Synthesis, Evaluation of Substituent Effect and Antimicrobial Activities of Substituted \((E)-1-(3\text{-bromo-4-morpholinophenyl})-3\text{-phenylprop-2-en-1-one\ Compounds\}}

Selvaraj Balaji\(^a\), Murugan Rajarajan\(^a\), Renganathan Vijayakumar\(^a\), Venkatesan Manikandan\(^a\), Rajamohan Senbagam\(^a\), Ganesan Vanangamudi\(^a\),*(b)*, Ganesamoorthy Thirunarayanab

\(^a\)PG & Research Department of Chemistry, Government Arts College, C. Mutlur, Chidambaram-608 102, India.
\(^b\)Department of Chemistry, Annamalai University, Annamalainagar-608 002, India.

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**Abstract:** A series of ten substituted \((E)-1-(3\text{-bromo-4-morpholinophenyl})-3\text{-phenylprop-2-en-1-one\ compounds were synthesized by Crossed-Aldol condensation of 3-bromo-4-morpholino acetonophene with various substituted and unsubstituted benzaldehydes in presence of sodium hydroxide. The entire ten compounds are novel and these have been newly synthesized compounds. The synthesized substituted 3-phenylprop-2-en-1-one were characterized by their physical constants and UV, IR, NMR spectral data. These observed UV absorption maximum \((\lambda_{\text{max}} \text{nm})\) value. The group frequencies of infrared absorption (cm\(^{-1}\)) of vCO s-cis and s-trans, deformation modes of vCH out of plane and in-plane, vCH=CH out of plane, v=C=C out of plane values, \(\Delta C\) chemical shifts (ppm) carbonyl carbons and vinyl protons, \(\Delta C\) chemical shifts (ppm) carbonyl carbons and vinyl carbons values were correlated with various Hammett substituent constants, and Swain-Lupton parameters using single and multi-regression analyses. From the results of statistical analysis, the effects of substituents on the functional group frequencies were studied. The antimicrobial activities of these synthesized substituted \((E)-1-(3\text{-bromo-4-morpholinophenyl})-3\text{-phenylprop-2-en-1-one\ ones have been screened using Kirby-Bauer method.**

**Keywords:** synthesis; UV; IR; NMR; spectral correlation analysis; substituent effects; antimicrobial activities

1. **INTRODUCTION**

Prop-2-en-1-ones are \(\alpha\), \(\beta\)-unsaturated ketones consist of two aromatic rings having diverse array of substituent. Aromatic rings are interconnected by a highly electrophilic three carbon \(\alpha\), \(\beta\)-unsaturated carbonyl system, which assumes linear or nearly planar structure [1]. Prop-2-en-1-ones \((\text{trans}-1, 3\text{-diaryl-2-propen-1-ones}),\) belongings to flavanoid family are precursors of open chain flavonoids and isoflavonoids.

Many prop-2-en-1-ones have been used as agrochemicals and drugs [2-6]. Prop-2-en-1-ones are 1, 3 diaryl-2-propen-1-ones are available in the flavonoids family contains medicinal effect like antimicrobial [7], anti-inflammatory [8], analgesic [9], anti-ulcerative [10], immune-modulatory [11], antimalarial [12], anti-cancer [13], antiviral [14], antileishmanial [15], anti-oxidant [16], anti-tubercular [16,17] and anti-hyperglycemic [18].

Since prop-2-en-1-one compounds have anti-oxidant activity prevents and counteracts the damage of the human issue by the normal effects of physiological oxidation [19]. Presence of the keto ethylenic group \((-\text{CO-CH=CH-}\)) in the prop-2-en-1-ones [20] and their analogues possesses the antioxidant activity. Prop-2-en-1-one compounds that associated with the antioxidant properties are hydroxyl and phenyl group [21].

Various methods are available for the synthesis of prop-2-en-1-one compounds the most convenient method is the one that involves the Crossed-Aldol condensation method, Crossed-Aldol condensation of equimolar quantities of acetylated aliphatic or aromatic ketone compounds with substituted benzaldehydes in the presence of aqueous alcoholic base [22]. Spectral data values are useful for study of effect of substituents using Hammett substituent constants, \(F\) and \(R\) parameters by single and multi-regression analysis. Chemists in recent year have synthesized and studied spectral correlations of pyrazolines [21], some aryl

\(\text{*Corresponding author. E-mail: balaji.s.cdm@gmail.com}\)
prop-2-en-1-ones [23-24] and Schiff bases [25]. In such case, satisfactory correlations were observed with Hammett substituent constants, $F$ and $R$ parameters. Literature survey shows that there is no information available regarding the study of UV, IR and NMR spectral data and correlation of substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds. Therefore, the authors have taken efforts to synthesis $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds from 3-bromo-4-morpholino acetophenone with various substituted and unsubstituted benzaldehydes by crossed-aldol condensation reaction. The various spectral data of these substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have been utilized for studying the quantitative structure activity relationships through Hammett correlations. The antimicrobial activity of the entire synthesized substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-ones have been screened using Kirby-Bauer [26] method.

2. MATERIAL AND METHODS

2.1. General

All the used chemicals were purchased from Sigma-Aldrich, E-Merck and Himedia Chemical Companies. Melting points of all synthesized substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-ones were observed in open glass capillaries on Mettler FP51 melting point apparatus and were uncorrected.

The Shimadzu-1650 ultraviolet spectrophotometer was utilized for recording the absorption maxima ($\lambda_{\text{max}}$, nm) of all substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-ones in spectral grade methanol. Infrared spectra (KBr, 4000–400 cm$^{-1}$) of all substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one were recorded in Shimadzu-2010 Fourier Transform Spectrophotometer. The NMR spectra of $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one were recorded in Bruker AV500 NMR spectrometer operating at 500 MHz and remaining nine substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-ones were recorded in Bruker AV400 NMR spectrometer operating at 400 MHz for $^1$H and 100 MHz for $^{13}$C spectra recorded in CDCl$_3$ solvent using TMS as internal standard.

2.2. General procedure for synthesis of $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds

A mixture of 3-bromo-4-morpholino acetophenone (0.05 mol) and benzaldehyde (0.05 mol) was dissolved in 50 mL rectified spirit in a 250mL round-bottom flask equipped with a magnetic stirrer. Then 50 mL NaOH solution (1g in 50 mL H$_2$O) was added drop wise to the reaction mixture on vigorous stirring for 30 minutes [27]. The reaction mixture was neutralized by the addition of 0.1N HCl, and then the precipitate was obtained. On filtering off, the crude $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compound was obtained and dried in air-ooven and recrystallized from rectified spirit to get glittering yellow color solid. Their melting points have been observed. The general reaction is shown in Scheme 1. The same procedure has been followed to synthesise the remaining nine more substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds using different substituted benzaldehydes.

The physical constants and analytical data are presented in Table 1. The UV, IR and NMR spectral value of these prop-2-en-1-ones are presented in Table 2.

Scheme 1. Synthesis of substituted $(E)$-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.
3. RESULTS AND DISCUSSION

3.1. Spectral linearity

In the present investigation, the spectral linearity of all the substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-ones was studied by evaluating the substituent effects [28-29] with respect to various spectral data. The assigned spectral data of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-ones such as absorption maximum \( \lambda_{\text{max}} \) (nm), infrared carbonyl stretches of \( \nu \text{CO} \) s-cis and s-trans, the deformation modes of \( \text{CH out of plane, in-plane, CH=CH and } \text{C=C out of planes} \) (cm\(^{-1}\)), NMR chemical shifts \( \delta \) (ppm) values of \( H_a, H_b, C_a, C_b, CO \) are assigned and these data are correlated with Hammett substituent constants and \( F \) and \( R \) parameters.

The Hammett correlation gives positive \( \rho \) value some cases and negative \( \rho \) value reaming cases. The positive \( \rho \) value indicates operation of normal substitution effect and negative \( \rho \) value indicates operation of reverse substituent effect.

3.1.1. UV spectral study

The absorption maxima \( (\lambda_{\text{max}} \text{ nm}) \) of synthesized substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds were assigned and presented in Table 2. These absorption maxima \( (\lambda_{\text{max}} \text{ nm}) \) of these substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one were correlated with Hammett substituent constants \([30-35]\) and \( F \) and \( R \) parameters \([36]\) using single and multi-linear regression analyses. Hammett correlation involving the absorption maxima, form the Hammett equation employed is

\[
\lambda = \rho \sigma + \lambda_o
\]  

where \( \lambda_o \) is the absorption maximum of the unsubstituted system.

These observed absorption maxima \( (\lambda_{\text{max}} \text{ nm}) \) of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have been correlated with Hammett substituent constants and \( F \) & \( R \) parameters and the results are shown in Table 3. From the Table-3, it is evident that the UV absorption maximum \( \lambda_{\text{max}} \) (nm) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds, except that with 3-NO\(_2\) substituent have shown satisfactory correlations with only \( R \) parameter \((r = 0.906)\). The 3-NO\(_2\) substituent that has been given exception is included in regression it reduces the correlations considerably. However, UV absorption maximum \( \lambda_{\text{max}} \) (nm) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown poor correlations \((r < 0.900)\) with all the Hammett substituent constants \( \sigma, \sigma^*, \sigma_b, \sigma_s \) and \( F \) parameter. This is attributed to the weak polar, inductive and field effect of the substituents for predicting their reactivity on the UV absorption maximum values through resonance as per the conjugative structure shown in Figure 1.

![Figure 1. Resonance conjugative structure.](image-url)
Table 2. The ultraviolet absorption maxima ($\lambda_{\text{max}}$, nm), infrared frequencies ($\nu$, cm$^{-1}$) and NMR chemical shifts ($\delta$, ppm) values of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

| Entry | $\delta_{\text{CO}}$ | X  | $\lambda_{\text{max}}$ | $\nu_{\text{CO}}(\text{cis})$ | $\nu_{\text{CO}}(\text{trans})$ | $\nu_{\text{CH}}$ | $\nu_{\text{CH}}$ | $\nu_{\text{CH}=\text{CH}}$ | $\nu_{\text{C}=$C=O$}$ | $\delta_{\alpha}$ | $\delta_{\beta}$ | $\delta_{\text{C}}$ | $\delta_{\text{C}}$
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Table 3. Results of statistical analysis of UV absorption maxima ($\lambda_{\text{max}}$, nm), IR frequencies (ν, cm$^{-1}$) and NMR chemical shifts (δ, ppm) values of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds with Hammett σ, σ', σI, σR and F and R parameters.

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<th>Frequency</th>
<th>Const.</th>
<th>r</th>
<th>I</th>
<th>σ</th>
<th>ρ</th>
<th>s</th>
<th>n</th>
<th>Correlated derivatives</th>
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<td>νCO$_{\text{en}}$ (cm$^{-1}$)</td>
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<td>1648.57</td>
<td>4.43</td>
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<td>7</td>
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<tr>
<td></td>
<td>σ'</td>
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<td>2.05</td>
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<tr>
<td></td>
<td>σI</td>
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<td>1646.72</td>
<td>6.54</td>
<td>1.76</td>
<td>10</td>
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<td>4.79</td>
<td>4.35</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ₁</td>
<td>0.814</td>
<td>1034.46</td>
<td>-2.95</td>
<td>4.90</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σR</td>
<td>0.917</td>
<td>1037.13</td>
<td>15.56</td>
<td>3.36</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.817</td>
<td>1034.61</td>
<td>-3.08</td>
<td>4.88</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0.812</td>
<td>1033.71</td>
<td>1.76</td>
<td>4.92</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vC=CH₂ (cm⁻¹)</td>
<td>σ</td>
<td>0.825</td>
<td>512.40</td>
<td>-2.89</td>
<td>7.30</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ⁺</td>
<td>0.803</td>
<td>511.70</td>
<td>5.38</td>
<td>6.85</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ₁</td>
<td>0.805</td>
<td>511.84</td>
<td>0.16</td>
<td>7.35</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σR</td>
<td>0.803</td>
<td>514.34</td>
<td>10.01</td>
<td>6.97</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.606</td>
<td>511.22</td>
<td>1.67</td>
<td>7.34</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0.906</td>
<td>509.26</td>
<td>-13.06</td>
<td>5.79</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>δHs(ppm)</td>
<td>σ</td>
<td>0.906</td>
<td>7.517</td>
<td>0.15</td>
<td>0.048</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ⁺</td>
<td>0.915</td>
<td>7.540</td>
<td>0.077</td>
<td>0.054</td>
<td>9</td>
<td>H, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ₁</td>
<td>0.795</td>
<td>7.520</td>
<td>0.06</td>
<td>0.065</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σR</td>
<td>0.906</td>
<td>7.587</td>
<td>0.174</td>
<td>0.053</td>
<td>9</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.823</td>
<td>7.520</td>
<td>0.055</td>
<td>0.065</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0.938</td>
<td>7.558</td>
<td>0.074</td>
<td>0.061</td>
<td>7</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>δHs(ppm)</td>
<td>σ</td>
<td>0.793</td>
<td>7.810</td>
<td>0.107</td>
<td>0.138</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ⁺</td>
<td>0.804</td>
<td>7.824</td>
<td>0.131</td>
<td>0.125</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ₁</td>
<td>0.814</td>
<td>7.790</td>
<td>0.102</td>
<td>0.139</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σR</td>
<td>0.835</td>
<td>7.881</td>
<td>0.214</td>
<td>0.132</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.801</td>
<td>7.825</td>
<td>0.008</td>
<td>0.141</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0.814</td>
<td>7.840</td>
<td>0.058</td>
<td>0.140</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>δCO(ppm)</td>
<td>σ</td>
<td>0.958</td>
<td>188.06</td>
<td>-1.065</td>
<td>0.156</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ⁺</td>
<td>0.970</td>
<td>187.90</td>
<td>-0.575</td>
<td>0.221</td>
<td>10</td>
<td>H, 3-Br, 4-Br, 3-Cl, 1- F, 4-F, 4-OCH₃, 4-CH₃, 3-NO₂, 3-OCH₃</td>
<td></td>
</tr>
</tbody>
</table>
All the correlations have been shown negative ρ values. This indicates the operation of reverse substituent effect with respect to UV absorption maximum $\lambda_{max}$ (nm) values in all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds. Since most of the single parameter correlations poor with all Hammett constants and $F$ parameter, so it is decided to go for multi regression analyses. While seeking the multi regression analysis, satisfactory correlations are observed as shown in the following equations (2) and (3).

$$
\lambda_{max}(\text{nm}) = 354.370(\pm 9.019) - 14.566(\pm 4.855)\sigma_1 - 32.888(\pm 10.962)\sigma_R
$$

(2)

(R = 0.953, n=10, P<95%)

$$
\lambda_{max}(\text{nm}) = 357.852(\pm 6.863) - 17.377(\pm 5.792)F - 30.557(\pm 10.185)R
$$

(3)

(R = 0.968, n=10, P<95%)

### 3.2. IR spectral study

The measured carbonyl stretching frequencies (cm$^{-1}$) of s-cis and s-trans isomers values are presented in Table-2 and the corresponding conformers were shown in Figure 2. The stretching frequencies for carbonyl absorption are assigned based on the assignments made by Hays and Timmons for s-cis and s-trans conformers at 1690 and 1670 cm$^{-1}$, respectively.

The IR frequency values are correlated with Hammett substituent constants [30-35] and Swain-Lupton’s parameters [36]. While seeking Hammett...
correlation involving group frequencies, the form of the Hammett equation employed is

\[ \nu = \rho \sigma + \nu_0 \]  

… (4)

where \( \nu_0 \) is the carbonyl frequencies of unsubstituted system.

![Figure 2. The s-cis and s-trans conformers of (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one observed compound.](image)

3. 2. 1. IR Spectral Correlation of \( \nu_{CO,cis} \) (cm\(^{-1}\))

The IR frequency \( \nu_{CO,cis} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds except those with 3-F, 4-F and 4-CH\(_3\) substituents have shown satisfactory correlation with Hammett substituent constant \( \sigma \) (\( r = 0.905 \)) only. When these substituents that have been given exception are included in regression they reduce the correlations considerably. The IR frequency \( \nu_{CO,cis} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown satisfactory correlations with Hammett substituent constant \( \sigma \) (\( r = 0.900 \)), \( \sigma^+ \) (\( r = 0.909 \)) and \( F \) (\( r = 0.908 \)) parameter. The remaining Hammett substituent constant \( \sigma_R \) and \( R \) parameter have shown poor correlations (\( r < 0.900 \)). This is attributed to the weak resonance effect of the substituents for predicting the reactivity on the IR frequency \( \nu_{CO,cis} \) (cm\(^{-1}\)) values through resonance as per the conjugative structure stated earlier. All the correlations (except \( \sigma_R \) and \( R \)) have shown positive \( \rho \) values. This indicates the operation of normal substituent effect with respect to IR frequency \( \nu_{CO,cis} \) (cm\(^{-1}\)) values in all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

3. 2. 2. IR Spectral Correlation of \( \nu_{CO,trans} \) (cm\(^{-1}\))

The IR frequency \( \nu_{CO,trans} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown poor correlations (\( r < 0.900 \)) with all Hammett substituent constants and \( F \) and \( R \) parameters. All the correlations (except \( R \) parameter) have shown positive \( \rho \) values. This indicates the operation of normal substituent effect with respect to IR frequency \( \nu_{CO,trans} \) (cm\(^{-1}\)) values in all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

3. 2. 3. IR Spectral Correlation of \( \nu_{CH_\beta} \) (cm\(^{-1}\))

The IR frequency \( \nu_{CH_\beta} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds except that with 3-NO\(_2\) substituent have shown satisfactory correlations with Hammett substituent constant \( \sigma_R \) (\( r = 0.905 \)). When the substituent that has been given exception is included in regression it reduces the correlations considerably. The IR frequency \( \nu_{CH_\beta} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown poor correlations with the remaining Hammett substituent constants \( \sigma \), \( \sigma^+ \), \( \sigma_R \) and \( F \) and \( R \) parameters. All the correlations (except \( \sigma^+ \) and \( \sigma_R \)) have shown positive \( \rho \) values. This is indicates the operation of normal substituent effect with respect to IR frequency \( \nu_{CH_\beta} \) (cm\(^{-1}\)) values in all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

3. 2. 4. IR Spectral Correlation of \( \nu_{CH_\alpha} \) (cm\(^{-1}\))

The IR frequency \( \nu_{CH_\alpha} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds except that with the 4-Br substituent have shown satisfactory correlation with Hammett substituent constant \( \sigma \) (\( r = 0.904 \)). When the substituent that has been given, exception is included in regression it reduces the correlation considerably. The IR frequency \( \nu_{CH_\alpha} \) (cm\(^{-1}\)) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown poor correlations with remaining Hammett substituent constant \( \sigma \), \( \sigma^+ \), \( \sigma_R \) and \( F \) and \( R \) parameters. All the correlations have shown positive \( \rho \) values. This is indicates the operation of normal substituent effect with respect to IR frequency \( \nu_{CH_\alpha} \) (cm\(^{-1}\)) values in all substituted (E)-1-(3-bromo-
4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

3.2.5. IR Spectral Correlation of νCH=CH_{OP} (cm⁻¹)

The IR frequency νCH=CH_{OP} (cm⁻¹) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown satisfactory correlations with Hammett substituent constant σᵣ (r = 0.917). The IR frequency νCH=CH_{OP} (cm⁻¹) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown poor correlations with the remaining Hammett substituent constant, σ, σ′, σ₁ and F and R parameters. All the correlations (except σ₂ and σ₃) have shown positive ρ values. This indicates the operation of normal substituent effect with respect to IR frequency νCH=CH_{OP} (cm⁻¹) values in all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

3.2.6. IR Spectral Correlation of νC=CoF (cm⁻¹)

The IR frequency νC=CoF (cm⁻¹) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown satisfactory correlations with Hammett substituent constant (r = 0.906). The IR frequency νC=CoF (cm⁻¹) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have shown poor correlations with the remaining Hammett substituent constant and F parameter. All the correlations (except σ and R) have shown positive ρ values. This indicates the operation of normal substituent effect with respect to IR frequency νC=CoF (cm⁻¹) values of all substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds. Most of the single regression analyses have shown poor correlation, so it is decided to go for multi-regression analysis. The multi-regression produced satisfactory correlations with Hammett substituent constants and F and R parameters [36]. The multi correlation equations are given in (5)-(16).

\[
\begin{align*}
\text{vCO}_{s-cis}(\text{cm}^{-1}) &= 1646.886(\pm1.271) + 7.154(\pm2.762)\sigma_1 + 0.969(\pm0.301)\sigma_R \quad …(5) \\
(R &= 0.971, \text{n}=10, P>95\%) \\
\text{vCO}_{s-trans}(\text{cm}^{-1}) &= 1646.389(\pm0.867) + 6.770(\pm1.912)F + 0.834(\pm0.278)R \quad …(6) \\
(R &= 0.983, \text{n}=10, P>95\%) \\
\text{vCO}_{s-\text{avg}}(\text{cm}^{-1}) &= 1596.735(\pm3.341) + 4.606(\pm1.535)\sigma_1 + 8.148(\pm2.716)\sigma_R \quad …(7) \\
(R &= 0.940, \text{n}=10, P>90\%) \\
\text{vCO}_{s-\text{avg}}(\text{cm}^{-1}) &= 1594.793(\pm2.463) - 0.545(\pm0.186)F - 9.468(\pm3.121)R \quad …(8) \\
(R &= 0.964, \text{n}=10, P>95\%) \\
\text{vCH}_p(\text{cm}^{-1}) &= 1189.554(\pm2.278) + 6.313(\pm1.950)\sigma_1 - 9.092(\pm3.030)\sigma_R \quad …(9) \\
(R &= 0.967, \text{n}=10, P>95\%) \\
\text{vCH}_p(\text{cm}^{-1}) &= 1191.896(\pm2.369) + 7.475(\pm2.491)F + 4.107(\pm1.369)R \quad …(10) \\
(R &= 0.949, \text{n}=10, P>90\%) \\
\text{vCH}_p(\text{cm}^{-1}) &= 770.794(\pm14.249) + 31.550(\pm10.516)\sigma_1 + 23.454(\pm7.818)\sigma_R \quad …(11) \\
(R &= 0.939, \text{n}=10, P>90\%) \\
\text{vCH}_p(\text{cm}^{-1}) &= 763.153(\pm11.651) + 41.748(\pm13.916)F + 16.548(\pm5.516)R \quad …(12) \\
(R &= 0.952, \text{n}=10, P>95\%) \\
\text{vCH}=\text{CH}_{sp}(\text{cm}^{-1}) &= 1037.103(\pm2.445) + 0.103(\pm0.034)\sigma_1 + 15.591(\pm5.197)\sigma_R \quad …(13) \\
(R &= 0.973, \text{n}=10, P>95\%) \\
\text{vCH}=\text{CH}_{sp}(\text{cm}^{-1}) &= 1034.648(\pm3.127) - 2.657(\pm0.885)F + 1.016(\pm0.338)R \quad …(14) \\
(R &= 0.925, \text{n}=10, P>90\%)
\end{align*}
\]
3. 3. NMR Spectral Study

In nuclear magnetic resonance spectra, the proton and the carbon chemical shifts ($\delta$) depends on the electronic environment of the nuclei concerned. The assigned proton and carbon chemical shifts value (ppm) have been correlated with Hammett substituent constants and F and R parameters using Hammett equation in the form of

$$
\delta = \rho \sigma + \delta_0 \quad \ldots (17)
$$

where $\delta_0$ is the chemical shift of unsubstituted system.

3. 3. 1. $^1$H NMR Spectral correlation

3. 3. 1.1. $^1$H NMR Spectral Correlations of $H_\alpha$ (ppm)

The assigned $H_\alpha$ chemical shift ($\delta$, ppm) values are correlated with Hammett substituted constants [30-35] and F and R parameters, all substituents have shown satisfactory correlation with Hammett substituent constant $\sigma$ ($r = 0.906$) except that with 3-Br substituent have shown satisfactory correlation with Hammett substituent constant $\sigma^-$ ($r = 0.915$) and except that with 3-NO$_2$ substituent have shown satisfactory correlation with Hammett substituent constant $\sigma_0$ ($r = 0.906$) and expect those with 3-F, 4-F and 3-C$_6$H$_5$ substituents have shown satisfactory correlation with R ($r=0.938$) parameter. When the substituent that has been given exception is included in regression it reduces the correlation considerably. The remaining few Hammett substituent constants $\sigma_0$, $\sigma_R$ and $F$ parameter [36] have shown poor correlations ($r < 0.900$). This is attributed to weak inductive, resonance and field effects of the substituents for predicting the reactivity on the chemical shifts through resonance as per the conjugative structure shown in Figure 1. All the correlations have shown positive $\rho$ values. This indicates the operation of normal substituent effect.

3. 3. 1.2. $^1$H NMR Spectral Correlations of $H_\beta$ (ppm)

The assigned $H_\beta$ chemical shifts ($\delta$, ppm) values are correlated with Hammett substituted constants and F and R parameters, all substituent have shown poor correlation with all Hammett substituent Constants and F and R parameters. This is due to incapability to the polar, inductive, resonance and field effect of the substituents. All the correlations have shown positive $\rho$ values. This indicates the operation of normal substituent effect.

Some of the single regression analysis has shown poor correlations with Hammett substituent constants and Swain-Lupton’s parameters [36]. It is decided to go for multi-regression, the multi-regression analysis produced satisfactory correlations with the chemical shifts of ($\delta$, ppm) $H_\alpha$ and $H_\beta$. The multi-correlation equations are given in (18)-(21).

$$
\delta H_\alpha(\text{ppm}) = 7.553(\pm0.0344) + 0.099(\pm0.033) \sigma_3 + 0.195(\pm0.078)\sigma_R \quad \ldots (18)
$$

$$
(R = 0.970, n=10, P>95\%)
$$

$$
\delta H_\alpha(\text{ppm}) = 7.523(\pm0.035) + 0.098(\pm0.032) F + 0.102(\pm0.034)R \quad \ldots (19)
$$

$$
(R = 0.955, n=10, P>95\%)
$$

$$
\delta H_\beta(\text{ppm}) = 7.832(\pm0.092) + 0.150(\pm0.050) \sigma_1 + 0.247(\pm0.082)\sigma_R \quad \ldots (20)
$$

$$
(R = 0.940, n=10, P>90\%)
$$

$$
\delta H_\beta(\text{ppm}) = 7.827(\pm0.089) + 0.037(\pm0.012) F + 0.069(\pm0.023) \quad \ldots (21)
$$

$$
(R = 0.915, n=10, P>90\%)
$$
3.3. 13C NMR spectral correlation

3.3.2. 13C NMR spectral correlation of δC_a carbon

The assigned C_a chemical shifts values (δ, ppm) correlated with Hammett substituent constants [30-35] and F and R parameters, except that with 3-NO_2 substituent have shown satisfactory correlation with Hammett substituent constant σ (r = 0.915). Except that with H (parent), and those with 4-CH_3 and 3-NO_2 substituents have shown satisfactory correlation with Hammett substituent constant σ_l (r = 0.900). When the substituent that has been given exception is included in regression it reduces the correlation considerably. The remaining few Hammett substituent constants σ^I, σ_R and F and R parameters have shown poor correlations (r < 0.900). This is attributed to weak inductive and resonance field effect of the substituents. This is due to the resonance effect of the substituents. All the correlations (except R) have shown positive ρ values. This indicates the operation of normal substituent effect.

3.3.2.2. 13C NMR spectral correlation of δC_b carbon

The assigned C_b chemical shifts values (δ, ppm) have correlated with Hammett substituent constants and F and R parameters. All the compounds expect that with 3-Br substituent have shown satisfactory correlation with Hammett substituent constant σ (r = 0.966), σ^I (r = 0.967), σ_l (r = 0.957) and F (r = 0.905) parameter. When the substituent that has been given exception is included in regression it reduces the correlation considerably. The remaining one Hammett substituent constants σ_R and R parameter [36] have shown poor correlations (r < 0.900). This is attributed to the resonance effect of the substituents. This is due to the reason stated earlier and associated with resonance- conjugative structure shown in Figure 1. All the correlations have shown negative ρ values. This indicates the operation of reverse substituent effect.

3.3.2.3. 13C NMR spectral correlation of δCO carbon

The assigned CO chemical shifts values (δ, ppm) are correlated with Hammett substituent constants and F and R parameters, all the substituents have shown satisfactory correlation with Hammett substituent constants σ (r = 0.958), σ^I (r=0.970), σ_l (r = 0.974). The remaining one Hammett substituent constants σ_R and F and R parameters have shown poor correlations (r < 0.900). This is attributed to the resonance and field effect of the substituents. All the correlations have shown negative ρ values. This indicates the operation of reverse substituent effect. Some of the single regression analysis have shown poor correlations with Hammett substituent constants and Swain-Lupton’s parameters [36]. So it is decided to go for multi-regression, the multi-regression analysis produce satisfactory correlations with the chemical shifts of (δ, ppm) C_a, C_b and CO. The multi correlation equations are given in (22)-(27).

\[
\delta C_a (ppm) = 121.283(±0.950) + 2.837(±0.945)\sigma_I + 0.785(±0.261)\sigma_R \\
(R = 0.946, n=10, P>90%) \tag{22}
\]

\[
\delta C_a (ppm) = 121.334(±0.861) + 2.273(±0.757) F + 0.540(±0.180)R \\
(R = 0.941, n=10, P>90%) \tag{23}
\]

\[
\delta C_b (ppm) = 143.158(±0.661) - 4.778(±1.592)\sigma_I - 2.134(±0.713)\sigma_R \\
(R = 0.978, n=10, P>95%) \tag{24}
\]

\[
\delta C_b (ppm) = 143.052(±0.755) - 3.381(±1.127) F - 1.086(±0.362)R \\
(R = 0.960, n=10, P>95%) \tag{25}
\]

\[
\delta CO (ppm) = 188.172(±0.087) - 1.320(±0.440)\sigma_I - 0.830(±0.276)\sigma_R \\
(R = 0.994, n=10, P>95%) \tag{26}
\]

\[
\delta CO (ppm) = 188.238(±0.139) -1.074(±0.307) F - 0.403(±0.134)R \\
(R = 0.978, n=10, P>95%) \tag{27}
\]
3.4. Antimicrobial activity

All the synthesized substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds were dissolved in Dimethyl sulfoxide (DMSO) separately at the concentration of 250 μg/mL for antimicrobial assay.

3.4.1. Antibacterial sensitivity assay

The antibacterial activities of all synthesized substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have been studied against five gram positive pathogenic strains *Bacillus subtilis*, *Clostridium botulinum*, *Staphylococcus aureus*, *Nocardia species* and *Enterococcus* species and five gram negative pathogenic strains *Escherichia coli*, *Klebsiella pneumonia*, *Proteus mirabilis*, *Salmonella typhi* and *Vibrio cholerae* have been studied by Kirby-Bauer method. Ciprofloxacin was used as standard.

The antibacterial screening effect of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds is shown in Figure 3 (Plates 1–20). The measured zone of inhibition values are given in Table 4 and the corresponding clustered column chart is shown in Figure 3. The zone of inhibition (mm) values of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds reveals that most of the compounds have shown moderate, good and excellent (some of the poor) activity against all the ten microorganisms evaluated in the present investigation. The 4-OCH₃ substituted compounds has shown excellent activity against *E. species*, *E. coli* and *P. mirabilis*. The 3-NO₂ substituted compound has shown excellent activity against *B. subtilis*, *E. coli* and *P. mirabilis*. The 3-Br substituted compound has shown excellent activity against *C. bululini* and *S. typhi*. The 4-F substituted compound has shown excellent activity against *Enterococcus species* and *E. coli*. The 3-OC₆H₅ substituted compound has shown excellent activity against *E. coli* and *P. mirabilis*. The H (parent) and 4-Br substituted compounds have shown excellent activity against *S. typhi*. The 3-Cl substituted compound has shown excellent activity against *P. mirabilis*. The 4-CH₃ substituted compound has shown excellent activity against *E. coli*. The remaining substituted compounds have shown good and moderate antibacterial activity.

**Table 4.** Zone of inhibition (mm) values of antibacterial activity of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Substituents</th>
<th>Gram positive Bacteria</th>
<th>Gram negative Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>B. subtilis</em></td>
<td><em>C. botulinum</em></td>
</tr>
<tr>
<td>1</td>
<td>H</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>3-Br</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>4-Br</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>3-Cl</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>3-F</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>4-F</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>4-OCH₃</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>4-CH₃</td>
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<td>0</td>
</tr>
<tr>
<td>9</td>
<td>3-NO₂</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>3-OC₆H₅</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Standard</td>
<td>Ciprofloxacin</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Control</td>
<td>DMSO</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 3. Antibacterial activity of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds (petri plates).
3.4.2 Antifungal Sensitivity Assay

The antifungal activities of all synthesized substituted \((E)\)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds have been studied against five fungal species namely \(A.\ niger\), \(A.\ flavus\), \(C.\ albicans\), \(T.\ viride\) and \(M.\ species\). The disc diffusion technique has been followed using the Kirby–Bauer method [25], Micnazole was used as standard. The antifungal screening effect of prepared substituted \((E)\)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds is shown in Figure 5, (Plates 21–30). The measured zone of inhibition values are given in Table 5 and the corresponding Clustered column chart is shown in Figure 6. All the compounds have shown moderate, good and excellent activity against all the five fungal species evaluated in general.

The 4-OCH\(_3\) and 3-NO\(_2\) substituted compounds have shown good activity against \(A.\ niger\). The 4-CH\(_3\) substituted compound has shown excellent activity against \(A.\ flavus\). 4-F, 4-OCH\(_3\), 3-NO\(_2\) and 3-OC\(_6\)H\(_5\) substituted compounds have shown good activity against \(A.\ flavus\). The 4-OCH\(_3\) and 3-NO\(_2\) substituted compounds have shown excellent activity against \(C.\ albicans\). The 4-CH\(_3\) substituted prop-2-en-1-ones has shown good activity against \(C.\ albicans\). The 3-Cl, 4-Br, 3-Cl and 3-F substituted have shown excellent activity against \(T.\ viride\). The 4-CH\(_3\) substituted has shown good activity against \(T.\ viride\). The 4-Br and 4-F substituted prop-2-en-1-ones have shown excellent activity against \(M.\ species\). The 3-F and 4-CH\(_3\) against substituted compound have shown good activity against \(M.\ species\).

![Figure 4. Antibacterial activity of substituted (\(E\))-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds (clustered column chart).](image)

| Table 5. Zone of inhibition (mm) values of antifungal activities of substituted \((E)\)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds. |
|---|---|---|---|---|---|
| Entry | Substituents | \(A.\ niger\) | \(A.\ flavus\) | \(C.\ albicans\) | \(M.\ species\) | \(T.\ viride\) |
| 1 | H | 7 | 0 | 7 | 13 | 0 |
| 2 | 3-Br | 9 | 0 | 7 | 13 | 0 |
| 3 | 4-Br | 0 | 0 | 0 | 15 | 13 |
| 4 | 3-Cl | 0 | 0 | 0 | 17 | 0 |
| 5 | 4-F | 0 | 7 | 0 | 15 | 9 |
| 6 | 4-OCH\(_3\) | 0 | 0 | 7 | 0 | 11 |
| 7 | 4-CH\(_3\) | 13 | 9 | 13 | 0 | 7 |
| 8 | 3-NO\(_2\) | 11 | 11 | 9 | 11 | 9 |
| 9 | 4-NO\(_2\) | 13 | 9 | 13 | 0 | 0 |
| 10 | 3-OC\(_6\)H\(_5\) | 0 | 9 | 7 | 0 | 9 |
| Standard | micnazole | 17 | 11 | 9 | 9 | 11 |
| Control | DMSO | 0 | 0 | 0 | 0 | 0 |
Figure 5. Antifungal activity of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one (petri plates).
4. CONCLUSION

A series of substituted (E)-1-(3-bromo-4-morpholinophenyl)-3-phenylprop-2-en-1-one compounds has been synthesized by crossed-aldol condensation method. These compounds were confirmed by their physical constants UV, IR and NMR spectral data. The spectral data values of these compounds have been correlated with Hammett sigma constants and F & R parameters using single and multi-linear regression analysis. Most of the single linear regression analyses have been satisfactory correlations, for all multi-linear regression analysis have been satisfactory correlations.

The 4-OCH3 and 3-NO2 substituted compounds have shown excellent activity against Enterococcus species, E. coli and P. mirabilis. The 3-NO2 substituted compound has shown excellent activity against B. subtilis, E. coli and P. mirabilis. The 3-OCH3 substituted compound has shown excellent activity against E. coli and P. mirabilis. The 4-Br and 4-F substituted prop-2-en-1-ones have shown excellent activity against M. species.

5. ACKNOWLEDGMENTS

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6. REFERENCES AND NOTES

[8] Viana, G. S.; Bandeira, M. A.; Matos, F. J. Phytomed. 2003, 10, 189. [CrossRef]


