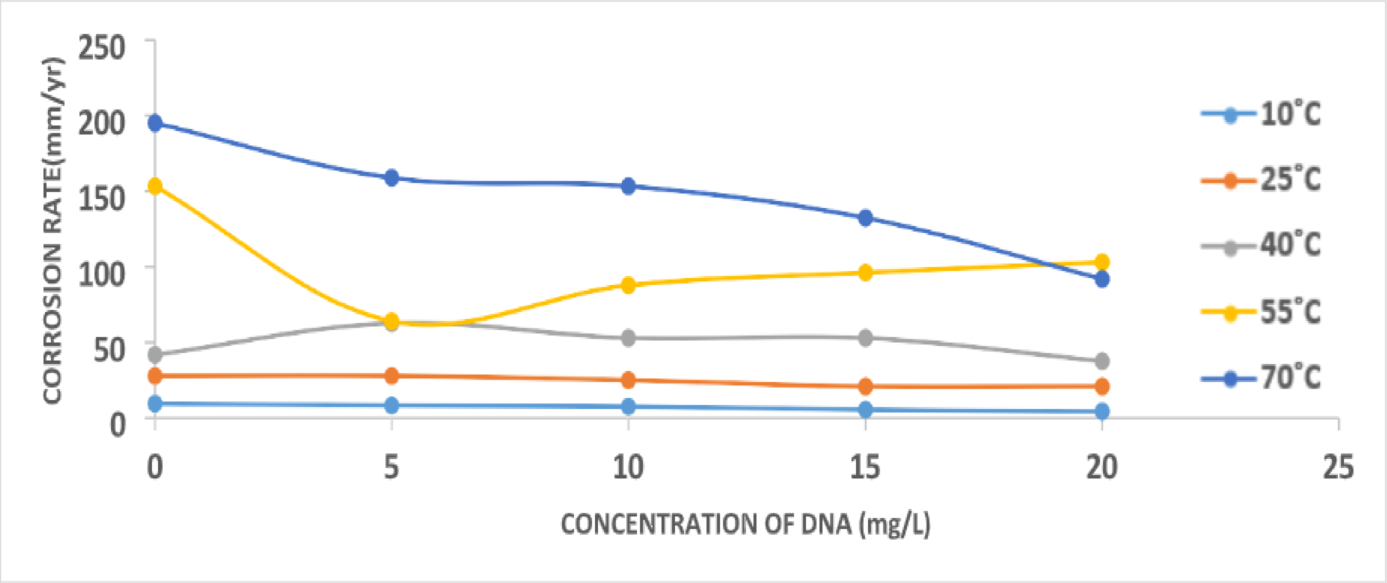

Figure 4.1: Corrosion Rate vs. Concentration of *Musa acuminate* DNA inhibitor at intervals of 15˚Cfora temperature range of 10˚C-70˚C

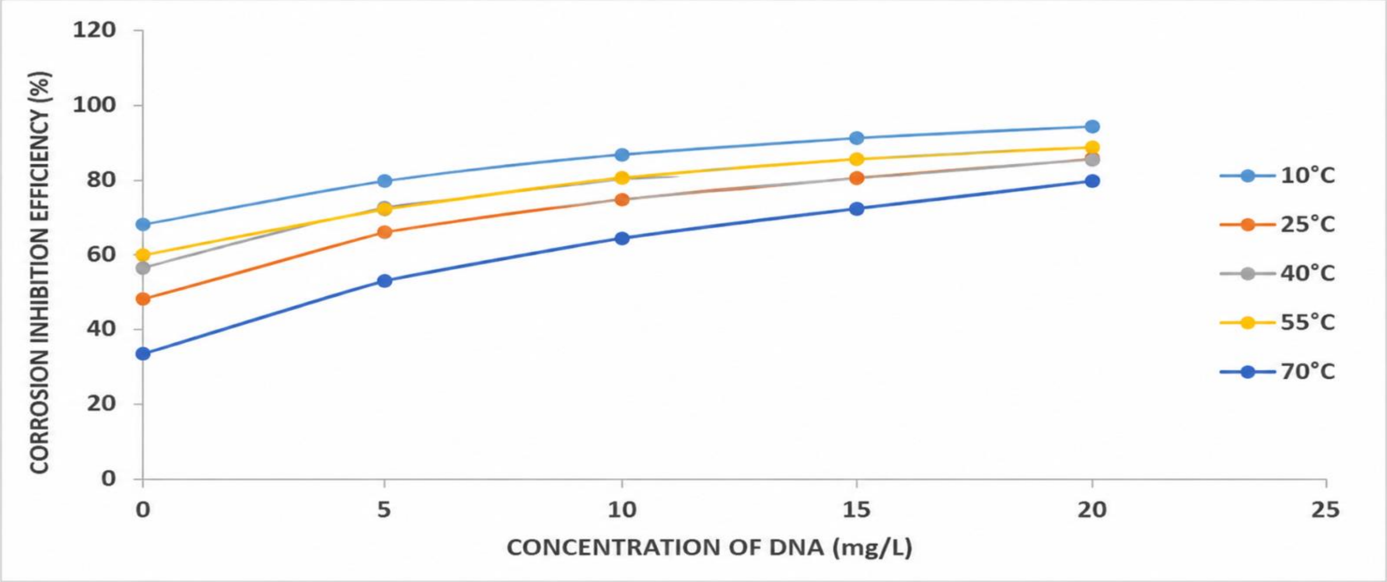

Figure 4.2: Corrosion Inhibition Efficiency vs. Concentration of *Musa acuminate* DNA inhibitor at intervals of 15°C for a temperature range of 10°C-70°C

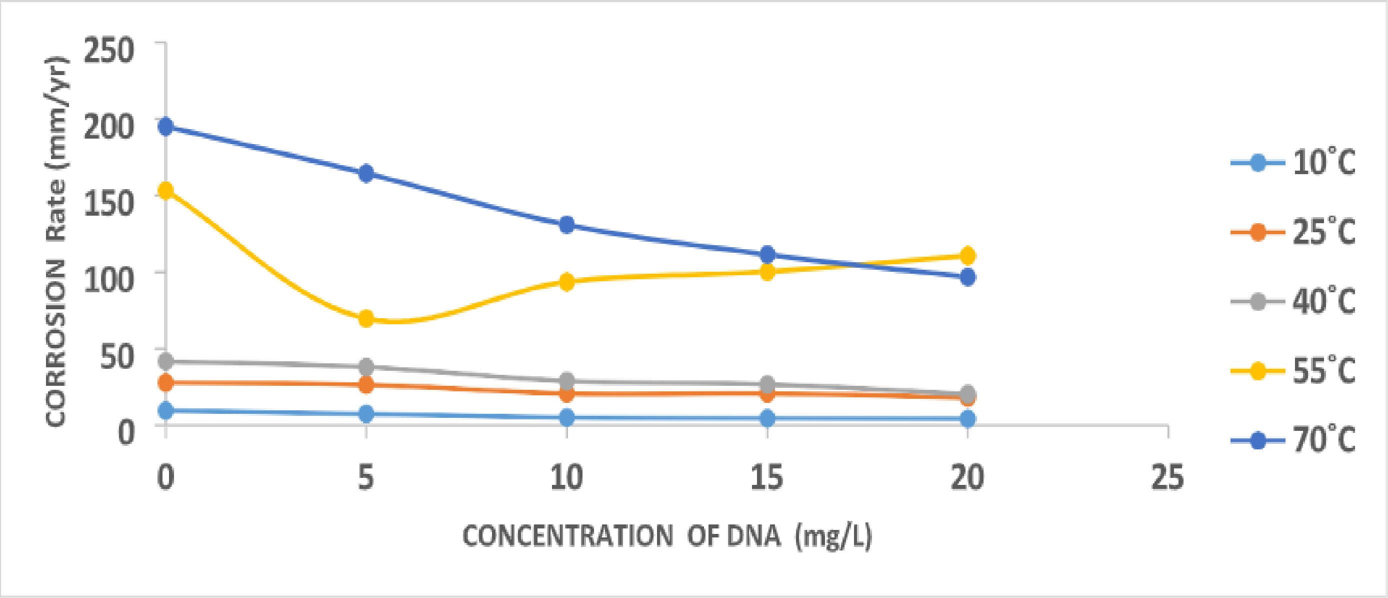

Figure 4.3: Corrosion Rate vs. Concentration of *Musa paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

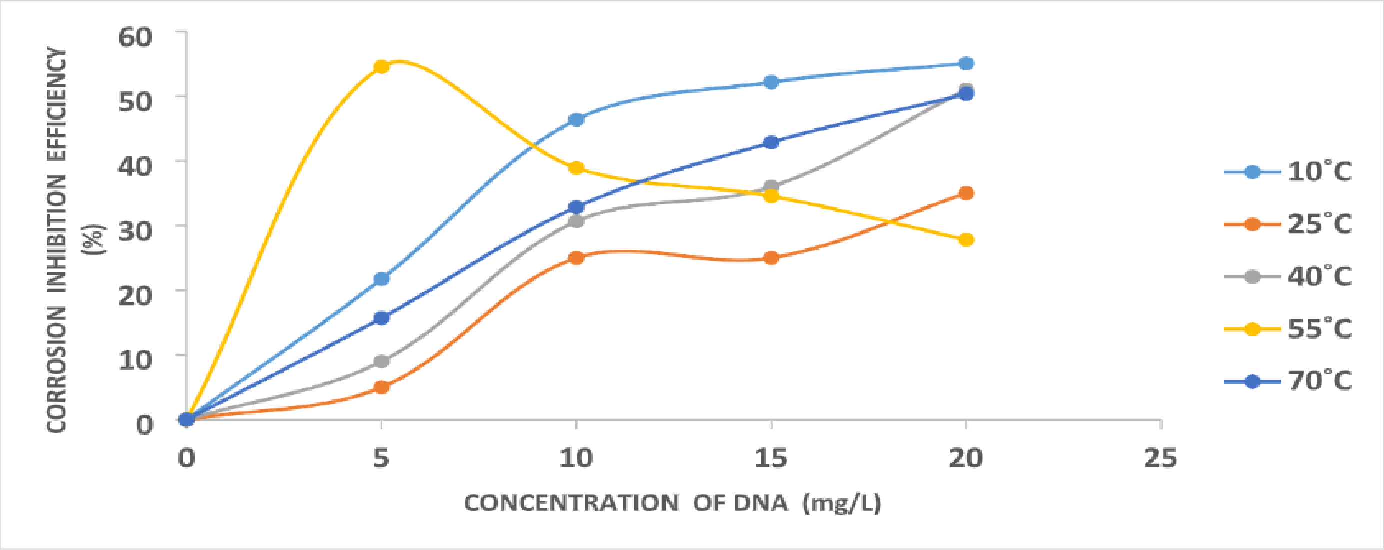

Figure 4.4: Corrosion Inhibition Efficiency vs. Concentration of *Musa paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

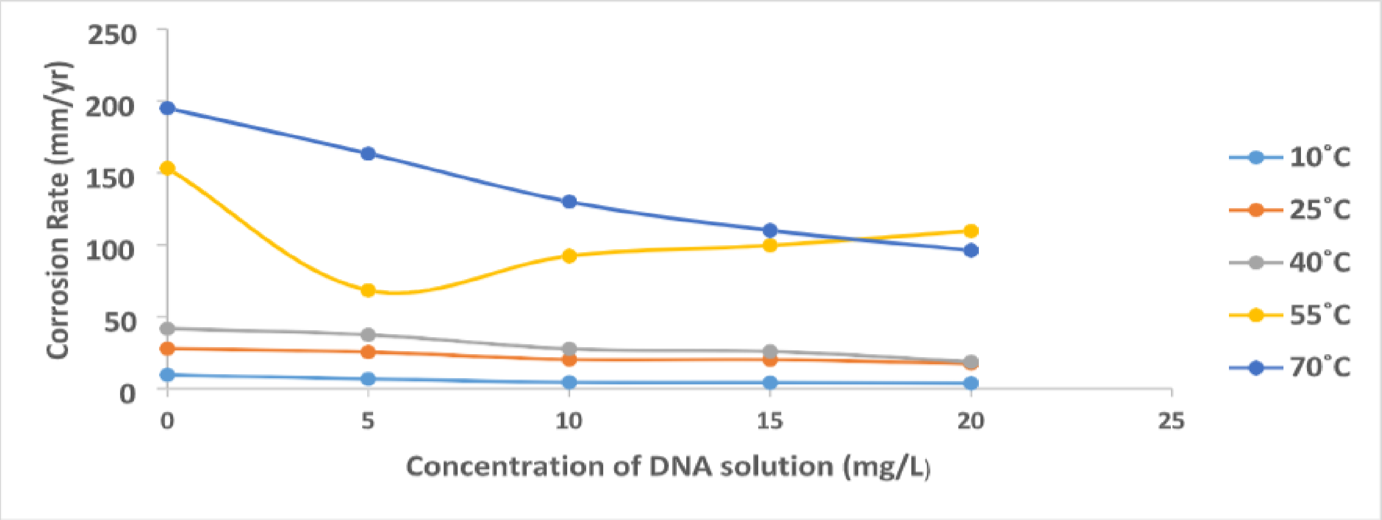

Figure 4.5: Corrosion Rate vs. Concentration of Hybrid of Musa acuminate and *Musa paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

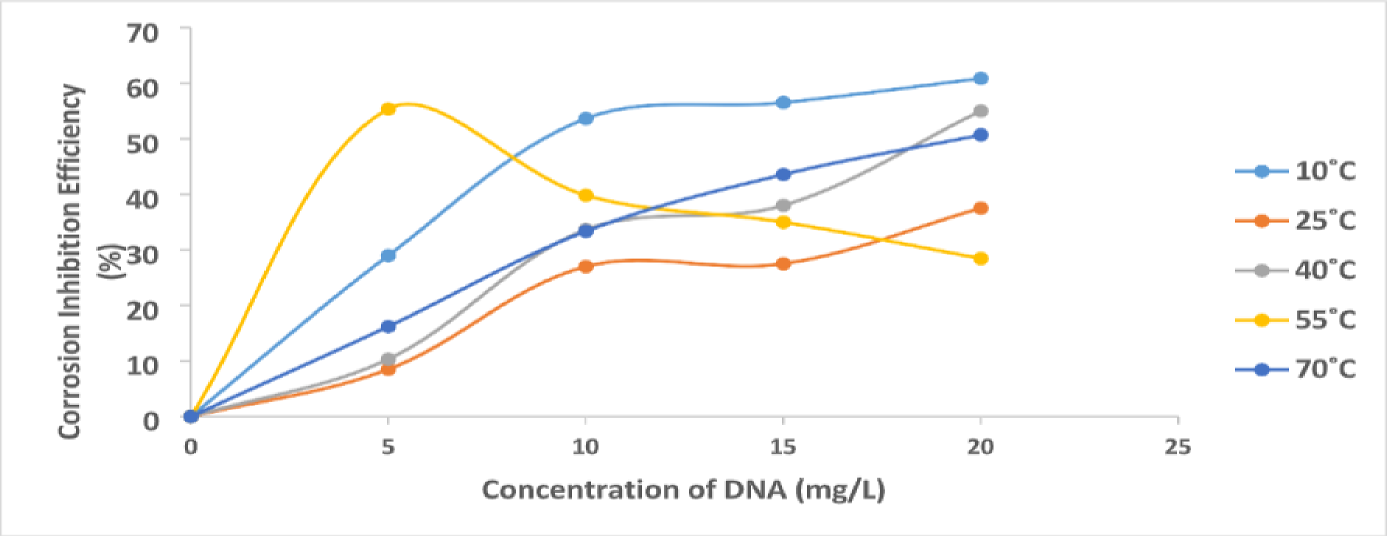

Figure 4.6: Corrosion Inhibition Efficiency vs. Concentration of Hybrid of Musa acuminate and *Musa paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

Hermodynamic Functions of Activation

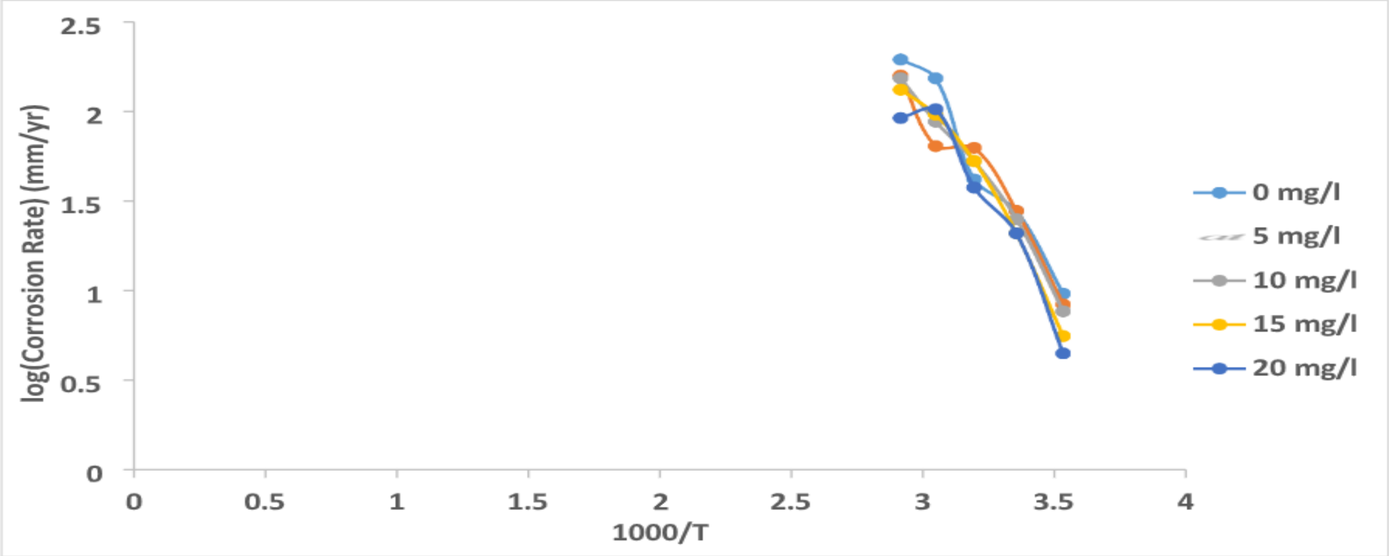

Figure 4.7: log (Corrosion Rate) vs. (1000/T) of *Musa acuminate* DNA inhibitor at varying concentration (0-20 mg/L)

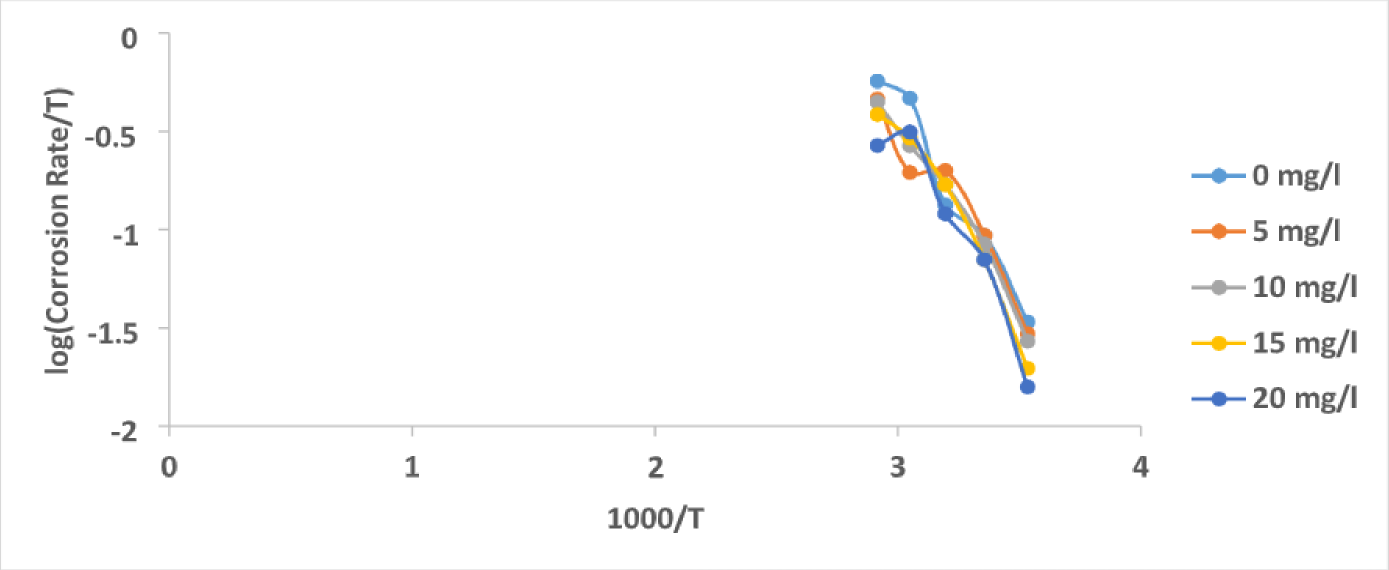

Figure 4.8: log (Corrosion Rate/T) vs. (1000/T) of *Musa acuminate* DNA inhibitor at varying concentration (0-20 mg/L)

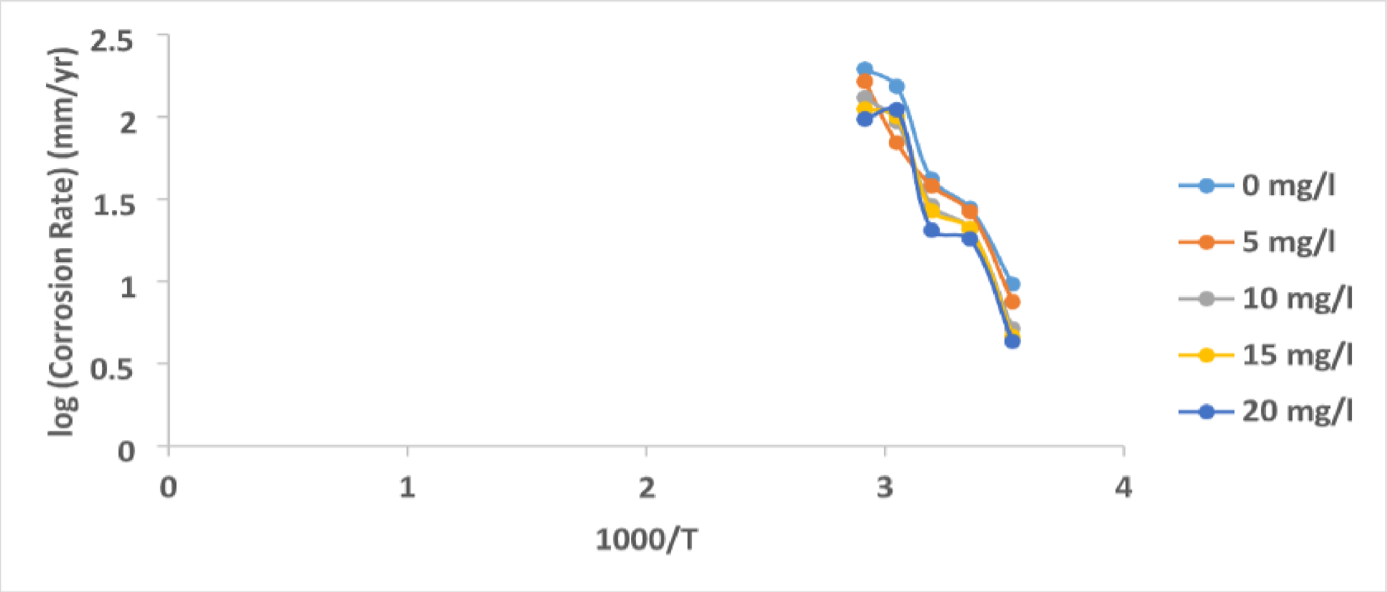

Figure 4.9: log (Corrosion Rate) vs. (1000/T) of *Musa Paradisiaca* DNA inhibitor at varying concentration (0-20 mg/L)

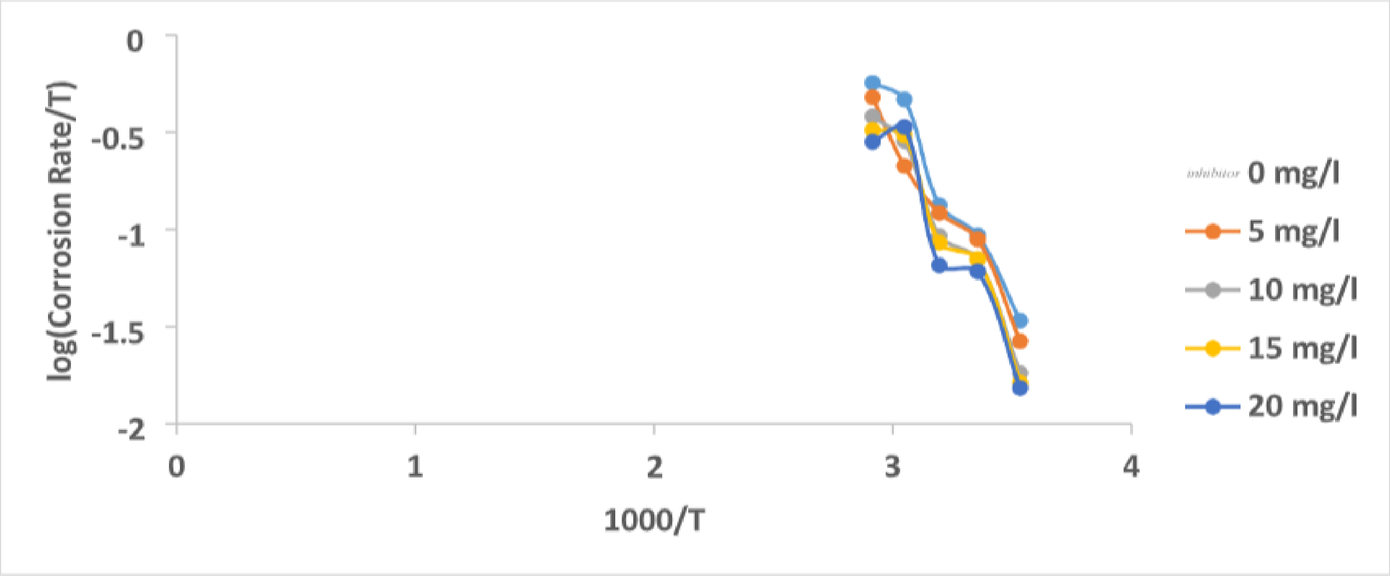

Figure 4.10: log (Corrosion Rate/T) vs. (1000/T) of *Musa Paradisiaca* DNA inhibitor at varying concentration (0-20 mg/L)

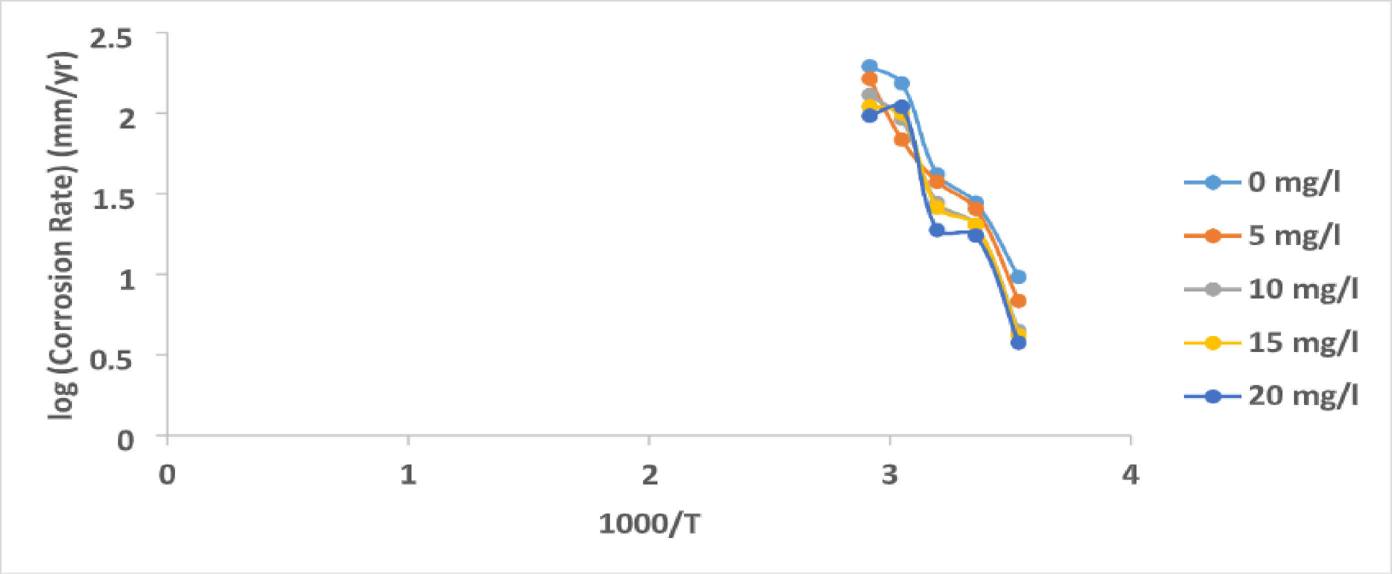

Figure 4.11: log (Corrosion Rate) vs. (1000/T) of Hybrid of *Musa acuminate* and *Musa paradisiaca* DNA inhibitor at varying concentration (0-20 mg/L)

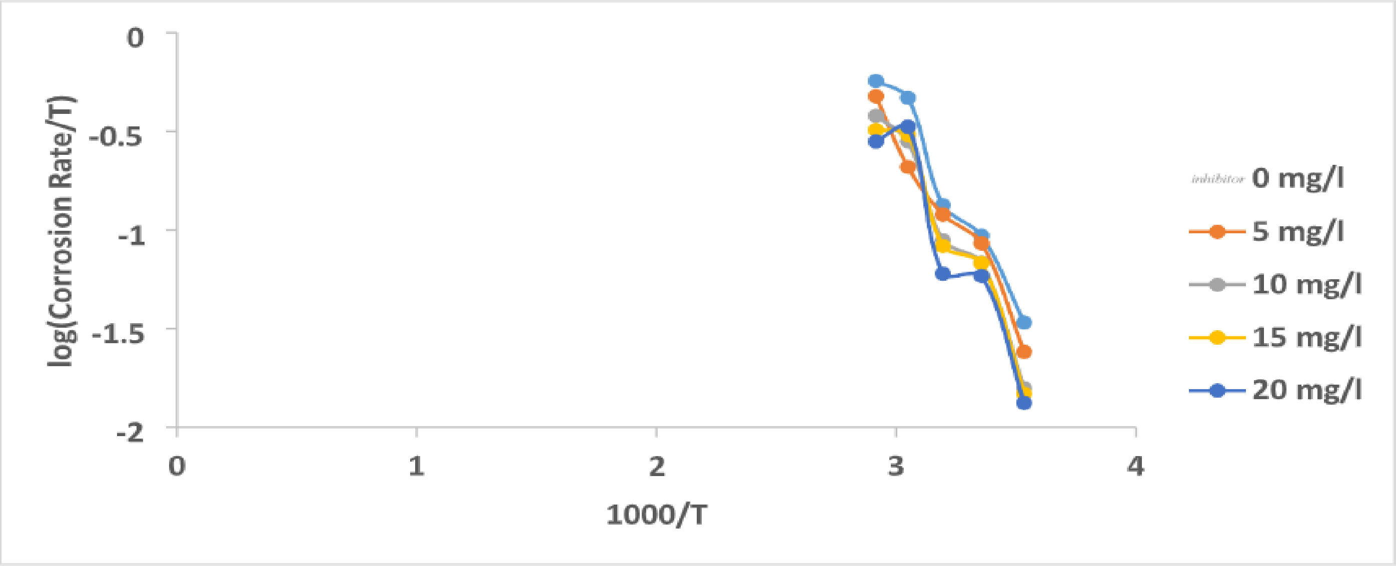

Figure 4.12: log (Corrosion Rate/T) vs. (1000/T) of Hybrid of *Musa acuminate and Musa paradisiaca* DNA inhibitor at varying concentration (0-20 mg/L)

Adsorption Isotherms

Musa Acuminate

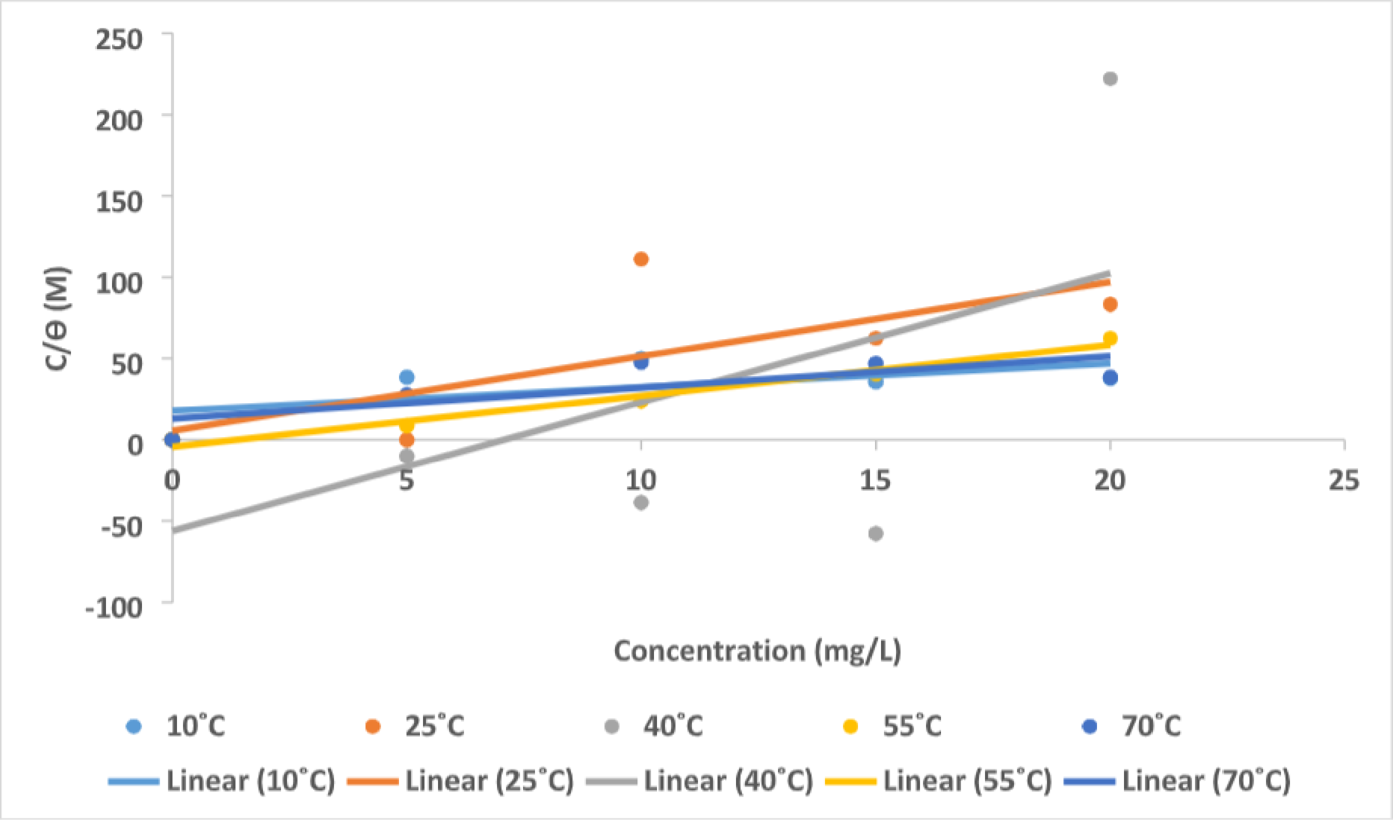

Figure 4.13: $\frac{C}{\theta}$ vs. Concentration of *Musa Acuminate* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

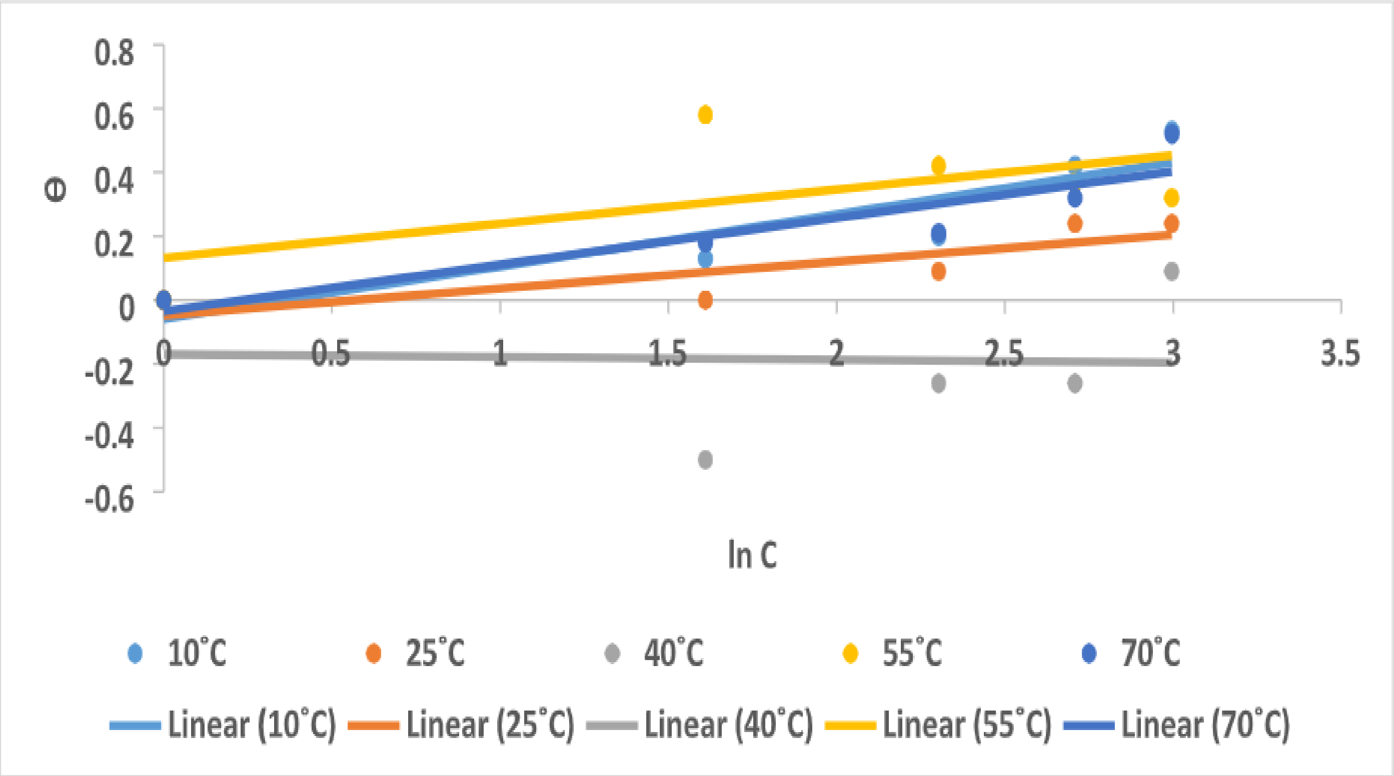

Figure 4.14: Θ vs. ln (Concentration) of *Musa Acuminate* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

Paradisiaca

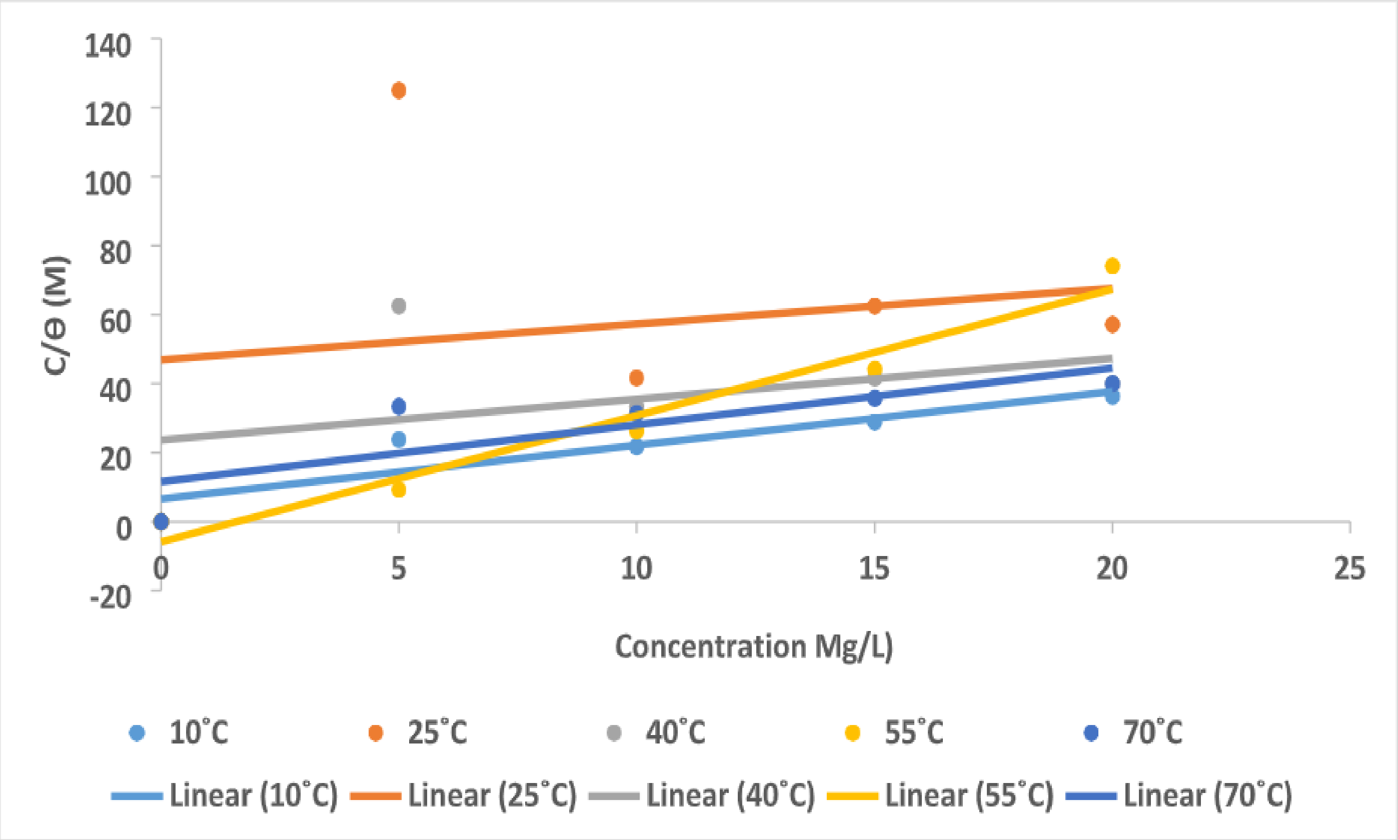

Figure 4.15: $\frac{C}{\theta}$ vs. Concentration of *Musa Paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

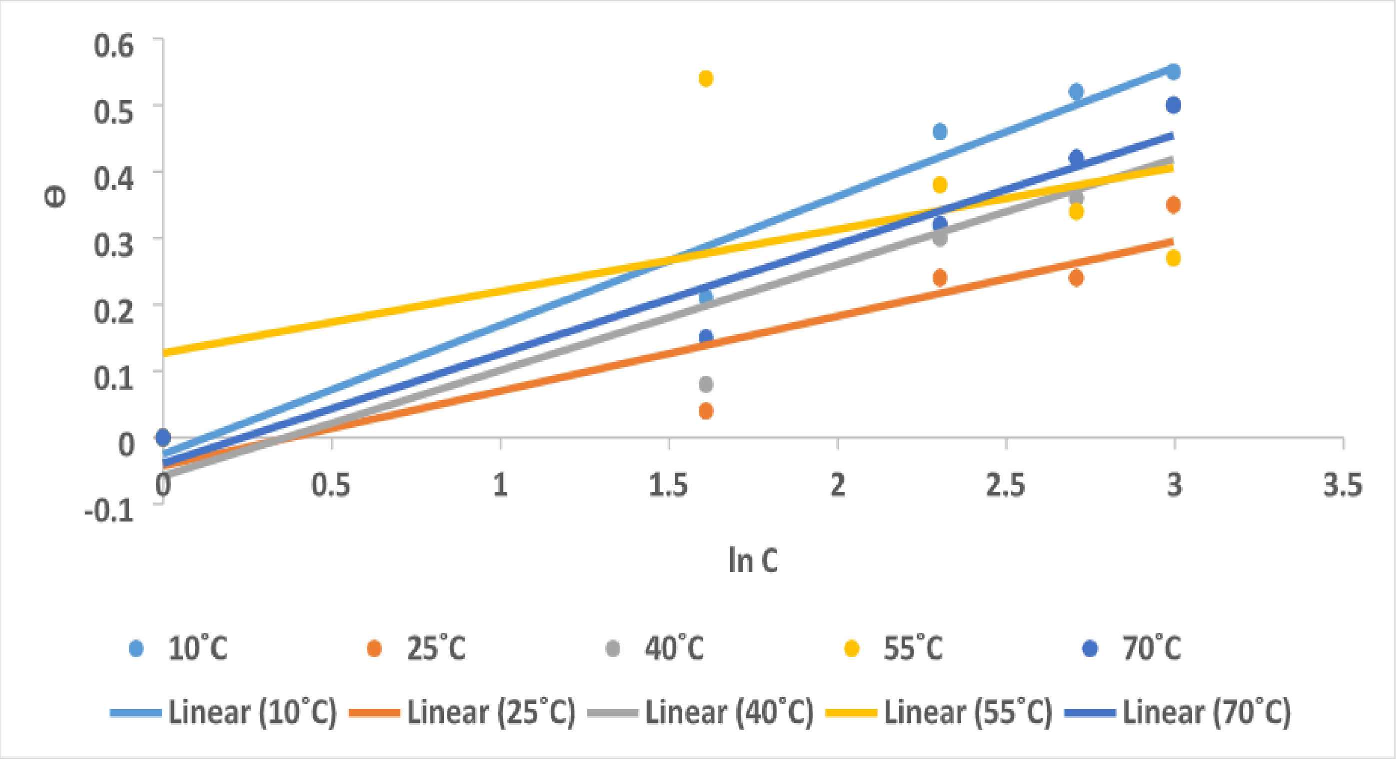

Figure 4.16: ϴ vs. ln (Concentration) of *Musa Paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

4.0.1 Hybrid of *Musa Acuminate* and *Musa Paradisiaca*

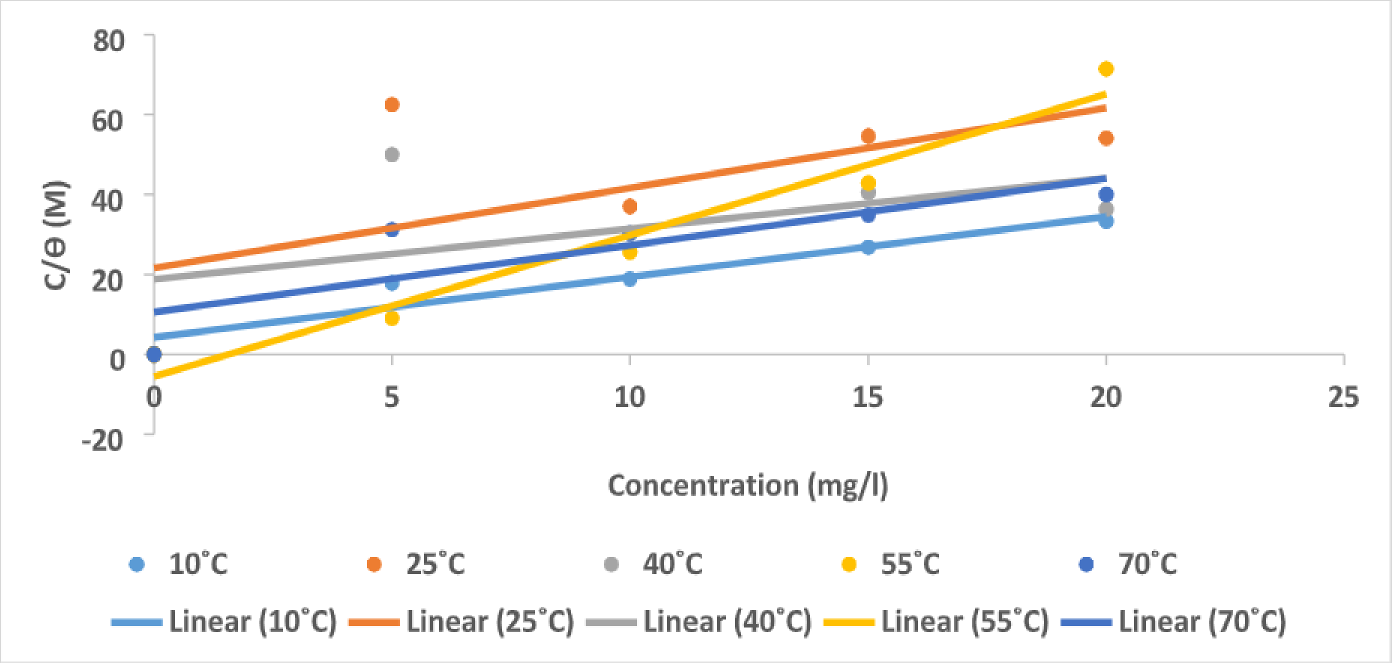

Figure 4.17: $\frac{C}{\theta}$vs. Concentration of hybrid of *Musa Acuminate* and *Musa Paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

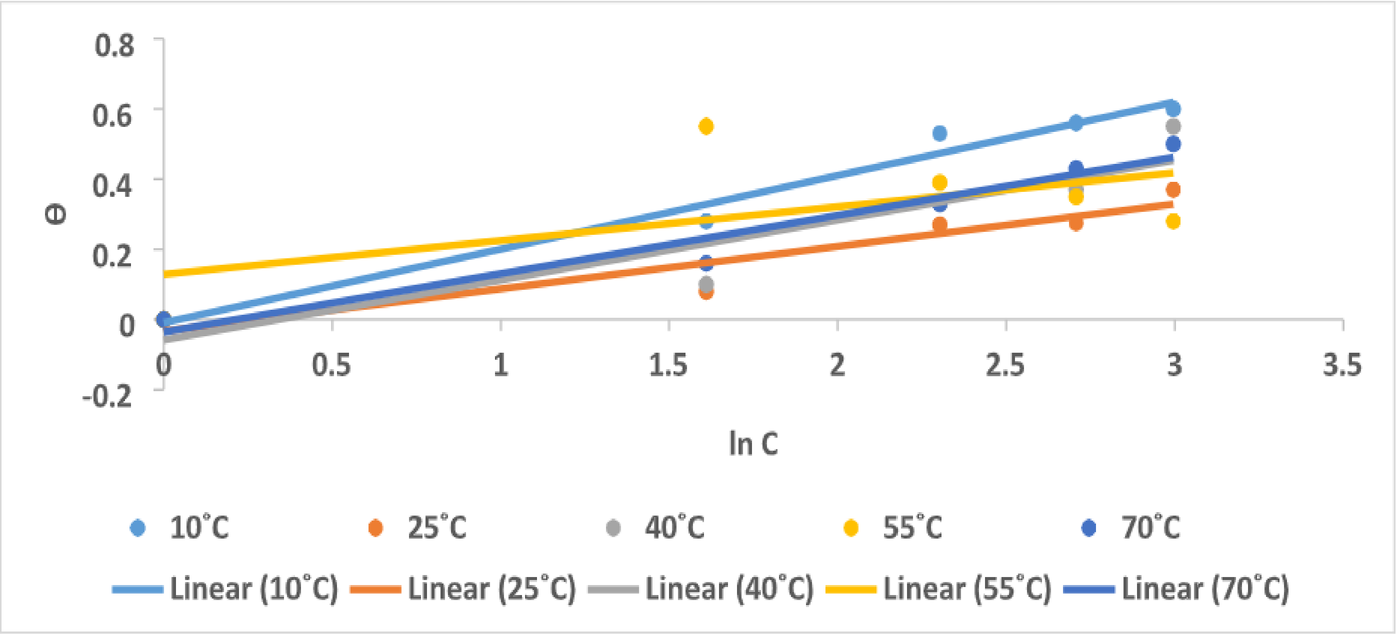

Figure 4.18: Ө vs. ln (Concentration) of hybrid of *Musa Acuminate* and *Musa Paradisiaca* DNA inhibitor at intervals of 15˚C for a temperature range of 10˚C-70˚C

Discussion of Results

Gravimetric Analysis

Weight loss method also known as gravimetric analysis (Section 3.4.1) was used for this project. Appendix A-1 to A-3, B-1 to B-3 and C-1 to C-3 show the results obtained and were used to plot the relevant graphs above using Microsoft Excel 2013. From the plots of corrosion rate (Figure 4.1, 4.3 and 4.5) it was observed that the corrosion rates of the metal samples increased with increasing temperature but decreased with increasing concentration. From this observation, it can be stated that the concentration of an inhibitor present in a corrosive medium is inversely proportional to the corrosion rate of the metal and directly proportional to the corrosion inhibition efficiency. This shows that the hybrid of *Musa Acuminate* and *Musa Paradisiaca* used as a DNA corrosion inhibitor is effective as the highest inhibition efficiency obtained was 60.8697% at the conditions, 10˚C and 20 mg/L. This result proves that temperature and concentration are fundamental factors in the rate of a reaction.

Although most of the samples follow the expected trend, samples using *Musa acuminate* DNA corrosion inhibitor at 40˚C and all samples at 55˚C exhibited anomalous behaviour. At 40˚C, corrosion was being aided with decreasing aid up until the concentration of 20 $\mathbf{mg}/\mathbf{L}$ where corrosion inhibition began. At 55˚C for both samples of DNA and the hybrid, it was observed that the rate of corrosion decreased after 5 $\mathbf{mg}/\mathbf{L}$ before gradually rising up slowly.

Linear Polarization Resistance

Data acquired from the linear polarization experiments (Appendix H-1 and H-2) were used to plot the Tafel polarization graphs (Figure 4.23 – 4.35). From the plots, the inhibitor is shown to be efficient because of the displacements present in the curves. Corrosion inhibition efficiency can be calculated from data extracted from the software NOVA 2.1 that was used to perform the polarization experiments by using the equation below:

$$\textit{Corrosion inhibition efficiency (\%)} = \frac{R_p - R_p^*}{R_p} \, X\ 100 \qquad \textit{Equation 4.1}$$

Where,

$\boldsymbol{R_p}$ = Polarization resistance with inhibitor

$\boldsymbol{R_p^*}$ = Polarization resistance without inhibitor

From the Tafel polarization plots of Figure 4.29 – 4.43, anodic and cathodic curves indicating that the inhibitors act as a mixed type inhibitor that affects both anodic and cathodic reactions.

Conclusion

From this research I conclude that,

- *Musa paradisiaca* DNA is a better corrosion inhibitor than *Musa acuminate* and the hybrid of *Musa acuminate and Musa paradisiaca* is a better corrosion inhibitor than both of them individually.
- The highest corrosion inhibition efficiency for *Musa acuminate* DNA was 58.1818% at the conditions, 55˚C and 5 $\mathbf{mg}/\mathbf{L}$ while for *Musa paradisiaca* DNA, the highest corrosion inhibition efficiency was 55.0720% at the conditions, 10˚C and 20 $\mathbf{mg}/\mathbf{L}$ and for the hybrid, the highest corrosion inhibition efficiency was 60.8697% at the conditions, 10˚C and 20 $\mathbf{mg}/\mathbf{L}$.
- The concentration of DNA present in the corrosive medium is inversely proportional to the corrosion rate and directly proportional to the corrosion inhibition efficiency.

Recommendation

I recommend that,

- The metal samples be immersed in the corrosive medium for a longer period of time. This will provide a better understanding of the corrosion rate because the metal sample would have acclimatized to the corrosive medium.
- The concentration of DNA used in the corrosive medium be increased inorder to achieve very high corrosion inhibition efficiencies.

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