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^{1}H and ^{13}C NMR spectral assignments of novel naphthalenylphenylpyrazolines

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Introduction

Compounds containing pyrazolinyl-1-carbothioamide scaffolds (Fig. 1A) can act as anticancer agents, antimicrobial agents, and monoamine oxidase inhibitors.[1–4] When ethyl 2-bromoacetate is added to pyrazolinyl-1-carbothioamide, 2-pyrazolin-1-ylthiazol-4(5*H*)-one (Fig. 1B) is produced.[5] Compounds containing thiazolone scaffolds show hepatitis C virus inhibitory effects, antitubercular, antibacterial, and antimicrobial activities.[6–8] We designed naphthalenylphenylpyrazolinyl-1-carbothioamides (Fig. 1C) and naphthalenylphenyl-2-pyrazolin-1-ylthiazol-4(5*H*)-ones (Fig. 1D). Five thousand compounds containing pyrazolinyl-1-carbothioamide scaffolds and three thousand compounds containing 2-pyrazolin-1-ylthiazol-4(5*H*)-one scaffolds have been reported. Similar to chalcones (Fig. 1E), naphthalenylphenylpyrazolinyl-1-carbothioamides and naphthalenylphenyl-2-pyrazolin-1-ylthiazol-4(5*H*)-ones contain a C6-C3-C6 skeleton. Chalcones are a group of plant-derived polyphenols. Because of their diverse biological activities, chalcones are still being derivatized.[9–12] Therefore, the NMR and mass spectrometric (MS) data of the compounds we have designed and synthesized could help us identify newly synthesized derivatives or derivatives isolated from natural sources in the future. We report herein the complete ^{1}H and ^{13}C NMR data and high resolution MS data of 13 novel naphthalenylphenylpyrazolinyl-1-carbothioamides and five novel naphthalenylphenylpyrazolinyl-1-thiazol-4(5*H*)-ones.

Experimental

Syntheses

1-Hydroxynaphthylchalcone (**I**), which was prepared via previously reported methods, was treated with thiosemicarbazide to give thioamide compounds (**1–3**).[13] The same procedures were applied to 2-hydroxynaphthylchalcone (**II**) to produce the corresponding thioamide compounds (**4-7**), which were reacted with ethyl bromoacetate to give thiazolone compounds (**14–18**).[14] Benzochalcone (**III**) was reacted with hydrazine to form pyrazoline (**IV**); then, **IV** was dissolved in ethanol and treated with an equimolar amount of methoxy-substituted isothiocyanate, and the resulting solution was refluxed.[15] The reaction mixture was cooled to room temperature to form a solid, which was recrystallized in ethanol to produce the pure pyrazole-1-carbothioamide compound. The synthetic process is summarized in Scheme 1.

NMR spectra

The synthesized naphthalenylphenylpyrazolines were prepared in deuterated dimethyl sulfoxide (DMSO-d$_6$), with concentrations of approximately 50 mM, for the NMR experiments. All NMR experiments were performed on an Avance 400 spectrometer (9.4 T; Bruker, Karlsruhe, Germany) at 25 °C. For the ^{1}H NMR experiments, the relaxation delay, 90° pulse, spectral width, number of data points, and digital resolution were set to 1 s, 11.8 μs, 5555 Hz, 32 K, and 0.339 Hz/point, respectively. For the ^{13}C NMR experiments, the same parameters were set to 3 s, 15.0 μs, 20 964 Hz, 64 K, and 0.640 Hz/point, respectively. For correlation spectroscopy (COSY), heteronuclear multiple quantum coherence (HMQC), and heteronuclear multiple bond connectivity (HMBC), the data points were set to $2\,\mathrm{K} \times 256$ ($t_2 \times t_1$). The long-range coupling time for HMBC was set to 40 and 70 ms. The chemical shifts were referenced to TMS. Prior to Fourier transformation, the two-dimensional NMR data were processed with zero filling of 2 K and the sine-squared bell window function using XWin-NMR (Bruker, Karlsruhe, Germany).[16] All NMR data were analyzed using Sparky.[17]

General experimental procedures

To obtain the high-resolution MS data of the naphthalenylphenyl pyrazoline derivatives, ultraperformance liquid chromatography-hybrid quadrupole-time-of-flight mass spectrometry was carried out on a Waters Acquity ultraperformance liquid chromatography system (Waters Corp., Milford, MA, USA) with the help of Professor Choong Hwan Lee at Konkuk University, Korea.[18] All mass data were M + H ions.

Results and discussion

All of the synthesized naphthalenylphenylpyrazolines are listed in Table 1. The procedure used to assign the NMR data of derivative **1**, 3-(1-hydroxynaphthalen-2-yl)-5-(2-methoxyphenyl)-4,5-dihydropyrazole-1-carbothioamide was as follows: The ^{13}C peak indicating a deshielding appeared at 178.8 ppm and was assigned

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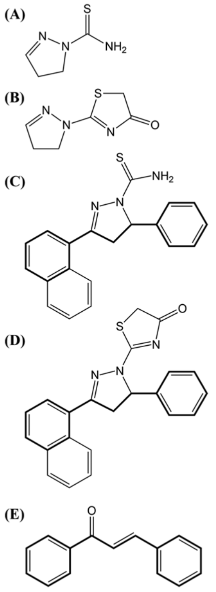
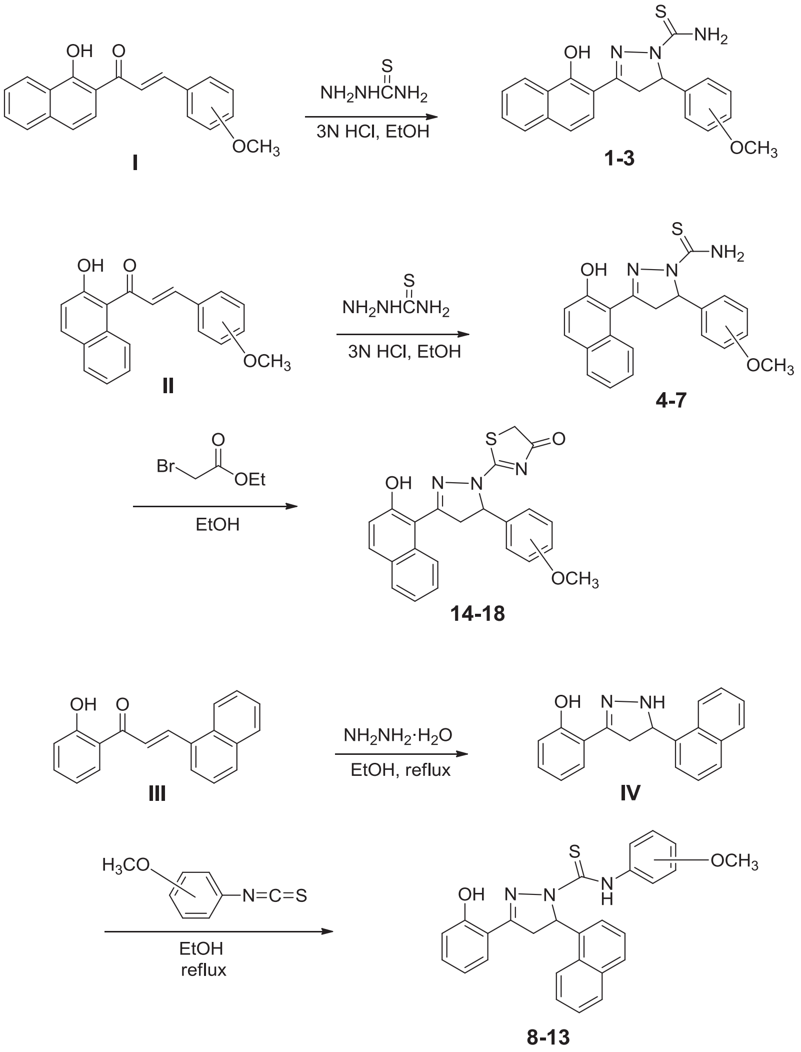


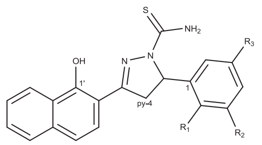
Figure 1. (A) Pyrazolinyl-1-carbothioamide, (B) 2-pyrazolin-1-ylthiazol-4(5*H*)-one, (C)naphthalenylphenylpyrazolinyl-1-carbothioamide, (D) naphthalenyl phenyl-2-pyrazolin-1-ylthiazol-4(5*H*)-one, and (E) chalcone. Bold lines denote C6-C3-C6 skeleton.

to the thioketone. On the contrary, the ^{13}C peak showing a shielding at 31.0 ppm was determined to be C-4 of the pyrazoline (named C-py-4). The two protons at 2.86 and 3.51 ppm were attached directly to C-py-4 in the HMQC spectrum, and hence, they were assigned as H-py-4a and H-py-4b. Correlations between the peaks at 2.86/3.51 ppm and 5.55 ppm were observed in the COSY spectrum, and the proton peak was attached directly to the ^{13}C peak at 72.3 ppm. In addition, based on the interpretation of DEPT, this carbon peak was determined to be a doublet, and hence, the ^{1}H peak at 5.55 ppm and the ^{13}C peak at 72.3 ppm were assigned to H-py-5 and C-py-5, respectively. Because the ^{13}C peaks at 127.5 and 142.8 ppm showed long-range coupling to H-py-4 and H-py-5 in the HMBC spectrum, they were labeled C-1 and C-py-3, respectively. The two proton peaks at 8.15 and 8.31 ppm were assigned to the primary amine of the carbothioamide. The proton peak at 10.47 ppm was assigned to 1′-OH. Six ^{1}H peaks at 7.49, 7.50, 7.56, 7.89, 8.10, and 8.39 ppm were correlated in the COSY spectrum, and they were assigned to the naphthyl group. Likewise, four proton peaks at 7.10, 7.13, 7.42, and 7.66 ppm were correlated in the COSY spectrum, and they were therefore determined to be produced by the phenyl group. The ^{1}H and ^{13}C peaks of the naphthyl and phenyl groups were assigned based on the interpretation of the COSY, HMQC, and HMBC spectra. The carbon peak at 55.7 ppm and the proton

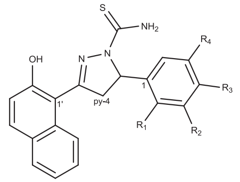


Scheme 1. The procedure for the preparation of naphthalenylphenylpyrazolines **1–18**.

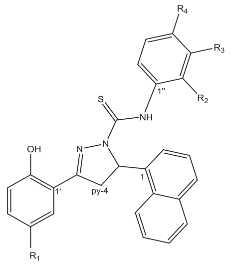
Table 1. Structures and names of naphthalenylphenylpyrazolines **1–18**, and their high-resolution mass spectrometric data



Derivative	R_1	R_2	R_3	Mass (calcd./found)	Name
1	OCH_3	H	H	378.1276/378.1287	3-(1-hydroxynaphthalen-2-yl)-5-(2-methoxyphenyl)-4,5-dihydropyrazole-1-carbothioamide
2	OCH_3	OCH_3	H	408.1382/408.1377	5-(2,3-dimethoxyphenyl)-3-(1-hydroxynaphthalen-2-yl)-4,5-dihydropyrazole-1-carbothioamide
3	H	OCH_3	OCH_3	408.1382/408.1394	5-(3,5-dimethoxyphenyl)-3-(1-hydroxynaphthalen-2-yl)-4,5-dihydropyrazole-1-carbothioamide



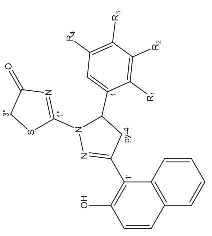
Derivative	R_1	R_2	R_3	R_4	Mass (calcd./found)	Name
4	OCH_3	H	OCH_3	H	408.1382/408.1378	5-(2,4-dimethoxyphenyl)-3-(2-hydroxynaphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide
5	OCH_3	OCH_3	H	H	408.1382/408.1380	5-(2,3-dimethoxyphenyl)-3-(2-hydroxynaphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide
6	OCH_3	OCH_3	OCH_3	H	438.1488/438.1499	3-(2-hydroxynaphthalen-1-yl)-5-(2,3,4-trimethoxyphenyl)-4,5-dihydropyrazole-1-carbothioamide
7	H	OCH_3	H	OCH_3	408.1382/408.1401	5-(3,5-dimethoxyphenyl)-3-(2-hydroxynaphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide



Derivative	R_1	R_2	R_3	R_4	Mass (calcd./found)	Name
8	H	H	H	H	424.1484/424.1468	3-(2-hydroxyphenyl)-5-(naphthalen-1-yl)-*N*-phenyl-4,5-dihydropyrazole-1-carbothioamide
9	H	OCH_3	H	H	454.1589/454.1602	3-(2-hydroxyphenyl)-*N*-(2-methoxyphenyl)-5-(naphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide
10	H	H	OCH_3	H	454.1589/454.1585	3-(2-hydroxyphenyl)-*N*-(3-methoxyphenyl)-5-(naphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide
11	OCH_3	H	H	H	454.1589/454.1605	3-(2-hydroxy-5-methoxyphenyl)-5-(naphthalen-1-yl)-*N*-phenyl-4,5-dihydropyrazole-1-carbothioamide
12	OCH_3	H	OCH_3	H	484.1695/484.1701	3-(2-hydroxy-5-methoxyphenyl)-*N*-(3-methoxyphenyl)-5-(naphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide
13	OCH_3	H	H	OCH_3	484.1695/484.1699	3-(2-hydroxy-5-methoxyphenyl)-*N*-(4-methoxyphenyl)-5-(naphthalen-1-yl)-4,5-dihydropyrazole-1-carbothioamide

(*Continues*)

Table 1. (Continued)



Derivative	R_1	R_2	R_3	R_4	Mass (calcd./found)	Name
14	OCH_3	H	H	H	418.1225/418.1229	2-(3-(2-hydroxynaphthalen-1-yl)-5-(2-methoxyphenyl)-4,5-dihydropyrazol-1-yl)thiazol-4(5*H*)-one
15	H	H	OCH_3	H	418.1225/418.1240	2-(3-(2-hydroxynaphthalen-1-yl)-5-(4-methoxyphenyl)-4,5-dihydropyrazol-1-yl)thiazol-4(5*H*)-one
16	OCH_3	H	OCH_3	H	448.1331/448.1311	2-(5-(2,4-dimethoxyphenyl)-3-(2-hydroxynaphthalen-1-yl)-4,5-dihydropyrazol-1-yl)thiazol-4(5*H*)-one
17	H	OCH_3	H	OCH_3	448.1331/448.1334	2-(5-(3,5-dimethoxyphenyl)-3-(2-hydroxynaphthalen-1-yl)-4,5-dihydropyrazol-1-yl)thiazol-4(5*H*)-one
18	OCH_3	OCH_3	OCH_3	H	478.1437/478.1438	2-(3-(2-hydroxynaphthalen-1-yl)-5-(2,3,4-trimethoxyphenyl)-4,5-dihydropyrazol-1-yl)thiazol-4(5*H*)-one

peak at 3.85 ppm were attributed to 2-OCH_3. This proton peak was long range coupled to the carbon peak at 156.2 ppm, which was C-2. The important correlations obtained from the COSY and HMBC spectra of derivative **1** are shown in Fig. 2A.

The procedure used to assign the NMR data of derivative **18**, 2-(3-(2-hydroxynaphthalen-1-yl)-5-(2,3,4-trimethoxyphenyl)-4,5-dihydropyrazol-1-yl)thiazol-4(5*H*)-one was as follows: In the manner as for derivative **1**, the ^1H and ^{13}C peaks of the pyrazoline group were determined. Correlations of two protons at 6.86 and 7.23 ppm and of six protons at 7.18, 7.43, 7.58, 7.88, 7.92, and 9.63 ppm were observed in the COSY spectrum and were assigned to the phenyl ring and naphthyl group, respectively. Because the ^{13}C peak at 151.0 ppm was long range coupled to the ^1H peaks of H-py-5 (5.46 ppm) in HMBC, it was assigned to C-2. This was long range coupled to the proton at 3.83 ppm that was assigned to 2-OCH_3. The carbon peak at 121.6 ppm was long range coupled to H-py-5, and hence, it was determined to be C-6. Among the two protons at 6.86 and 7.23 ppm mentioned previously, the peak at 7.23 ppm was assigned to H-6 because it was attached to C-6 directly as seen in the HMQC spectrum. Because this proton was long range coupled to the carbon at 153.7 ppm, this carbon peak could be assigned to C-4. The ^1H peak at 3.81 ppm was long range coupled to C-4, so this proton was assigned to 4-OCH_3. The remained methoxy proton at 3.78 ppm should be 3-OCH_3. The most deshielded proton at 11.99 ppm was assigned 2′-OH. Because the carbon at 33.3 ppm was methylene determined by DEPT experiments, it was C-3″ of thiazolone group. The proton peak at 3.95 ppm was determined to be H-3″. Two carbon peaks at 163.7 and 174.1 ppm could be assigned C-1″ and/or C-4″ contained in thiazolone group. As shown in Fig. S1 in Supporting Information, which is the partial spectrum of HMBC, they were long range coupled to H-3″. The peak showing the strong coupling (174.1 ppm) was expected to be C-4″ because the long-ranged coupling between C-1″ and H-3″ was caused via sulfur atom. Besides, 5.46 ppm (H-py5) and 163.7 ppm were long range coupled in HMBC (Fig. S2 in Supporting Information). This result agrees with the data published previously in the case of 2-(5-(2-chloroquinolin-3-yl)-3-phenyl-4,5-dihydro-1*H*-pyrazoly-1-yl)thiazol-4(5*H*)-one where C=N and C=O of thiazolone were 178.1 and 187.5 ppm, respectively.[19] The important correlations obtained from the COSY and HMBC spectra of derivative **18** are shown in Fig. 2B. The NMR data of the other naphthalenylphenylpyrazoline derivatives were interpreted using the same procedure as for derivatives **1** and **18**.

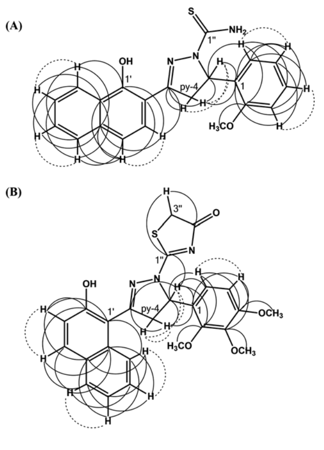


Figure 2. The important correlations obtained from the COSY (dot lines) and heteronuclear multiple bond connectivity (solid lines) spectra of (A) derivatives **1** and (B) **18**.

The complete assignments of the ^{1}H and ^{13}C NMR data for all derivatives dissolved in DMSO-d$_6$ are listed in Tables 2 and 3, respectively. For reference, the ^{1}H and ^{13}C NMR spectra collected in DMSO-d$_6$ are provided as Supporting Information.

Derivatives **1–3** contain a 1′-hydroxynaphthyl group, and derivatives **4–7** contain a 2′-hydroxynaphthyl group. The different position of the naphthyl group attached to the pyrazoline causes the differences in the chemical shifts of the pyrazoline carbons.

Table 2. ^{1}H NMR chemical shifts of naphthalenylphenylpyrazolines **1–18**, where py denotes pyrazoline, and multiplicity and coupling constants are given in parentheses

Position	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
H-py-4a	2.86 (dd, 17.3, 12.5)	2.91 (dd, 17.2, 12.6)	3.01 (dd, 17.1, 11.3)	3.05 (dd, 17.0, 12.7)	3.05 (dd, 17.1, 12.7)	3.12 (dd, 17.1, 12.8)	3.11 (dd, 16.5, 11.8)	3.20 (dd, 18.3, 3.4)	3.22 (dd, 18.3, 3.3)
H-py-4b	3.51 (dd, 17.3, 3.0)	3.50 (dd, 17.2, 2.9)	3.61 (dd, 17.1, 3.1)	3.45 (dd, 17.0, 3.1)	3.54 (dd, 17.1, 3.2)	3.50 (dd, 17.1, 3.2)	3.60 (dd, 16.5, 3.3)	4.28 (dd, 18.3, 11.5)	4.30 (dd, 18.3, 11.5)
H-py-5	5.55 (dd, 12.5, 3.0)	5.54 (dd, 12.6, 2.9)	5.41 (dd, 11.3, 3.1)	5.40 (dd, 12.7, 3.1)	5.47 (dd, 12.7, 3.2)	5.37 (dd, 12.8, 3.2)	5.29 (dd, 11.8, 3.3)	6.80 (dd, 11.5, 3.4)	6.76 (dd, 11.5, 3.3)
NH	—	—	—	—	—	—	—	10.42 (s)	10.10 (s)
NH$_2$-a	8.15 (s)	8.14 (s)	8.16 (s)	8.37 (s)	8.37 (s)	8.39 (s)	8.41 (s)	—	—
NH$_2$-b	8.31 (s)	8.28 (s)	8.32 (s)	9.21 (s)	9.21 (s)	9.32 (s)	9.20 (s)	—	—
H-2	—	—	6.81 (d, 2.1)	—	—	—	6.76 (d, 2.1)	7.14 (d, 7.3)	7.14 (d, 7.2)
H-3	7.13 (dd, 8.4, 0.8)	—	—	6.65 (d, 2.3)	—	—	—	7.45 (dd, 8.2, 7.3)	7.45 (dd, 8.2, 7.2)
H-4	7.42 (ddd, 8.4, 7.9, 1.9)	7.13 (dd, 8.0, 1.7)	6.52 (d, 2.1)	—	7.12 (dd, 7.0, 2.8)	—	6.52 (d, 2.1)	7.83 (d, 8.2)	7.83 (d, 8.2)
H-5	7.10 (ddd, 7.9, 7.6, 0.8)	7.20 (dd, 8.0, 7.9)	—	6.74 (dd, 8.4, 2.3)	7.18 (dd, 7.9, 7.0)	6.91 (d, 8.8)	—	7.97 (dd, 8.2, 1.6)	7.98 (dd, 8.1, 1.6)
H-6	7.66 (dd, 7.6, 1.9)	7.25 (dd, 7.9, 1.7)	6.81 (d, 2.1)	7.47 (d, 8.4)	7.19 (dd, 7.9, 2.8)	7.30 (d, 8.8)	6.76 (d, 2.1)	7.58 (ddd, 8.2, 6.8, 1.4)	7.58 (ddd, 8.1, 6.8, 1.3)
H-7	—	—	—	—	—	—	—	7.64 (ddd, 8.5, 6.8, 1.6)	7.63 (ddd, 8.4, 6.8, 1.6)
H-8	—	—	—	—	—	—	—	8.22 (dd, 8.5, 1.4)	8.21 (dd, 8.4, 1.3)
H-3′	8.39 (d, 8.8)	8.37 (d, 8.8)	8.37 (d, 8.9)	7.16 (d, 9.0)	7.18 (d, 8.9)	7.17 (d, 9.0)	7.23 (d, 8.9)	6.94 (dd, 8.3, 1.2)	6.94 (dd, 8.2, 1.5)
H-4′	7.49 (d, 8.8)	7.49 (d, 8.8)	7.48 (d, 8.9)	7.89 (d, 9.0)	7.91 (d, 8.9)	7.90 (d, 9.0)	7.91 (d, 8.9)	7.31 (ddd, 8.3, 7.8, 1.9)	7.32 (ddd, 8.2, 7.7, 1.8)
H-5′	7.89 (dd, 8.0, 1.7)	7.87 (dd, 7.9, 1.6)	7.88 (dd, 7.1, 2.0)	7.88 (dd, 7.4, 1.7)	7.89 (dd, 8.1, 1.6)	7.88 (dd, 8.0, 1.6)	7.89 (dd, 7.9, 1.6)	6.88 (ddd, 8.0, 7.8, 1.2)	6.90 (ddd, 7.9, 7.7, 1.5)
H-6′	7.56 (ddd, 8.0, 7.1, 1.3)	7.55 (ddd, 7.9, 6.9, 1.1)	7.57 (ddd, 7.1, 6.9, 1.8)	7.42 (ddd, 7.4, 7.1, 1.4)	7.44 (ddd, 8.1, 7.0, 1.3)	7.43 (ddd, 8.0, 7.0, 1.2)	7.43 (ddd, 7.9, 7.3, 1.2)	7.81 (dd, 8.0, 1.9)	7.74 (dd, 7.9, 1.8)
H-7′	7.50 (ddd, 8.2, 7.1, 1.7)	7.48 (ddd, 8.0, 6.9, 1.6)	7.54 (ddd, 7.9, 6.9, 2.0)	7.59 (ddd, 8.4, 7.1, 1.7)	7.60 (ddd, 8.4, 7.0, 1.6)	7.60 (ddd, 8.4, 7.0, 1.6)	7.59 (ddd, 8.3, 7.3, 1.6)	—	—
H-8′	8.10 (dd, 8.2, 1.3)	8.07 (dd, 8.0, 1.1)	8.19 (dd, 7.9, 1.8)	9.37 (dd, 8.4, 1.4)	9.21 (dd, 8.4, 1.3)	9.20 (dd, 8.4, 1.2)	9.38 (dd, 8.3, 1.2)	—	—
H-2″	—	—	—	—	—	—	—	7.56 (dd, 8.5, 1.3)	—
H-3″	—	—	—	—	—	—	—	7.35 (dd, 8.5, 8.0)	7.09 (dd, 8.2, 1.2)
H-4″	—	—	—	—	—	—	—	7.17 (dd, 8.0, 1.3)	7.17 (ddd, 8.2, 8.1, 1.5)
H-5″	—	—	—	—	—	—	—	7.35 (dd, 8.5, 8.0)	6.93 (ddd, 8.1, 8.1, 1.2)
H-6″	—	—	—	—	—	—	—	7.56 (dd, 8.5, 1.3)	8.09 (dd, 8.1, 1.5)
2-OCH$_3$	3.85 (s)	3.79 (s)	—	3.82 (s)	3.80 (s)	3.85 (s)	—	—	—
3-OCH$_3$	—	3.85 (s)	3.78 (s)	—	3.85 (s)	3.79 (s)	3.78 (s)	—	—
4-OCH$_3$	—	—	—	3.80 (s)	—	3.83 (s)	—	—	—
5-OCH$_3$	—	—	3.78 (s)	—	—	—	3.78 (s)	—	—
1′-OH	10.47 (s)	10.44 (s)	10.50 (s)	—	—	—	—	—	—
2′-OH	—	—	—	10.50 (s)	10.52 (s)	10.51 (s)	10.54 (s)	9.91 (s)	9.85 (s)
5′-OCH$_3$	—	—	—	—	—	—	—	—	—
2″-OCH$_3$	—	—	—	—	—	—	—	—	3.89 (s)
3″-OCH$_3$	—	—	—	—	—	—	—	—	—
4″-OCH$_3$	—	—	—	—	—	—	—	—	—

C-py-3 and C-py-4 of derivatives **1–3** exhibit peaks at lower frequency than those of derivatives **4–7**. On the contrary, C-py-5 of derivatives **1–3** shows peaks at higher frequency than that of derivatives **4–7**. Derivatives **4–7** and **14–18** contain a 2′- hydroxynaphthyl group, but the former has a carbothioamide group and the latter a thiazol-4(5*H*)-one. C-py-3 of derivatives **4–7** shows peaks at lower frequency than that of derivatives **14–18**. Unlike derivatives **1–7**, derivatives **8–13** contain an *N*-phenyl group. The *N*-phenyl group

Table 2. (Continued)

Position	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
H-py-4a	3.20 (dd, 18.3, 3.4)	3.26 (dd, 18.4, 3.4)	3.26 (dd, 18.4, 3.4)	3.24 (dd, 18.4, 3.4)	2.92 (dd, 16.6, 12.3)	3.09 (dd, 16.6, 12.0)	2.98 (dd, 16.6, 12.4)	3.15 (dd, 16.6, 11.6)	3.04 (dd, 16.6, 12.4)
H-py-4b	4.28 (dd, 18.3, 11.5)	4.27 (dd, 18.4, 11.6)	4.27 (dd, 18.4, 11.6)	4.25 (dd, 18.4, 11.6)	3.83 (dd, 16.6, 3.1)	3.76 (dd, 16.6, 3.0)	3.76 (dd, 16.6 3.0)	3.75 (dd, 16.6, 3.2)	3.77 (dd, 16.6, 3.1)
H-py-5	6.79 (dd, 11.5, 3.4)	6.80 (dd, 11.6, 3.4)	6.80 (dd, 11.6, 3.4)	6.78 (dd, 11.6, 3.4)	5.55 (dd, 12.3, 3.1)	5.34 (dd, 12.0, 3.0)	5.48 (dd, 12.4, 3.0)	5.35 (dd, 11.6, 3.2)	5.46 (dd, 12.4, 3.1)
NH	10.36 (s)	10.40 (s)	10.35 (s)	10.28 (s)	—	—	—	—	—
NH$_2$-a	—	—	—	—	—	—	—	—	—
NH$_2$-b	—	—	—	—	—	—	—	—	—
H-2	7.14 (d, 7.2)	7.15 (d, 7.2)	7.14 (d, 7.2)	7.13 (d, 7.2)	—	7.47 (d, 8.7)	—	6.71 (d, 2.2)	—
H-3	7.45 (dd, 8.2, 7.2)	7.47 (dd, 8.2, 7.2)	7.47 (dd, 8.2, 7.2)	7.47 (dd, 8.2, 7.2)	7.08 (dd, 8.2, 1.0)	6.98 (d, 8.7)	6.63 (d, 2.3)	—	—
H-4	7.82 (d, 8.2)	7.84 (d, 8.2)	7.84 (d, 8.2)	7.83 (d, 8.2)	7.37 (ddd, 8.2, 7.2, 1.6)	—	—	6.49 (d, 2.2)	—
H-5	7.97 (dd, 8.1, 1.7)	7.99 (dd, 8.2, 1.6)	7.99 (dd, 8.2, 1.6)	7.98 (dd, 8.1, 1.7)	7.03 (ddd, 7.6, 7.2, 1.0)	6.98 (d, 8.7)	6.60 (dd, 8.6, 2.3)	—	6.86 (d, 8.7)
H-6	7.57 (ddd, 8.1, 6.8, 1.3)	7.58 (ddd, 8.2, 6.9, 1.2)	7.58 (ddd, 8.2, 6.8, 1.2)	7.58 (ddd, 8.1, 6.8, 1.4)	7.54 (dd, 7.6, 1.6)	7.47 (d, 8.7)	7.45 (d, 8.6)	6.71 (d, 2.2)	7.23 (d, 8.7)
H-7	7.63 (ddd, 8.4, 6.8, 1.7)	7.64 (ddd, 8.4, 6.9, 1.6)	7.64 (ddd, 8.4, 6.8, 1.6)	7.63 (ddd, 8.4, 6.8, 1.7)	—	—	—	—	—
H-8	8.21 (dd, 8.4, 1.3)	8.23 (dd, 8.4, 1.2)	8.22 (dd, 8.4, 1.2)	8.21 (dd, 8.4, 1.4)	—	—	—	—	—
H-3′	6.93 (dd, 8.3, 1.2)	6.87 (d, 8.9)	6.87 (d, 8.9)	6.86 (d, 8.9)	7.20 (d, 8.9)	7.19 (d, 8.9)	7.18 (d, 8.9)	7.23 (d, 8.9)	7.18 (d, 8.9)
H-4′	7.31 (ddd, 8.3, 7.7, 1.7)	6.94 (dd, 8.9, 3.0)	6.94 (dd, 8.9, 3.0)	6.93 (dd, 8.9, 3.1)	7.92 (d, 8.9)	7.92 (d, 8.9)	7.92 (d, 8.9)	7.94 (d, 8.9)	7.92 (d, 8.9)
H-5′	6.88 (ddd, 8.2, 7.7, 1.2)	—	—	—	7.89 (dd, 7.9, 1.6)	7.89 (dd, 7.9, 1.6)	7.89 (dd, 7.9, 1.6)	7.89 (dd, 7.7, 1.6)	7.88 (dd, 8.0, 1.7)
H-6′	7.81 (dd, 8.2, 1.7)	7.38 (d, 3.0)	7.38 (d, 3.0)	7.36 (d, 3.1)	7.43 (ddd, 7.9, 6.9, 1.4)	7.43 (ddd, 7.9, 6.9, 1.0)	7.43 (ddd, 7.9, 6.9, 1.0)	7.43 (ddd, 7.7, 7.2, 1.3)	7.43 (ddd, 8.0, 6.9, 1.0)
H-7′	—	—	—	—	7.58 (ddd, 8.8, 6.9, 1.6)	7.59 (ddd, 8.7, 6.9, 1.6)	7.58 (ddd, 8.8, 6.9, 1.6)	7.58 (ddd, 8.7, 7.2, 1.6)	7.58 (ddd, 8.8, 6.9, 1.7)
H-8′	—	—	—	—	9.62 (dd, 8.8, 1.4)	9.65 (dd, 8.7, 1.0)	9.62 (dd, 8.8, 1.0)	9.63 (dd, 8.7, 1.3)	9.63 (dd, 8.8, 1.0)
H-2″	7.24 (dd, 2.5, 2.5)	7.56 (dd, 8.4, 1.3)	7.24 (dd, 2.0, 2.0)	7.38 (d, 8.9)	—	—	—	—	—
H-3″	—	7.36 (dd, 8.4, 8.1)	—	6.92 (d, 8.9)	3.93 (s)	3.96 (s)	3.95 (s)	3.96 (s)	3.95 (s)
H-4″	6.75 (ddd, 8.0, 2.5, 1.3)	7.18 (dd, 8.1, 1.3)	6.76 (ddd, 8.2, 2.0, 1.2)	—	—	—	—	—	—
H-5″	7.25 (dd, 8.1, 8.0)	7.36 (dd, 8.4, 8.1)	7.26 (dd, 8.4, 8.2)	6.92 (d, 8.9)	—	—	—	—	—
H-6″	7.18 (ddd, 8.1, 2.5, 1.3)	7.56 (dd, 8.4, 1.3)	7.17 (ddd, 8.4, 2.0, 1.2)	7.38 (d, 8.9)	—	—	—	—	—
2-OCH$_3$	—	—	—	—	3.82 (s)	—	3.81 (s)	—	3.83 (s)
3-OCH$_3$	—	—	—	—	—	—	—	3.76 (s)	3.78 (s)
4-OCH$_3$	—	—	—	—	—	3.77 (s)	3.79 (s)	—	3.81 (s)
5-OCH$_3$	—	—	—	—	—	—	—	3.76 (s)	—
1′-OH	9.87 (s)	9.47 (s)	9.48 (s)	9.46 (s)	11.96 (s)	11.99 (s)	11.93 (s)	12.01 (s)	11.99 (s)
2′-OH	—	3.72 (s)	3.72 (s)	3.71 (s)	—	—	—	—	—
5′-OCH$_3$	—	—	—	—	—	—	—	—	—
2″-OCH$_3$	3.74 (s)	—	3.75 (s)	—	—	—	—	—	—
3″-OCH$_3$	—	—	—	3.75 (s)	—	—	—	—	—
4″-OCH$_3$	—	—	—	—	—	—	—	—	—

Table 3. ^{13}C NMR chemical shifts of naphthalenylphenylpyrazolines **1–18**, where py denotes pyrazoline

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
C-py-3	142.8	142.8	142.1	146.9	146.2	146.3	145.6	157.0	156.8	156.8	156.6	156.6	156.8	157.7	157.7	157.9	157.3	157.8
C-py-4	31.0	31.1	31.1	32.9	33.4	33.2	33.5	43.9	44.3	43.8	43.8	43.8	43.8	32.9	33.4	32.7	33.4	32.8
C-py-5	72.3	72.6	76.3	71.7	72.0	72.0	76.3	60.3	60.0	60.1	60.2	60.2	60.2	72.2	76.6	71.9	76.8	72.3
C=S	178.8	178.7	178.7	178.9	179.1	179.0	179.0	174.0	173.2	173.6	173.9	173.6	174.5	—	—	—	—	—
1	127.5	132.7	142.0	119.2	132.47	124.6	141.7	137.7	137.5	137.6	137.7	137.7	137.8	127.5	131.6	119.6	142.1	125.0
2	156.2	146.1	104.4	157.6	146.2	151.2	104.5	120.8	121.0	120.8	120.7	120.7	120.9	156.0	127.9	157.3	104.4	151.0
3	111.2	152.3	160.6	98.4	152.3	141.7	160.5	125.7	125.7	125.6	125.6	125.6	125.6	111.3	113.9	98.5	160.6	141.7
4	129.6	113.1	99.4	160.7	113.1	153.8	99.8	127.5	127.5	127.3	127.3	127.3	127.2	129.7	159.3	160.6	99.9	153.7
5	120.69	124.3	160.6	105.0	124.2	107.9	160.5	129.0	128.9	128.8	128.8	128.8	128.7	120.8	113.9	105.1	160.6	108.0
6	126.6	118.6	104.4	128.0	118.7	122.0	104.5	126.0	126.0	125.8	125.8	125.8	125.8	126.7	127.9	127.8	104.4	121.6
7	—	—	—	—	—	—	—	126.6	126.5	126.3	126.3	126.3	126.3	—	—	—	—	—
8	—	—	—	—	—	—	—	123.6	123.5	123.4	123.5	123.4	123.5	—	—	—	—	—
9	—	—	—	—	—	—	—	129.2	129.2	129.1	129.1	129.1	129.1	—	—	—	—	—
10	—	—	—	—	—	—	—	133.9	133.9	133.8	133.8	133.8	133.8	—	—	—	—	—
1′	153.3	153.2	152.5	112.3	112.5	112.5	112.5	116.4	116.5	116.3	116.4	116.4	116.5	111.8	111.7	111.6	111.8	111.7
2′	114.5	114.4	114.7	158.1	157.8	157.9	157.3	156.7	156.9	156.6	150.9	150.9	150.8	158.4	158.0	158.4	157.7	158.2
3′	122.4	122.3	122.3	118.8	118.8	118.8	118.9	117.1	117.1	116.9	118.0	117.9	118.0	119.2	119.0	119.1	119.1	119.1
4′	120.66	120.6	120.6	132.4	132.49	132.4	132.5	132.5	132.5	132.3	119.3	119.3	119.3	133.4	133.2	133.2	133.3	133.3
5′	127.69	127.6	127.7	128.6	128.6	128.6	128.6	119.7	119.8	119.5	152.2	152.2	152.2	128.8	128.7	128.7	128.7	128.7
6′	127.67	127.6	127.6	124.1	124.2	124.1	124.1	129.9	129.4	129.7	112.8	112.8	112.7	124.3	124.1	124.1	124.2	124.2
7′	126.0	126.1	126.1	128.0	128.0	128.0	128.0	—	—	—	—	—	—	128.1	127.9	128.0	128.0	128.1
8′	121.8	121.8	121.8	126.4	126.3	126.3	126.3	—	—	—	—	—	—	127.3	127.2	127.2	127.2	127.2
9′	124.5	124.5	124.6	130.3	130.3	130.3	130.2	—	—	—	—	—	—	131.0	130.9	130.9	130.8	130.9
10′	134.5	134.5	134.6	129.6	129.7	129.7	129.7	—	—	—	—	—	—	129.7	129.5	129.5	129.6	129.6
1″	—	—	—	—	—	—	—	139.8	128.5	140.8	139.8	140.8	132.7	163.9	163.6	163.6	163.8	163.7
2″	—	—	—	—	—	—	—	125.9	151.9	111.1	125.9	111.3	127.8	—	—	—	—	—
3″	—	—	—	—	—	—	—	128.2	111.5	159.0	128.0	159.0	113.3	33.3	33.2	33.2	33.3	33.3
4″	—	—	—	—	—	—	—	125.2	125.9	110.3	125.0	110.4	156.4	174.3	174.0	174.1	174.1	174.1
5″	—	—	—	—	—	—	—	128.2	120.0	128.7	128.0	128.7	113.3	—	—	—	—	—
6″	—	—	—	—	—	—	—	125.9	124.6	117.6	125.9	117.8	127.8	—	—	—	—	—
2-OCH$_3$	55.7	60.7	—	55.7	60.7	61.4	—	—	—	—	—	—	—	55.8	—	55.7	—	61.4
3-OCH$_3$	—	55.8	55.3	—	55.8	60.4	55.3	—	—	—	—	—	—	—	55.1	—	55.3	60.5
4-OCH$_3$	—	—	—	55.3	—	55.9	—	—	—	—	—	—	—	—	—	55.3	—	56.0
5-OCH$_3$	—	—	55.3	—	—	—	55.3	—	—	—	—	—	—	—	—	—	55.3	—
5′-OCH$_3$	—	—	—	—	—	—	—	—	—	—	55.7	55.7	55.7	—	—	—	—	—
2″-OCH$_3$	—	—	—	—	—	—	—	—	56.1	—	—	—	—	—	—	—	—	—
3″-OCH$_3$	—	—	—	—	—	—	—	—	—	55.1	—	55.1	—	—	—	—	—	—
4″-OCH$_3$	—	—	—	—	—	—	—	—	—	—	—	—	55.2	—	—	—	—	—

causes deshielding of the C-py-3 and C-py-4 peaks and shielding of the C-py-5 peak. Similar chemical shift changes were observed in the ^{1}H NMR data. The results provided herein will help us to identify new naphthalenylphenylpyrazolines in the future.

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