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Preheated fly-ash catalyzed cyclization of chalcones: Synthesis of some substituted pyrazole-1-carbothioamides and spectral correlations in 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides

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ABSTRACT

Some substituted 1-thiocarbomyl pyrazolines including 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides using solvent-free preheated fly-ash catalyzed cyclization between chalcones and thiosemicarbazide microwave irradiation. The yields of these thiocarbomyl pyrazolines are more than 80 %. The purities of these synthesised pyrazoline derivatives are checked by their physical constants and spectral data earlier reported in the literature The spectral data of these 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides had been correlated, using single and multi-linear regression analysis.

***Keywords*:** Pre-heated fly-ash; Solvent free synthesis; Hammett correlations; 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides

1. INTRODUCTION

Many solvent-free [1,2] synthetic methods had been applied for stereospecific, stereoselective and regioselective synthesis of organic compounds. These solvent free reactions involving the formation of carbon-carbon bond and carbon-heteroatom bond are important and interesting in green synthesis. In the five membered bi-nitrogen heterocyclics, the 1-thiocarbomyl pyrazoline derivatives are important compounds and they possess –CS-NH_2 group in N_1 atom of pyrazoline ring [3,4]. These substituted 1-thiocarbomyl pyrazoline derivatives possess many important biological activities such as, anti-bacterial [5], anti-fungal [5], anti-depressants [7], anti-convulsant [8], anti-inflammatory [9], anti-tumour [10], anaesthetic [11], analgesic [12], anti-cancer [13] MAO-B inhibitors [14], steroidal, nitric oxide synthase inhibitor, anti-viral and cannabinoid CBI receptor antagonists [9]. Several solvent-free and thermal methods were reported in literature for synthesis of thiocarbomyl pyrazoline derivatives [3,13,15-18]. In these methods, many substituted pyrazoline derivatives were synthesised by cyclization of chalcones with hydrazine hydrate [19] or phenylhydrazine [20] or phenyl hydrazine hydrochloride [21-23]. Similarly substituted 1-

thiocarbomyl pyrazoline derivatives were synthesised by cyclization of chalcones with thiosemicarbazide [3,13,14,24] or substituted thiosemicarbazide [3,9,14] or hydrazenidium dithiocyanate [25]. In recent years, synthetic organic chemists, scientists and researchers preferred greener synthesis due to easy working procedure, shorter reaction time, higher yields, less hazardousness and solvent usage [26-31].

Based on the above important advantages, the greener synthetic methods such as, solvent-free microwave irradiation and ultrasonication were used for synthesis of thiocarbomyl pyrazoline derivatives [23,32,33]. Several liquid and solid phase catalysts were utilized for synthesis of substituted 1-thiocarbomyl pyrazoline derivatives such as Lewis acids, bases and their salts [13, 32, 33], CH_3COOH/CH_3COONa [3], NaOH/EtOH [24,32,35], KOH/EtOH [20,33], neat reaction in ethanol [3,14] and Basic alumina/ K_2CO_3 [36,37].

These thiocarbomyl pyrazolines are important as starting material for synthesis of thiazole substituted pyrazoles [18]. Chawla et al., [36] have synthesised more than 80 % yield of some 3-substituted phenyl-5-substitutedphenyl-4,5-dihydropyrazole-1-carbothioamides by microwave irradiation method and evaluated the antimicrobial activities.

The same yield of 5-(1,3-benzodioxol-yl)-3-(substituted)phenyl-4,5-dihydro-1H-pyrazol-1-carbothioamides have been synthesised by microwave irradiation method and studied the anticancer activities by Mathew et al., [13]. Ashok co-workers have been synthesised 80 % yields of some 3-(3-benzoyl-6-hydroxy-3-methylbenzo[b]furon-5-yl)-5-(aryl)-4,5-dihydro-1H-pyrazole carbothioamides using microwave irradiation technique and studied the antibacterial activities [15-17].

Patil et al., [37] have synthesised 60-85 % yields of 1-thiocarbomyl-2-(2,4-dichloro-5-fluorophenyl)-5-(substituted phenyl)-pyrazoline derivatives using microwave with alumina/K_2CO_3 as catalyst. Spectroscopic data applied for predicting the ground state equilibrium of organic compounds. The uv absorption maxima (λ max, nm) is also applied for prediction of effect of substituents [31]. In pyrazoline molecules (^{1}H pyrazoles), the infrared spectra is utilized for predicting the effects of substituents on the vibrations of C=N, C-H, N-H [21]. From NMR spectroscopy, the spatial arrangements of the protons H_a, H_b and H_c or H_a, H_b, H_c and H_d of the types shown in Fig. 1 were assigned from their frequencies with multiplicities viz., doublet or triplet or doublet of doublets.

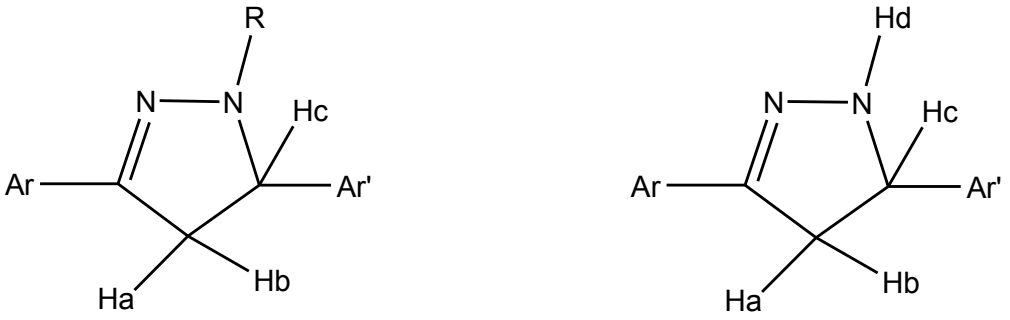


Fig. 1. General structure of 1*H*-pyrazoles.

Based on the stereo chemical terms, the chemical shifts of the protons of respective pyrazoles have been assigned and the effects of substituent were studied. The effects of substituent on the 2-naphthyl based pyrazoline ring protons were studied first by Sakthinathan et. al., [21]. In their study, they assigned infrared νC=N (cm^{-1}), NMR chemical shifts (δ, ppm) of H_a, H_b, H_c, C=N values and correlated with Hammett substituents. In these

correlations they observed satisfactory r values. Recently Thirunarayanan et al. [23] have synthesised some 1-phenyl-3-(5-bromothiophen-2-yl)-5-(substituted phenyl)-2-pyrazolines by solvent free method and investigated the effect of substituents using spectral data with Hammett substituent constants and F and R parameters. The literature survey reveals that there is no information available for solvent-free synthesis of some substituted thiocarbomyl pyrazolines including 1-thiocarbomyl-2-(3,4-dichlorophenyl)-5-(substituted phenyl)-pyrazoline derivatives by cyclization of the respective chalcones and thiosemicarbazide in presence of solid pre heated fly-ash. Therefore the authors have taken efforts to prepared some thiocarbomyl pyrazolines including 1-thiocarbomyl-2-(3,4-dichlorophenyl)-5-(substituted phenyl)-pyrazoline derivatives by solvent free microwave assisted cyclization of chalcones and thiosemicarbazide in presence of preheated fly-ash.

The purities of these pyrazolines were checked by their physical constants and spectral data published earlier in literature. Also the authors have recorded the infrared and NMR spectra of these synthesised 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides for studying the Hammett spectral correlations.

2. EXPERIMENTAL

2. 1. General

All chemicals used were procured from Sigma-Aldrich and E-Merck. Fly-ash was collected from the Thermal Power Plant II, Neyveli Lignite Corporation, Tamilnadu, India. Melting points of all pyrazole-1-carbothioamides have been determined in open glass capillaries on Mettler FP51 melting point apparatus and are uncorrected. Infrared spectra (KBr, 4000-400 cm^{-1}) have been recorded on BRUKER (Thermo Nicolet) Fourier transform spectrophotometer. The NMR spectra of all pyrazolines have been recorded on Bruker AV400 spectrometer operating at 400 MHz for recording ^{1}H and 100 MHz for ^{13}C spectra in $CDCl_3$ solvent using TMS as internal standard. Mass spectra have been recorded on SHIMADZU spectrometer using chemical ionization technique.

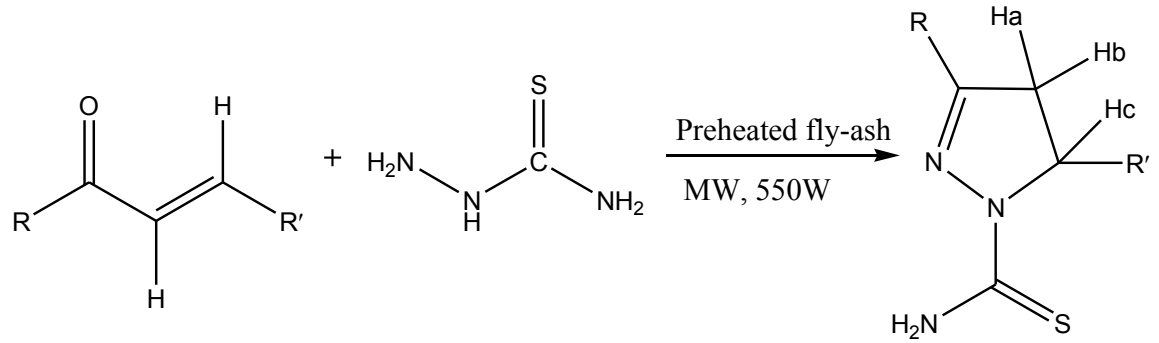
2. 2. Preparation of preheated fly-ash

The preheated fly-ash has been prepared by the procedure reported in the literature [38]. The fly-ash was heated on hot air oven at 110 °C for 2 h. During the heating demoisturising takes place. This preheating helps for avoiding colloidal formation during the reaction.

2. 3. Synthesis of substituted pyrazole-1-carbothioamide derivatives

Appropriate equi-molar quantities of chalcones (2 mmol), thiosemicarbazide (2 mmol) and preheated fly-ash (0.5 g) were taken in a 50 mL borosil glass tubes. The mixture was subjected to microwave irradiation for 4-6 minutes in a microwave irradiation at 550 watts, 2540 MHz frequency, 140 °C and atmospheric pressure in a microwave oven (Scheme 1) (Samsung Grill, GW73BD Microwave oven, 230 V A/c, 50 Hz, 2450 Hz, 100-750 W (IEC-705). The completion of the reaction was monitored by TLC. After completion, the reaction mixture was cooled to room temperature. The product was isolated by adding 10 mL of dichloromethane and evaporation. The solid, on recrystallization from benzene-hexane mixture afforded glittering product. The insoluble catalyst has been recycled by washing with

ethyl acetate (8 mL) followed by drying in an oven at 100 °C for 1h and reused for further reactions.



Scheme 1. Synthesis of 1-thiocarbomyl pyrazolines by preheated fly-ash catalyzed solvent free cyclization of chalcones and thiosemicarbazide under microwave irradiation.

3. RESULTS AND DISCUSSION

In our research laboratory, we attempts to synthesize substituted pyrazoline-1-carbothioamides derivatives by cyclization of chalcones and thiosemicarbazide in the presence of preheated fly-ash catalyst in microwave irradiation. Hence the authors have synthesized the substituted 1-thiocarbomyl pyrazoline derivatives by the cyclization of 2 mmole of chalcone, 2 mmole of thiosemicarbazide in microwave irradiation with 0.5 g preheated fly-ash catalyst at 550W, 4-6 minutes (Samsung Grill, GW73BD Microwave oven, 230 V A/c, 50 Hz, 2450 Hz, 100-750 W (IEC-705), (Scheme 1). During the course of this reaction preheated fly-ash assisted for the cyclization between chalcones and thiosemicarbazide to elimination of water followed by proton transfer gave the 1-thiocarbomyl pyrazolines. The yields of the pyrazolines in this reaction are more than 80 %.

The chalcones containing electron donating substituent (-OCH_3) gave higher yields than electron-withdrawing halogens and -NO_2 substituents. Further we have investigated this cyclization reaction with equimolar quantities of the styryl 3,4-dichlorophenyl ketone (entry 25) and thiosemicarbazide under the same condition as above. In this reaction the obtained yield was 85 %. The effect of catalyst on this reaction was studied by varying the catalyst quantity from 0.1 g to 1 g. As the catalyst quantity is increased from 0.1 g to 1 g, the percentage of yield of product is increased from 80 to 85 %. Further increase the catalyst amount beyond 0.4 g, there is no significant increasing the percentage of the product. The effect of catalyst loading is shown in (Fig. 2). The optimum quantity of catalyst loading was found to be 0.4 g. The results, analytical and mass spectral data are summarized in Table 1.

The reusability of this catalyst was studied for the cyclization of styryl 2,4-dichlorophenyl ketone and thiosemicarbazide (entry 25) is presented in Table 2. From the Table 2, first two runs gave 85 % product. The third, fourth and fifth runs of reactions gave the yields 84.5 %, 84.5 % and 84 % of 1-thiocarbomyl pyrazolines. There was no appreciable loss in its effect of catalytic activity were observed up to fifth run. The effect of solvents on the yield also studied with methanol, ethanol, dichloromethane and tetrahydrofuran from each component of the catalyst (entry 25). The effect of solvents on the yields of 1-thiocarbomyl pyrazolines was presented in Table 3. From the table, the highest yield of 1-thiocarbomyl

pyrazolines obtained from the cyclization of chalcone and thiosemicarbazide with the catalyst preheated fly-ash in microwave irradiation.

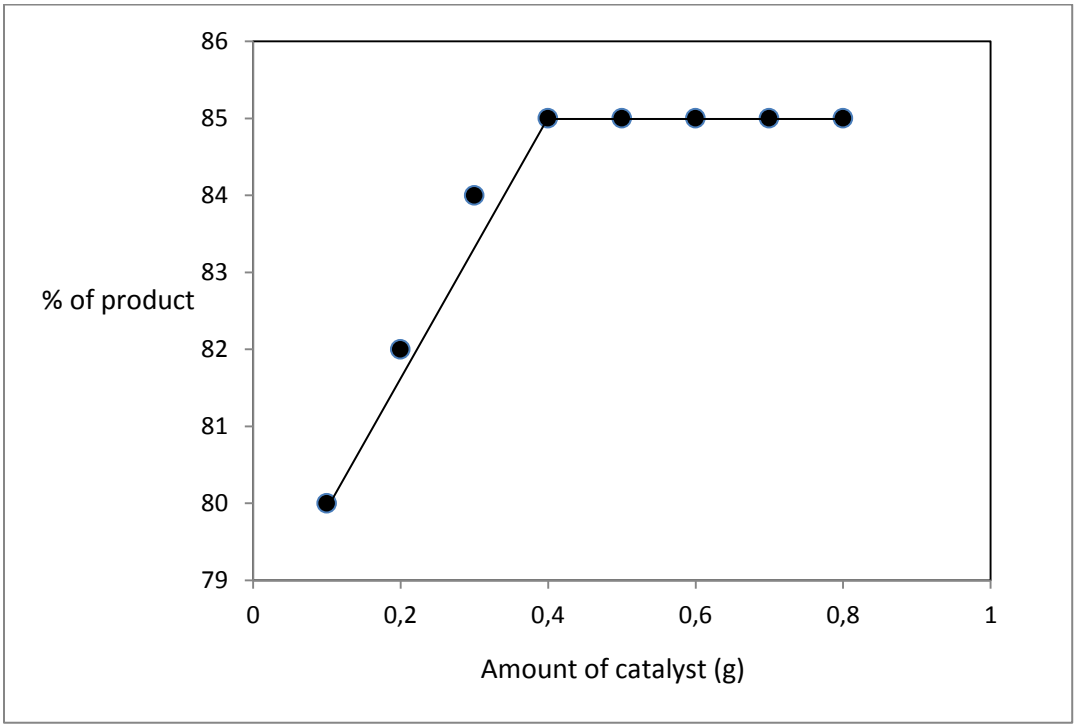


Fig. 2. Effect of catalyst loading.

Table 1. Analytical, physical constants, yields and mass fragments of 1-thiocarbomyl pyrazolines synthesised by preheated fly-ash catalyzed solvent-free cyclization of chalcones and thiosemicarbazide reaction of the type under microwave irradiation.

Entry	R	R′	Product	M. W.	Yield	m. p. (°C)	Mass (m/z)
1	CH_3	C_6H_5	$C_{11}H_{13}N_3S$	219	85	273-274 273 [25]	219[M^+]
2	CH_3	4-$OCH_3C_6H_4$	$C_{12}H_{15}N_3OS$	249	84	182-183 182 [25]	249[M^+]
3	CH_3	4-$N(CH_3)_2C_6H_4$	$C_{13}H_{18}N_4S$	263	86	238-239 238 [25]	263[M^+]
4	CH_3	C_4H_3O(2-Furyl)	$C_9H_{15}N_3OS$	213	80	221-222 220-222 [25]	213[M^+]
5	CH_3	C_4H_3S (2-Thienyl)	$C_9H_{15}N_3S_2$	229	81	119-220 220 [25]	213[M^+]
6	C_4H_3S (2-Thienyl)	C_6H_5	$C_{14}H_{17}N_3S_2$	291	83	164-165 160-165 [32]	291[M^+]
7	C_4H_3S (2-Thienyl)	4-BrC_6H_4	$C_{14}H_{16}BrN_3S_2$	370	82	254-255 250- 255[32]	370[M^+], 372[M^{2+}]
8	C_4H_3S (2-Thienyl)	2,4,5-$(OCH_3)_3C_6H_2$	$C_{17}H_{23}N_3O_3S_2$	381	83	214-215 210-215	381[M^+]

						[32]	
9	C_4H_3S (2-Thienyl)	4-$N(CH_3)_2C_6H_4$	$C_{16}H_{18}N_4S_2$	330	80	174-175 170-175 [32]	330[M^+]
10	C_6H_5	2,4-Cl_2-C_6H_3	$C_{16}H_{13}Cl_2N_3S$	350	80	220-221 217-220 [33]	350[M^+], 352[M^{2+}]
11	2,4-Cl_2-5-F-C_6H_2	C_6H_5	$C_{16}H_{12}Cl_2FN_3S$	368	81	165-166 165[37]	368[M^+], 370[M^{2+}], 372[M^{+4}]
12	2,4-Cl_2-5-F-C_6H_2	2-ClC_6H_4	$C_{16}H_{11}Cl_3FN_3S$	402	80	145-146 145[37]	402[M^+], 404[M^{2+}], 408[M^{+4}], 410[M^{+6}]
13	2,4-Br_2-C_6H_3	4-C_6H_4	$C_{16}H_{13}Br_2N_3S$	439	80	132-133	439[M^+], 441[M^{2+}], 443[M^{4+}]
14	2,4-Br_2-C_6H_3	2-BrC_6H_4	$C_{16}H_{12}Br_3N_3S$	519	81	217-218 214-216 [24]	519[M^+], 521M^{2+}], 523[M^{4+}]
15	4-$OCH_3C_6H_4$	C_6H_5	$C_{17}H_{17}N_3OS$	311	84	162-163 160-162 [36]	311[M^+]
16	4-ClC_6H_4	C_6H_5	$C_{16}H_{14}ClN_3S$	315	80	123-124 122-123 [36]	315[M^+], 317[M^{2+}]
17	3-$NO_2C_6H_4$	C_6H_5	$C_{16}H_{14}N_4O_2S$	326	80	129-130 128-130 [36]	326[M^+]
18	4-$OCH_3C_6H_4$	4-ClC_6H_4	$C_{17}H_{16}ClN_3OS$	345	84	127-128 125-127 [36]	360[M^+], 362[M^{2+}],
19	4-ClC_6H_4	4-ClC_6H_4	$C_{16}H_{13}Cl_2N_3S$	350	82	148-149 147-148 [36]	350[M^+], 352[M^{2+}], 354[M^{2+4}],
20	3-$NO_2C_6H_4$	4-ClC_6H_4	$C_{16}H_{13}ClN_4O_3S$	237	81	150-151 148-150 [36]	337[M^+], 396[M^{2+}]
21	2,4-$(CH_3)_2$-C_6H_3	4-FC_6H_4	$C_{18}H_{18}FN_3S$	327	83	225-226 223-225 [24]	327[M^+], 329[M^{2+}]
22	2,4-$(CH_3)_2$-C_6H_3	4-$NO_2C_6H_4$	$C_{18}H_{18}N_4O_2S$	354	83	203-204 202-203 [24]	354[M^+]
23	C_4H_3O (2-Furyl)	C_6H_5	$C_{14}H_{13}N_3OS$	271	82	177-178 176-177 [34]	271[M^+]
24	C_4H_3O (2-Furyl)	C_4H_3O (2-Furyl)	$C_{12}H_{11}N_3O_2S$	293	82	164-165 163-164 [34]	293[M^+]
25	2,4-Cl_2-C_6H_3	C_6H_5	$C_{16}H_{13}Cl_2N_3S$	351	85	135-136	351[M^+], 353M^{2+}], 355[M^{4+}]
26	2,4-Cl_2-C_6H_3	2-BrC_6H_4	$C_{16}H_{12}BrCl_2N_3S$	426	81	230-231 229-230 [24]	429[M^+], 431M^{2+}], 433[M^{4+}]
27	2,4-Cl_2-C_6H_3	4-BrC_6H_4	$C_{16}H_{12}BrCl_2N_3S$	426	80	216-217	429[M^+],

						214-216 [24]	431M^{2+}], 433[M^{4+}]
28	2,4-Cl_2-C_6H_3	2-ClC_6H_4	$C_{16}H_{12}Cl_3N_3S$	385	82	243-244 241-243 [24]	385 [M^{+}], 387[M^{2+}], 389[M^{4+}]
29	2,4-Cl_2-C_6H_3	4-ClC_6H_4	$C_{16}H_{12}Cl_3N_3S$	385	82	212-213 211-213 [24]	385 [M^{+}], 387[M^{2+}], 389[M^{4+}]
30	2,4-Cl_2-C_6H_3	2-FC_6H_4	$C_{16}H_{12}Cl_2FN_3S$	367	81	236-237 235-236 [24]	367[M^{+}], 369[M^{2+}], 371[M^{4+}]
31	2,4-Cl_2-C_6H_3	4-FC_6H_4	$C_{16}H_{13}Cl_2N_3OS$	367	81	208-209 206-208 [24]	367[M^{+}], 369[M^{2+}], 371[M^{4+}]
32	2,4-Cl_2-C_6H_3	4-OHC_6H_4	$C_{16}H_{13}Br_2N_3OS$	365	81	222-223 221-223 [24]	365[M^{+}], 367[M^{2+}], 369[M^{4+}]
33	2,4-Cl_2-C_6H_3	4-$OCH_3C_6H_4$	$C_{17}H_{15}Cl_2N_3OS$	381	84	236-237 235-237 [24]	381[M^{+}], 383[M^{2+}]
34	2,4-Cl_2-C_6H_3	4-$CH_3C_6H_4$	$C_{17}H_{15}Cl_2N_3OS$	365	83	224-225 223-224 [24]	365[M^{+}], 367[M^{2+}], 369[M^{4+}]
35	2,4-Cl_2-C_6H_3	4-$NO_2C_6H_4$	$C_{16}H_{12}Cl_2N_4O_2S$	395	80	205-206 203-205 [24]	395[M^{+}], 397[M^{2+}], 401[M^{4+}]

Table 2. Reusability of preheated fly-ash catalyst on cyclization of styryl 2,4-dichloro-5-fluoro ketone (2 mmol) and thiosemicarbazide (2 mmol) under microwave irradiation (entry 25).

Run	1	2	3	4	5
Yield	85	85	84.5	84.5	84

Table 3. The effect of solvents in conventional heating and without solvent in microwave irradiation on yield of 1-thiocarbomyl pyrazoline (entry 25).

Solvents				**Microwave irradiation**
MeOH	EtOH	DCM	THF	
73	76	78	75	85

MeOH = Methanol; EtOH = Ethanol; DCM = Dichloromethane; THF = Tetrahydrofuran.

3. 1. IR spectral study

The synthesis of substituted 1-thiocarbomyl pyrazoline derivatives are shown in Scheme 1. In the present study, the authors have chosen a series of 1-thiocarbomyl pyrazoline derivatives namely 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides (entries 25-35) for studying the effects of substituent on the spectral data.

The infrared νC=N, NH and C=S stretching frequencies (cm^{-1}) of 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides (entries 25-35) have been assigned and are presented in Table 4. These data have been correlated [1,2,21,23,28-31,38-49] with Hammett substituent constants and Swain-Lupton's [50] parameters. In this correlation the structure parameter Hammett equation employed is as shown in equation (1):

$$\nu = \rho\sigma + \nu_o \quad \ldots(1)$$

where ν_o is the frequency for the parent member of the series.

The observed νC=N stretching frequencies (cm^{-1}) of these 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides are correlated with various Hammett substituent constants and F and R parameters through single and multi-regression analyses including Swain-Lupton's [50] parameters. The results of statistical analyses of single parameter correlations are shown in Table 5. The correlation of νC=N (cm^{-1}) frequencies of 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides with Hammett σ, σ^+ and σ_I constants were satisfactory excluding H, 4-Br 4-F and 4-CH_3 substituents. If these substituents are included in the regression, they reduced the correlation considerably. The σ_R constant, F and R parameters has shown poor correlation. The poor correlations were observed for νC=S (cm^{-1}) frequencies of 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides with Hammett substituent constants, F and R parameters. All correlations gave positive ρ values. This may mean that the normal substituent effect operates in all thiocarbomyl pyrazolines.

Hammett σ, σ_I constants and F parameters gave satisfactory correlations for the νNH stretches (cm^{-1}) of these 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides excluding 2F, 4-F and 4-OH substituents. The remaining Hammett substituent constant has shown poor correlation. The failure in correlation was due to the absence of transmittance of inductive, resonance and field effects of the substituent on the spectral group frequencies νC=N, C=S and NH (cm^{-1}) and is associated with the resonance-conjugative structure shown in Fig. 3. Some of the Hammett single parameter correlations of νC=N, C=S and NH (cm^{-1}) frequencies of 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides were fail individually. So, the authors think that, it is worthwhile to seek the multi-regression analysis of these frequencies with Swain-Lupton's [50] constants. The multi-regressions gave satisfactory correlation with inductive, resonance and field effects of the substituents. The corresponding multi-regression equations are given in (2) – (7).

$$\nu_{CN}\,(cm^{-1}) = 1592.89(\pm1.578) + 4.416\sigma_I\,(\pm0.362) + 4.448\,\sigma_R\,(\pm1.1780) \quad \ldots(2)$$
$$(R = 0.907,\ P > 90\ \%,\ n = 11)$$

$$\nu_{CN}\,(cm^{-1}) = 1592.82(\pm4.314) + 5.060F\,(\pm2.712) + 4.689R\,(\pm1.754) \quad \ldots(3)$$
$$(R = 0.962,\ P > 95\ \%,\ n = 11)$$

$$\nu_{C=S}\,(cm^{-1}) = 1377.8(\pm2.598) + 5.577\sigma_I\,(\pm1.551) + 4.389\,\sigma_R\,(\pm1.907) \quad \ldots(4)$$
$$(R = 0.938,\ P > 90\ \%,\ n = 11)$$

$$\nu_{C=S}\,(cm^{-1}) = 1377.80(\pm2.589) + 5.577\,F\,(\pm1.551) + 4.359R\,(\pm0.590) \quad \ldots(5)$$
$$(R = 0.952,\ P > 95\%,\ n = 11)$$

Table 4. The spectroscopic data of 1-thiocarbomyl pyrazolines (entries 25-35).

Entry	X	IR (v, cm-1)			^{1}H NMR (δ, ppm)				^{13}C NMR (δ, ppm)		
		C=N	NH	C=S	Ha (*dd*, 1H)	Hb (*dd*, 1H)	Hc (*dd*, 1H)	X	C=N	C=S	X
25	H	1596	3459	1382	3.190	3.891	6.295	---	159.23	177.58	--
26	2-Br	1594	3456	1378	3.192	3.918	6.334	---	161.76	178.71	---
27	4-Br	1591	3457	1376	3.146	3.817	5.943	---	161.08	17.94	---
28	2-Cl	1593	3455	1375	3.103	3.910	6.331	---	163.14	176.47	---
29	4-Cl	1594	3457	1377	3.144	3.801	5.442	---	165.94	175.28	---
30	2-F	1593	3456	1381	3.120	3.721	6.341	---	166.12	175.14	---
31	4-F	1597	3467	1384	3.143	3.783	7.421	---	167.01	177.17	---
32	4-OH	1592	3459	1379	3.212	3.791	5.981	---	163.74	176.19	---
33	4-OCH_3	1590	3451	1374	3.135	3.741	5.971	3.744	160.91	177.24	57.41
34	4-CH_3	1591	3453	1376	3.145	3.761	5.981	2.314	161.09	177.46	26.70
35	4-NO_2	1597	3471	1385	3.166	3.771	5.943	---	168.41	179.16	---

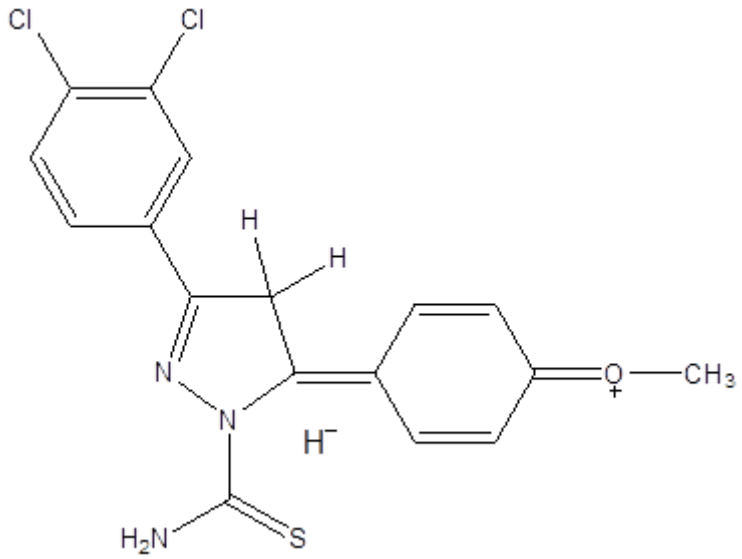


Fig. 3. The resonance-conjugative structure.

Table 5. Results of statistical analysis of infrared ν(cm^{-1}) C=N, C=S, NH, CF, NMR chemical shifts (δ,ppm) of Ha, Hb, Hc, C=N and C=S of 1-thiocarbamyl pyrazolines with Hammett σ, σ^+, σ_I σ_R constants and F and R parameters (entries 25-35).

Frequency	Constants	r	I	ρ	s	n	Correlated derivatives
νC=N	σ	0.905	1593.00	3.798	4.32	8	2-Br, 2-Cl, 4-Cl, 2-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.904	1593.91	2.023	4.10	8	2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.903	1592.02	3.916	4.00	9	2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-NO_2
	σ_R	0.883	1594.37	3.888	6.25	11	H, 2-Br, 2-Cl, 4-Cl, 2-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.876	1591.97	3.624	6.52	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.881	1594.47	3.334	6.20	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
νNH	σ	0.905	3457.06	10.244	5.09	9	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.888	3458.01	3.702	5.74	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.902	3453.27	13.314	5.31	9	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.832	3460.46	9.229	5.84	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.905	3453.30	12.144	5.28	10	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.825	3459.98	5.602	5.97	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
νC=S	σ	0.884	1378.25	4.796	3.55	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.832	1378.66	2.146	3.70	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.803	1376.96	5.084	3.72	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.802	1379.68	3.651	3.82	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.844	1376.14	6.538	3.50	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl,

							2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.814	1379.44	2.04	3.86	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
δH_a	σ	0.819	3.156	-0.026	0.03	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.827	3.115	-0.016	0.03	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.828	3.169	-0.042	0.03	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.820	3.161	0.037	0.03	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.830	3.170	-0.039	0.03	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.808	3.570	0.111	0.03	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
δH_b	σ	0.811	3.807	0.023	0.07	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.830	3.806	0.058	0.06	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.807	3.817	0.022	0.07	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.821	3.831	0.093	0.06	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.527	3.839	-0.073	0.06	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.842	3.842	0.100	0.06	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
δH_c	σ	0.806	6.193	-0.097	0.51	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.806	6.195	-0.097	0.51	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.807	6.175	0.063	0.51	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.817	6.042	0.375	0.59	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.841	5.942	-0.982	0.47	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.838	5.873	0.784	0.47	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl,

							2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
δCN	σ	0.850	162.94	4.676	2.70	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ^+	0.834	163.36	1.845	2.95	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_I	0.907	159.74	10.238	2.06	10	H, 2-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.908	163.20	-1.235	3.13	10	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3
	F	0.980	159.54	9.657	1.84	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.887	63.151	-1.117	3.12	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH3, 3-NO_2
δCS	σ	0.900	174.30	-39.988	48.69	10	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-CH_3, 4-NO_2
	σ^+	0.902	173.73	-16.702	49.62	10	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-CH_3, 4-NO_2
	σ_I	0.815	175.13	-34.281	49.95	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	σ_R	0.812	173.56	-29.183	58.18	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	F	0.805	170.67	-10.970	50.49	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2
	R	0.890	175.55	-10.381	50.36	11	H, 2-Br, 4-Br, 2-Cl, 4-Cl, 2-F, 4-F, 4-OH, 4-OCH_3, 4-CH_3, 4-NO_2

r = correlation co-efficient; ρ = slope; I = intercept; s = standard deviation;
n = number of substituents

$$\nu_{NH}(cm^{-1}) = 3455.46(\pm3.417) + 14.875\sigma_I\,(\pm7.302) + 11.118\sigma_R\,(\pm7.767) \quad \ldots(6)$$
($R = 0.964$, $P > 95$ %, n = 11)

$$\nu_{NH}(cm^{-1}) = 3455.09(\pm3.101) + 15.358F\,(\pm6415) + 9.655R\,(\pm3.964) \quad \ldots(7)$$
($R = 0.967$, P > 95 %, n = 11)

3. 2. ^{1}H NMR spectral study

The ^{1}H NMR spectra of synthesised 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamide derivatives (entries 25-34) under investigation have been recorded in deuteriochloroform solution employing tetramethylsilane (TMS) as internal standard. The signals of the 3-(2,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides ring protons have been assigned. They have been calculated as AB or AA' systems respectively. The chemical shifts (ppm) of H_a are at higher fields than

those of H_b and H_c in this series of 1-thiocarbomyl pyrazolines. This is due to the deshielding of H_b and H_c which are in different chemical as well as magnetic environment. These H_a protons gave an AB pattern and the H_b proton doublet of doublet in most cases was well separated from the signals H_c and the aromatic protons. The assigned chemical shifts (ppm) of the pyrazoline ring H_a, H_b and H_c protons are presented in Table 4.

In nuclear magnetic resonance spectra, the ^1H or the ^{13}C chemical shifts (δ, ppm) depend on the electronic environment of the nuclei concerned. These chemical shifts have been correlated with reactivity parameters. Thus the Hammett equation may be used in the form as shown in (8):

$$\text{Log } \delta = \text{Log } \delta_0 + \rho\sigma \quad \text{... (8)}$$

where δ_0 is the chemical shift of the corresponding parent compound.

The assigned H_a, H_b and H_c proton chemical shifts (ppm) of synthesized 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides have been correlated with various Hammett sigma constants. The results of statistical analysis [1,2,21,23,28-31,38-49] are presented in Table 5. The H_a H_b and H_c proton proton chemical shifts (δ, ppm) with Hammett substituent constants, F and R parameters gave poor correlations. The failure in correlation is associated with the conjugative structure shown in Fig. 3.

In view of the inability of the Hammett σ constants to produce satisfactory correlation individually, the authors think that it is worthwhile to seek multiple correlations involving either σ_I and σ_R constants or Swain-Lupton's [50] F and R parameters. The correlation equations for H_{a-c} proton chemical shifts (δ, ppm) are given in (9)-(14):

$$\delta H_a^{(ppm)} = 3.175(\pm0.023) - 0.039(\pm0.002)\sigma_I + 0026\ (\pm0.010)\sigma_R \quad \ldots(9)$$
$$(R = 0.933,\ P > 90\ \%,\ n = 11)$$

$$\delta H_a^{(ppm)} = 3.170(\pm0.002) - 0.451(\pm0.046)\ F + 0.246\ (\pm0.002)\ R \quad \ldots(10)$$
$$(R = 0.930,\ P > 90\ \%,\ n = 11)$$

$$\delta H_b^{(ppm)} = 3.855(\pm0.049) - 0.491\ (\pm0.155)\ \sigma_I + 0.092\ (\pm0.001)\sigma_R \quad \ldots(11)$$
$$(R = 0.928,\ P > 90\ \%,\ n = 11)$$

$$\delta H_b^{(ppm)} = 3.856(\pm0.043) - 0.043\ (\pm0.161)F - 0.094\ (\pm0.008)\ R \quad \ldots(12)$$
$$(R = 0.944,\ P > 90\ \%,\ n = 11)$$

$$\delta H_c^{(ppm)} = 5.858(\pm0.337) + 0.269(\pm0.071)\sigma_I - 0.947\ (\pm0.061)\sigma_R \quad \ldots(13)$$
$$(R = 0.943,\ P > 90\ \%,\ n = 11)$$

$$\delta H_c^{(ppm)} = 5.790(\pm0.311) + 0.604(\pm0.643)\ F - 0.646\ (\pm0.054)\ R \quad \ldots(14)$$
$$(R = 0.945,\ P > 90\ \%,\ n = 11)$$

3. 3. ^{13}C NMR spectra

Chemists, Organic and physical organic chemistry researchers [1,2,21,23,28-31,38-49] have made extensive study of ^{13}C NMR spectra for a large number of ketones, styrenes and keto-epoxides. In their study, they investigated the linear correlation of the chemical shifts

(ppm) of vinyl and carbonyl carbons with Hammett σ constants, F and R parameters in alkenes, alkynes, acid chlorides and styrenes.

In the present study, the chemical shifts (δ, ppm) of 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides C=N and C=S carbon have been assigned and are presented in Table 4. Attempts have been made to correlate the above assigned carbon chemical shifts (δ, ppm) with Hammett substituent constants, field and resonance parameters with the help of single and multi-regression analyses to study the reactivity through the effect of substituents.

The observed C=N and C=S chemical shifts (δ, ppm) of synthesised 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides have been correlated with Hammett substituent constants and the results of statistical analysis are presented in Table 5. The C=N chemical shifts (δ, ppm) has shown satisfactory correlation with Hammett σ_I, σ_R constants and F parameters excluding 4-Br and 4-NO_2 substituents. The remaining Hammett substituent constants and R parameter were fail in correlation. The failure in the correlation is due to incapability of transmittance of the resonance effect of the substituents on the C=N carbon chemical shifts (δ, ppm). The chemical shifts (δ, ppm) observed for the C=S carbon of the 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides have been shown poor correlation with Hammett substituent constants, F and R parameters along with negative ρ values. The failure in the correlation was due to the reason stated earlier and it is associated with the resonance - conjugative structure shown in Fig. 3. In view of the inability of some of the σ constants to produce individually satisfactory correlation, the authors think that, it is worthwhile to seek multiple correlation involving either σ_I, σ_R or F and R parameters [50]. The generated correlation equations are given in (15) to (18):

$$\delta_{C=N}^{(ppm)} = 159.75(\pm1.409) + 10.243(\pm3.184)\sigma_I + 0.066\ (\pm0.033)\sigma_R \quad \ldots(15)$$
$$(R = 0.975,\ P > 95\ \%,\ n = 11)$$

$$\delta_{C=N}^{(ppm)} = 159.85(\pm\ 1.209) + 10.154\ (\pm2.401)\ F + 1.602\ (\pm0.235)R \quad \ldots(16)$$
$$(R = 0.982,\ P > 95\ \%,\ n = 11)$$

$$\delta_{C=S}^{(ppm)} = 173.46(\pm35.458) - 38.093(\pm6.029)\sigma_I - 34.018\ (\pm6.875)\sigma_R \quad \ldots(17)$$
$$(R = 0.921,\ P > 90\ \%,\ n = 11)$$

$$\delta_{C=S}^{(ppm)} = 174.72(\pm\ 33.907) - 17.492\ (\pm7.042)\ F - 21.066\ (\pm9.536)R \quad \ldots(18)$$
$$(R = 0.912,\ P > 90\ \%,\ n = 11)$$

4. CONCLUSION

A series of some 1-thiocarbomyl pyrazolines including 3-(3,4-dichlorophenyl)-5-(substituted phenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides have been synthesised by microwave assisted preheated fly-ash catalyzed solvent free cyclization of chalcones and thiosemicarbazide. The yields of the synthesized carbothioamides are more than 80 %. The correlation study of infrared ν(cm^{-1}) of C=N, C=S frequencies, ^1H and ^{13}C NMR chemical shifts (δ, ppm) of $H_{a\text{-}c}$ and C=N, C=S, of 3-(3,4-dichlorophenyl)-5-(substitutedphenyl)-4,5-dihydro-1*H*-pyrazole-1-carbothioamides have shown satisfactory correlation co-efficient in both single and multi-regression analyses.

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