# Syntheses of 2,3-Dicyano-5a,8a-dihydro-5a-hydroxycyclopentano[1',2':4,5]pyrrolo[2,3-*b*]pyrazines and 2,3-Dicyanocyclohexano[1',2':4,5]pyrrolo-[2,3-*b*]pyrazines



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Previously synthesized 2-(3'-chloro-5',6'-dicyanopyrazin-2'-yl)cyclopentan-1-one **1**, obtained from the reaction of 2,3-dichloro-5,6-dicyanopyrazine with 1-pyrrolidino-1-cyclopentene, was further reacted with primary alkylamines to give mixtures of diastereomer of 5-alkyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclopentano[1',2':4,5]pyrrolo[2,3-*b*]pyrazines **3a-h** in high yield. The reaction of 2-alkylamino-3-chloro-5,6-dicyanopyrazine with 1-pyrrolidino-1-cyclohexene gave 5-alkyl-2,3-dicyanocyclopentano[1',2':4,5]pyrrolo[2,3-*b*]pyrazines **5a-b** together with 5-alkylamino-2,3-dicyano-6-pyrrolidinopyrazines **6a-b**. The products prepared are all of interest as potential pesticides and new fluorescent chromophores.

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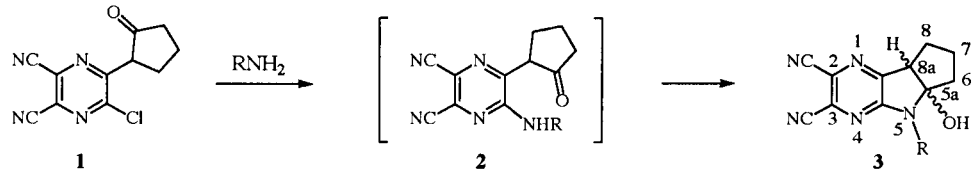
Herbicidal properties of a series of 2,3-dicyanopyrazines have been studied by Nakamura and coworkers [1], and Hodogaya company patented the usefulness of diaminodicyanopyrazine derivatives as agricultural fungicides [2]. Pyrazine chemistry based on diaminomaleonitrile as a tetramer of hydrogen cyanide had been studied extensively by du Pont [3] and Dow Chemicals [4]. We also have studied pyrazine chemistry from diaminomaleonitrile [5], 2,3-dichloro-5,6-dicyanopyrazine [6], and 2,5-diamino-3,6-dicyanopyrazine [7] which are all available as industrial scale raw materials from Nippon Soda Co. Ltd. The products synthesized were all of interest as functional coloring materials for such as nonlinear optics and electroluminescence materials, copy preventing inks and fluorescent pigments.

In the previous papers, we reported that 2,3-dichloro-5,6-dicyanopyrazine reacted with enamine such as Fisher's base to give vinylaminopyrazines in high yields [8]. On the other hand, treatment of 2,3-dichloro-5,6-dicyanopyrazine with 1-pyrrolidino-1-cyclopentene or 1-pyrrolidino-1-cyclohexene afforded the corresponding 2-(3'-chloro-5',6'-dicyanopyrazine-2'-yl)-1-pyrrolidino-1-cyclopentene or 2-(3'-chloro-5',6'-dicyanopyrazine-2'-yl)-1-pyrrolidino-1-cyclohexene in high yields. But the former product was unstable, and during isolating by column chromatography on silica gel with chloroform as eluent, hydrolysis of the product occurred to give 2-(3'-chloro-5',6'-dicyanopyrazine-2'-yl)cyclopentan-1-one **1** in 61% yields, but the latter was stable and isolated in 95% yield [9].

Compound **1** has an active chlorine at the 3-position and the carbonyl group on the cyclopentane ring. Reaction of **1** with primary alkylamines in benzene at room temperature yielded, via ring-closure, the novel heterocycles, 5-alkyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclopentano[1',2' : 4,5]pyrrolo[2,3-*b*]pyrazines **3a-h** (Scheme 1). We found that **1** reacted with primary amines at first to yield the corresponding 3-amino derivatives **2a-h** which spontaneously reacted with the carbonyl group by intramolecular addition to give the ring-closure products **3a-h**. The reaction of **1** with several primary alkylamines are summarized in Table 1. Reaction of **1** with amines was very fast in general, and the products **3a-h** were obtained in high yields (Runs 1-8). The yields for compounds **3a-h** were all above 90% except for **3a**, which was obtained in 83% yield. When aqueous ammonia was used (Run 9), and tar-like products were obtained. Attempts to identify the products were unsuccessful.

The structural assignments of **3a-h** were established on the basis of $^1$H nmr, ir and mass spectra as well as elemental analyses. Compound **3** has two asymmetric carbons at the 5a- and 8a-positions and exists as mixtures of diastereomer. The $^1$H nmr spectra of **3a**, for example, indicated two proton chemical shifts with different coupling constants for the 8a-proton and two methyl singlets for the *N*-methyl group at the 5-position. Similar $^1$H nmr spectra were observed for **3b-h** and they are assigned as diastereomer. From the integral values of the 8a-proton for each of compounds **3a-h**, the ratio of diastereoisomers are assigned to 1:1 with regard to asymmetric 8a-carbon (see experimental section). In the ir spectra, characteristic stretching vibrations for the cyano and the hydroxy groups were typically observed as strong peaks in the ranges of 2218-2241 cm$^{-1}$ for the cyano groups and 3494-3323 cm$^{-1}$ for the hydroxy groups, respectively. There are no prominent differences in the $\pi$-conjugation by the alkyl groups at the 5-position and no significant substituent effects were observed in their uv spectra which absorbed around 350 nm. The mass spectra indicated clearly the expected molecular ions and usual

Scheme 1



**a - h**: R = Me, Et, *n*-Pr, *i*-Pr, *n*-Bu, Benzyl, 2-Methoxyethyl, Allyl

Table 1

Reaction of **1** with primary alkylamines [a]

| Run | Reagent | Time (hours) | Product [b] | Yield (%) |
|---|---|---|---|---|
| 1 | 40% $MeNH_2$ [c] | 1/3 | **3a** | 83 |
| 2 | $EtNH_2$ | 1/3 | **3b** | 98 |
| 3 | *n*-$PrNH_2$ | 1/3 | **3c** | 93 |
| 4 | *i*-Pr $NH_2$ | 1/3 | **3d** | 93 |
| 5 | *n*-$BuNH_2$ | 1/3 | **3e** | 92 |
| 6 | $PhCH_2NH_2$ | 4 | **3f** | 95 |
| 7 | $MeOCH_2CH_2NH_2$ | 1/3 | **3g** | 93 |
| 8 | $CH_2$=$CHCH_2NH_2$ | 3 | **3h** | 94 |
| 9 | 25% aq. $NH_3$ | 1/3 or 24 | **3i** | 0 |

[a] To **1** (2 mmol) in benzene (100 ml) was dropwise added amine (4 mmol), and the mixture was stirred at room temperature. [b] A mixture of diastereomer. [c] In methanol.

molecular fragmentations. All these spectral data as well as microanalyses are in agreement with the depicted structures (see experimental section).

Reaction of 2,3-dichloro-5,6-dicyanopyrazine with two equivalents of primary or secondary alkylamines gave 2-alkylamino-3-chloro-5,6-dicyanopyrazines in high yields [10]. Compounds **4a, 4b** and **4d** were synthesized by the same method reported previously, and **4c** and **4e** were previously known [10]. Compounds **4a-c** were reacted with 1-pyrrolidino-1-cyclohexene in benzene. Two types of products, 5-alkyl-2,3-dicyanocyclopentano[1',2': 4,5]-pyrrolo[2,3-*b*]pyrazines **5** and 5-alkylamino-2,3-dicyano-6-pyrrolidinopyrazines **6**, were obtained after separation by column chromatography (Scheme 2). It was proposed that compound **5** was obtained by the following reactions; nucleophilic displacement of the enamine to the chlorine atom at the 5-position, followed by hydrolysis of the pyrrolidine moiety to give the substituted-cyclohexanone, followed by attack of the adjacent amino group on the carbonyl giving the ring-closure product which underwent dehydration to give **5**. The reaction pathways are almost the same as those of the case shown in Scheme 1. We propose that dehydration was possible in the six-five-six ring system in **5** but not in the six-five-five ring system in **3** because of higher ring-strain in the dehydrated product of **3**. It is proposed that the formation of **5e**, in the reaction of **4c** with the enamine results from the reaction of **5c** with cyclohexanone that was generated from hydrolysis of the enamine under severe reaction conditions (see Table 2, Run 3). Pyrrolidine, the counter part of the other hydrolysis product of the enamine, also reacted with **4c** to give **6c**. All of **6** were obtained by the reaction of **4** with pyrrolidine generated from hydrolysis of the enamine during the reaction. Formations of **6a-c** and **6e** were confirmed by the corresponding reaction of **4a-c** and **4e** with pyrrolidine in high yields, **6a** (95%), **6b** (94%), **6c** (79%) and **6e** (79%), respectively. But, the reaction of **4d** with pyrrolidine gave the mixture of products, **6d** (30%), **6e** (50%) together with small amounts of **4e**.

In the reaction of **4d** with 1-pyrrolidino-1-cyclohexene, the corresponding **5** was not obtained because the dimethylamino group could not react with the carbonyl group, rather substitution of the enamine to replace of the dimethylamino group occurred to give **7a**, 2-[2'-(azacyclopent-1"-yl)-1'-cyclohexen-1'-yl]-3-chloro-5,6-dicyanopyrazine, in 53% yield together with **4e** in 4% yield. Similar reaction of **4d** with 1-morpholino-1-cyclohexene gave the corresponding **7b** in 51% yield. In the formations of **4e** and **7**, much more basic pyrrolidine was predominantly attacked to replace with the dimethylamino group but not with the chlorine atom in **4d**. Further reaction of **7a** with *n*-propylamine in benzene was unsuccessful even under reflux conditions, and **7a** was recovered. It was proposed that the chlorine atom of **7a** has less reactivity to amine because of steric hindrance. Compounds **7a** and **7b** were previously synthesized by the reaction of 2,3-dichloro-5,6-dicyanopyrazine with the corresponding enamines [9].

Recently, we have reported the same type of the reaction to give **5** and 5-alkyl-2,3-dicyanopyrrolo[2,3-*b*]-pyrazines [5]. The enamine previously prepared from the carbonyl compounds and primary alkylamine was reacted with 2,3-dichloro-5,6-dicyanopyrazine to give **5** and/or 5-alkyl-2,3-dicyanopyrrolo[2,3-*b*]pyrazines in a one-pot procedure. These methods have many advantages to introduce long alkyl groups to the pyrrole ring.

The structural assignments of all products were established on the basis of $^1H$ nmr, ir and mass spectra as well as elemental analyses (see experimental section).

In conclusion, 2,3-dichloro-5,6-dicyanopyrazine reacted with 1-pyrrolidino-1-cyclopentene to afford 2-(3'-chloro-

Scheme 2

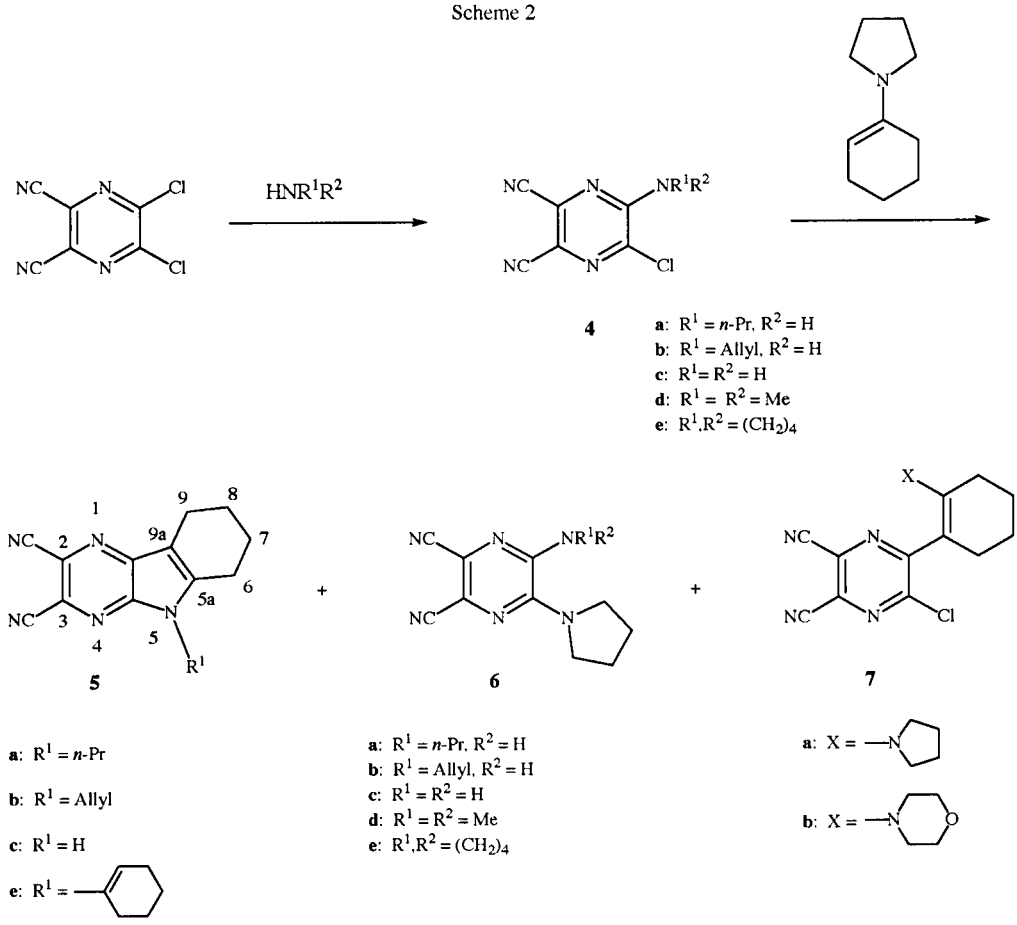



Table 2

Reaction of **4** with 1-pyrrolidino-1-cyclohexene [a]

| Run | Reactant | Time (hours) | Product (yield %) |
|---|---|---|---|
| 1 | **4a** | 4 | **5a** (40), **6a** (30) |
| 2 | **4b** | 17 | **5b** (53), **6b** (30) |
| 3 | **4c** [b] | 6 | **5c** (26), **5e** (24) **6c** (5) |
| 4 | **4d** | 5 | **7a** (53), **4e** (4) |
| 5 | **4d** [c] | 4 | **7b** (51) [d] |

[a] To **4** (2 mmol) in benzene (50 ml) was dropwise added enamine (4 mmol), and the mixture was stirred at room temperature. [b] Reaction was carried out under reflux conditions. [c] 1-Morpholino-1-cyclohexene was used as an enamine. [d] Other products were neglected for isolation.

5',6'-dicyanopyrazin-2'-yl)cyclopentan-1-one **1**. Reaction of **1** with primary alkylamines yielded the amination products **2** at first, and then intramolecular addition of the amino group to the carbonyl group at the adjacent position gave the mixture of diastereomer; 5-alkyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclohexano[1',2':4,5]-pyrrolo[2,3-*b*]pyrazines **3**. On the other hand, reaction of 2-alkylamino-3-chloro-5,6-dicyanopyrazines with 1-pyrrolidino-1-cyclohexene gave two types of products, 5-alkyl-2,3-dicyanocyclohexano[1',2':4,5]pyrrolo[2,3-*b*]-pyrazines **5** and 5-alkylamino-2,3-dicyano-6-pyrrolidinopyrazines **6**. Compounds **3** and **5** are novel nitrogen- and cyano-heterocycles which are of interest as potential pesticides [11] and new fluorescent chromophores. Related pyrazinophthalocyanines were synthesized and their fluorescent properties were reported [12,13].

## EXPERIMENTAL

The $^1$H nmr were taken on a Jeol FX 270 (270 MHz) and Shimadzu FT-nmr QE (300 MHz) spectrometers using tetramethyl silane as an internal reference. The ms spectra were recorded on a Shimadzu GCMS-QP5000 spectrometer. Absorption spectra were measured on a Hitachi U-2010 spectrophotometer. Fluorescence emission spectra were measured on a Hitachi F-4500 fluorescence spectrophotometer and those in the solid state on a Hamamatsu Photonic Multi-channel Analyzer PMA-11 using a Jasco SM-3 type monochromator as a

light source. Melting points were determined on a Yamato melting point apparatus (MP-21) without correction. Microanalyses were conducted with a Yanaco CHN MT-3 recorder. Wako gel C-300 (silica gel) was used for column chromatography. Compounds **1, 7a, 7b** [9] and **4c, 4e** [10] were previously synthesized and identified.

5-Alkyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazines (**3a-h**).

To **1** (2 mmol) in benzene (100 ml) was added dropwise alkylamine (4 mmol), and then the mixture was stirred at room temperature until all of **1** disappeared by tlc. The precipitate formed was removed by filtration and the filtrate was evaporated to dryness. The residues were washed with water and dried. Purification of the products by column chromatography on silica gel using chloroform as eluent gave **3** in high yield (see Table 1).

2,3-Dicyano-5a,8a-dihydro-5a-hydroxy-5-methylcyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3a**).

Compound **3a** was prepared by the above general procedure; mp: 162-163°C; ms: m/z 241 ($M^+$), 212 ($M^+$-29, 100); $^1H$ nmr (deuteriochloroform): δ 3.49 (d, J = 3.7 Hz, 0.5H), 3.46 (d, J = 3.6 Hz, 0.5H), 3.24 (broad, 1H), 3.13 (s, 1.5H), 3.12 (s, 1.5H), 2.45 (m, 1H), 2.15 (m, 1H), 2.08 (m, 1H), 1.90 (m, 2H), 1.45 (m, 1H); (deuteriodimethylsulfoxide): δ 6.71 (s, 1H), 3.34 (d, J = 3.7 Hz, 0.5H), 3.14 (d, J = 3.7 Hz, 0.5H), 2.98 (s, 3H), 2.28 (m, 1H), 2.08 (m, 1H), 1.85 (m, 1H), 1.70 (m, 2H), 1.38 (m, 1H); λmax absorption (chloroform) 352 nm, λmax emission (chloroform) 432 nm, stoke's shift 80 nm.

*Anal.* Calcd. for $C_{12}H_{11}N_5O$: C, 59.75; H, 4.56; N, 29.05. Found: C, 59.89; H, 4.28; N, 28.94.

2,3-Dicyano-5-ethyl-5a,8a-dihydro-5a-hydroxycyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3b**).

Compound **3b** was prepared by the above general procedure; mp: 146-148°C; ms: m/z 255 ($M^+$), 226 ($M^+$-29, 100); $^1H$ nmr (deuteriochloroform): δ 3.72 (q, J = 7.3 Hz, 0.5H), 3.67 (q, J = 7.3 Hz, 0.5H), 3.58 (q, J = 7.3 Hz, 0.5H), 3.50 (q, J = 7.3 Hz, 0.5H), 3.49 (d, J = 3.7 Hz, 0.5H), 3.46 (d, J = 3.0 Hz, 0.5H), 3.45 (broad, 1H), 2.45 (m, 1H); 2.12 (m, 2H), 1.88 (m, 2H), 1.48 (m, 1H), 1.36 (t, J = 7.3 Hz, 3H); λmax absorption (Ethyl acetate) 354 nm, λmax emission (chloroform) 432 nm, stoke's shift 78 nm.

*Anal.* Calcd. for $C_{13}H_{13}N_5O$: C, 61.18; H, 5.10; N, 27.45. Found: C, 61.01; H, 5.18; N, 27.13.

2,3-Dicyano-5a,8a-dihydro-5a-hydroxy-5-propylcyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine(**3c**).

Compound **3c** was prepared by the above general procedure; mp: 124-125°C; ms: m/z 269 (41, $M^+$), 240 ($M^+$-29, 100); $^1H$ nmr (deuteriochloroform): δ 3.55 (m, 1H), 3.45 (m, 2H), 3.40 (m, 1H), 2.45 (m, 1H), 2.12 (m, 2H), 1.88 (m, 2H), 1.80 (m, 2H), 1.48 (m, 1H), 1.00 (t, J = 7.3 Hz, 3H); λmax absorption (Ethyl acetate) 351 nm, λmax emission (chloroform) 434 nm, stoke's shift 83 nm.

*Anal.* Calcd. for $C_{14}H_{15}N_5O$: C, 62.45; H, 5.58; N, 26.02. Found: C, 62.67; H, 5.43; N, 25.65.

2,3-Dicyano-5a,8a-dihydro-5a-hydroxy-5-isopropylcyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3d**).

Compound **3d** was obtained by the above general procedure; mp: 148-152°C; ms: m/z 269 ($M^+$), 254 ($M^+$-15, 100); $^1H$ nmr (deuteriochloroform): δ 4.04 (d+septet, J = 7.3, 6.7 Hz, 1H), 3.67 (broad, 1H), 3.47 (d, J = 3.1 Hz, 0.5H), 3.44 (d, J = 3.7 Hz, 0.5H), 2.43 (m, 1H), 2.15 (m, 1H), 2.04 (m, 1H), 1.90 (m, 2H), 1.55 (d, J = 7.3 Hz, 3H), 1.48 (d, J = 6.7 Hz, 3H), 1.25 (t+t, J = 7.3, 6.70 Hz, 1H); λmax absorption (Ethyl acetate) 352 nm, λmax emission (chloroform) 434 nm, stoke's shift 82 nm.

*Anal.* Calcd. for $C_{14}H_{15}N_5O$: C, 62.45; H, 5.58; N, 26.02. Found: C, 62.04; H, 5.71; N, 25.41.

5-Butyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3e**).

Compound **3e** was prepared by the above general procedure; mp: 131-132°C; ms: m/z 283 ($M^+$), 41 (100); $^1H$ nmr (deuteriochloroform): δ 3.60 (m, 2H), 3.49 (d, J = 3.1 Hz, 0.5H), 3.46 (d, J = 3.6 Hz, 0.5H), 3.45 (broad, 1H), 2.45 (m, 1H),2.12 (m, 2H), 1.89 (m, 2H), 1.74 (m, 2H), 1.45 (m, 3H), 0.983 (t, J = 7.3 Hz, 1.5H), 0.978 (t, J = 7.3 Hz, 1.5H); λmax absorption (Ethyl acetate) 352 nm, λmax emission (chloroform) 436 nm, stoke's shift 84 nm.

*Anal.* Calcd. for $C_{15}H_{17}N_5O$: C, 63.60; H, 6.01; N, 24.73. Found: C, 63.46; H, 6.03; N, 23.88.

5-Benzyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3f**).

Compound **3f** was prepared by the above general procedure; mp: 169-170°C; ms: m/z 317 ($M^+$), 91 (100); $^1H$ nmr (deuteriochloroform): δ 7.33 (m, 5H), 4.79 (s, 1H), 4.78 (s, 1H), 3.49 (d, J = 3.7 Hz, 0.5H), 3.45 (d, J = 3.7 Hz, 0.5H), 3.18 (s, 1H), 2.45 (m, 1H), 2.00 (m, 2H), 1.85 (m, 2H), 1.40 (m, 1H); λmax absorption (Ethyl acetate) 353 nm, λmax emission (chloroform) 433 nm, stoke's shift 80 nm.

*Anal.* Calcd. for $C_{18}H_{15}N_5O$: C, 68.14; H, 4.73; N, 22.08. Found: C, 68.49; H, 4.95; N, 21.00.

2,3-Dicyano-5a,8a-dihydro-5a-hydroxy-5-(2-methoxyethyl)-cyclopentano[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3g**).

Compound **3g** was prepared by the above general procedure; mp: 127-128°C; ms: m/z 285 ($M^+$), 240 ($M^+$-45, 100); $^1H$ nmr (deuteriochloroform): δ 5.14 (broad, 1H), 4.07 (t, J = 2.5 Hz, 0.5H), 4.02 (t, J = 2.5 Hz, 0.5H), 3.60 (m, 3H), 3.42 (s, 3H), 3.40 (m, 1H), 2.45 (m, 1H), 2.05 (m, 2H), 1.85 (m, 2H), 1.48 (m, 1H); λmax absorption (Ethyl acetate) 350 nm, λmax emission (chloroform) 430 nm, stoke's shift 80 nm.

*Anal.* Calcd. for $C_{14}H_{15}N_5O_2$: C, 58.95; H, 5.26; N, 24.56. Found: C, 58.45; H, 5.23; N, 24.70.

5-Allyl-2,3-dicyano-5a,8a-dihydro-5a-hydroxycyclopentano-[1',2':4,5]pyrrolo[2,3-*b*]pyrazine (**3h**).

Compound **3h** was prepared by the above general procedure; mp: 97-98°C; ms: m/z 267 ($M^+$), 252 ($M^+$-15), 238 ($M^+$-29,-100); $^1H$ nmr (deuteriochloroform): δ 5.90 (m, 1H), 5.34 (d, J = 16 Hz, 1H), 5.26 (d, J = 9 Hz, 1H), 4.20 (m, 2H), 3.51 (d, J = 3.6 Hz, 0.5H), 3.47 (d, J = 3.6 Hz, 0.5H), 3.30 (broad, 1H), 2.43 (m, 1H), 2.20 (m, 1H), 2.05 (m, 1H), 1.85 (m, 2H), 1.45 (m, 1H); λmax absorption (Ethyl acetate) 349 nm, λmax emission (chloroform) 431 nm, stoke's shift 82 nm.

*Anal.* Calcd. for $C_{14}H_{13}N_5O$: C, 62.92; H, 4.87; N, 26.22. Found: C, 63.28; H, 4.85; N, 25.71.

2-Alkylamino-3-chloro-5,6-dicyanopyrazines (**4a, 4b** and **4d**).

To 2,3-dichloro-5,6-dicyanopyrazine (10 mmol) in benzene (50 ml) was added dropwise alkylamine (20 mmol), and then the

mixture was stirred at room temperature until all of the 2,3-dichloro-5,6-dicyanopyrazine disappeared by tlc. The precipitate formed was removed by filtration and the filtrate was evaporated to dryness. The residues were washed with water and dried. Purification of the products by column chromatography on silica gel using chloroform as eluent gave **4** in high yield.

5-Chloro-6-propylaminopyrazine-2,3-dicarbonitrile (**4a**).

Compound **4a** was prepared by the above general procedure; yield (91%); mp 137-138°C (chloroform); ms: m/z 223 ($M^+$+2), 221 ($M^+$), 192 ($M^+$-29, 100); $^1$H nmr (deuteriochloroform): δ 6.17 (broad, 1H), 3.53 (q, J = 7.5 Hz, 2H), 1.72 (sex., J = 7.5 Hz, 2H), 1.02 (t, J = 7.5 Hz, 3H); λmax absorption (chloroform) 352 nm, λmax emission (chloroform) 415 nm, stoke's shift 63 nm.

*Anal.* Calcd. for $C_9H_8N_5Cl$: C, 48.76; H, 3.61; N, 31.60. Found: C, 48.77; H, 3.57; N 31.51.

5-Allylamino-6-chloropyrazine-2,3-dicarbonitrile (**4b**).

Compound **4b** was prepared by the above general procedure; yield (94%); mp 112-113°C (chloroform); ms: m/z 221 ($M^+$+2); 219 ($M^+$), 204 ($M^+$-15, 100); $^1$H nmr (deuteriochloroform): δ 6.255 (broad, 1H), 5.92 (d+d+t, J = 17.1, 10.2, 6.0 Hz, 1H), 5.32 (d+q, J = 17.1, 1.5 Hz, 1H), 5.30 (d+q, J = 10.2, 1.2 Hz, 1H), 4.19 (t+t, J = 6.0, 1.5 Hz, 2H); λmax absorption (chloroform) 348 nm, λmax emission (chloroform) 411 nm, stoke's shift 63 nm.

*Anal.* Calcd. for $C_9H_6N_5Cl$: C, 49.20; H, 2.73; N, 31.89. Found: C, 49.93; H, 2.98; N, 30.93.

5-Chloro-6-dimethylaminopyrazine-2,3-dicarbonitrile (**4d**).

Compound **4d** was prepared by the above general procedure; yield (85%); mp 55-56°C (chloroform); ms: m/z 209 ($M^+$+2), 207 ($M^+$), 192 ($M^+$-15), 129 (100); $^1$H nmr (deuteriochloroform): δ 3.366 (s, 3H), 3.363 (s, 3H); λmax absorption (chloroform) 367 nm, λmax emission (chloroform) 467 nm, stoke's shift 100 nm.

*Anal.* Calcd. for $C_8H_6N_5Cl$: C, 46.27; H, 2.89; N, 33.73. Found: C, 46.20; H, 2.69; N 33.85.

5-Alkyl-2,3-dicyanocyclohexano[1',2':4,5]pyrrolo[2,3-*b*]-pyrazines (**5a-c** and **5e**), 5-alkylamino-2,3-dicyano-6-pyrrolidinopyrazines (**6a-e**) and 5-chloro-6-(2-pyrrolidin-1-yl-1-cyclohexenyl)-pyrazine-2,3-dicarbonitrile (**7a**).

To **4** (5 mmol) in benzene (30 ml) was added dropwise 1-pyrrolidino-1-cyclohexene (10 mmol), and then the mixture was stirred at room temperature until all of **4** disappeared by tlc. The precipitate formed was removed by filtration and the filtrate was evaporated to dryness. The residues were washed with water and dried. Separation and purification of the products by column chromatography on silica gel using benzene as eluent gave the products in order of **6, 7** and **5**. In the case of **4c**, products were isolated in order of **5e, 6c** and **5c** using chloroform as eluent (see Table 2).

2,3-Dicyano-5-propylcyclohexano[1',2':4,5]pyrrolo[2,3-*b*]-pyrazine (**5a**).

Compound **5a** was prepared by the above general procedure; mp 178-179°C (Benzene); ms: m/z 265 ($M^+$); $^1$H nmr (deuteriochloroform): δ 4.20 (t, J = 7.5 Hz, 2H), 2.91 (t, J = 6 Hz, 2H), 2.83 (t, J = 6 Hz, 2H), 2.05 (m, 2H), 2.92 (m, 2H), 1.83 (q, J = 7.5 Hz, 2H), 1.01 (t, J = 7.5 Hz, 3H); λmax absorption (chloroform) 376 nm, λmax emission (chloroform) 492 nm, stoke's shift 116 nm.

*Anal.* Calcd. for $C_{15}H_{15}N_5$: C, 67.92; H, 5.66; N, 26.42. Found: C, 68.35; H, 5.38; N, 27.40.

5-Allyl-2,3-dicyanocyclohexano[1',2':4.5]pyrrolo[2,3-*b*]pyrazine (**5b**).

Compound **5b** was prepared by the above general procedure; mp 179-180°C (Benzene); ms: m/z 263 ($M^+$); $^1$H nmr (deuteriochloroform): δ 6.59 (d+d+t, J = 16.8, 10.2, 5.4 Hz, 1H), 5.24 (d+q, J = 10.2, 0.6 Hz, 1H), 4.97 (d+q, J = 16.8, 1.2 Hz, 1H), 4.88 (d+t, J = 5.4, 1.5 Hz, 2H), 2.87 (t+t, J = 6.3, 1.2 Hz, 2H), 2.84 (t+t, J = 6.3, 1.2 Hz, 2H), 2.02 (m, 2H), 1.92 (m, 2H); λmax absorption (chloroform) 371 nm, λmax emission (chloroform) 482 nm, stoke's shift 111 nm.

*Anal.* Calcd. for $C_{15}H_{13}N_5$: C, 68.44; H, 4.94; N, 26.62. Found: C, 68.74; H, 4.67; N, 27.71.

2,3-Dicyanocyclohexano[1',2':4,5]pyrrolo[2,3-b]pyrazine (**5c**).

Compound **5c** was prepared by the above general procedure; mp 187-189°C (chloroform); ms: m/z 223 ($M^+$); 195 ($M^+$-28, 100); $^1$H nmr (deuteriochloroform): δ 12.30(broad, 1H), 2.61 (t, J = 6.0 Hz, 2H), 2.48 (t, J = 6.0 Hz, 2H), 1.70-1.55 (m, 4H); λmax absorption (chloroform) 355 nm, λmax emission (chloroform) 471 nm, stoke's shift 116 nm.

*Anal.* Calcd. for $C_{12}H_9N_5$: C, 64.57; H, 4.04; N, 31.39. Found: C, 64.20; H, 4.00; N, 31.22.

2,3-Dicyano-5-(1-cyclohexenyl)-cyclohexano[1',2':4,5]pyrrolo-[2,3-*b*]pyrazine (**5e**).

Compound **5e** was prepared by the above general procedure; mp 251-253°C (chloroform); ms: m/z 303 ($M^+$), 81 ($M^+$-222, 100); $^1$H nmr (deuteriochloroform): δ 5.88 (m, 1H), 2.84 (t, J = 6.0 Hz, 2H), 2.80 (t, J = 6.0 Hz, 2H), 2.33 (m, 4H), 1.98 (m, 2H), 1.90 (m, 2H), 1.79 (m, 2H), 1.607 (m 2H); λmax absorption (chloroform) 373 nm, λmax emission (chloroform) 438 nm, stoke's shift 65 nm.

*Anal.* Calcd. for $C_{18}H_{17}N_5$: C, 71.29; H, 5.61; N, 23.10. Found: C, 70.60; H, 5.61; N, 22.81.

5-Propylamino-6-(1-pyrrolidinyl)-pyrazine-2,3-dicarbonitrile (**6a**).

Compound **6a** was prepared by the above general procedure; mp 174-175°C (chloroform); ms: m/z 256 ($M^+$, 100), 227 ($M^+$-29, 100); $^1$H nmr (deuteriochloroform): δ 5.27 (broad, 1H), 3.66 (t, J = 17.1, 1.5 Hz, 4H), 3.42 (t+t, J = 7.5 Hz, 2H), 2.01 (t, J = 6.6 Hz, 4H), 1.67 (sext., J = 7.5 Hz, 2H), 1.00 (t, J = 7.5 Hz, 3H); λmax absorption (chloroform) 348 nm, λmax emission (chloroform) 442 nm, stoke's shift 94 nm.

*Anal.* Calcd. for $C_{13}H_{16}N_6$: C, 60.94; H, 6.25; N, 32.81. Found: C, 60.60; H, 6.33; N, 32.38.

5-Allylamino-6-(1-pyrrolidinyl)-pyrazine-2,3-dicarbonitrile (**6b**).

Compound **6b** was prepared by the above general procedure; mp 174-176°C (chloroform); ms: m/z 254 ($M^+$), 239 ($M^+$-15, 100), 213 ($M^+$-41); $^1$H nmr (deuteriochloroform): δ 5.95 (d+d+t, J = 17.1, 10.2, 5.7 Hz, 1H), 5.29 (broad, 1H), 5.27 (d+q, J = 17.1, 1.5 Hz, 1H), 5.23 (d+q, J = 10.2, 1.2 Hz, 1H), 4.09 (t+t, J = 5.7, 1.5 Hz, 2H), 3.68 (t, J = 6.6 Hz, 4H), 2.02 (t, J = 6.6 Hz, 4H); λmax absorption (chloroform) 345 nm, λmax emission (chloroform) 429 nm, stoke's shift 84 nm.

*Anal.* Calcd. for $C_{13}H_{14}N_6$: C, 61.42; H, 5.51; N, 33.07. Found: C, 61.62; H, 5.67; N, 32.71.

5-Amino-6-(1-pyrrolidinyl)-pyrazine-2,3-dicarbonitrile (**6c**).

Compound **6c** was prepared by the above general procedure; mp 164-166°C (chloroform); ms: m/z 214 ($M^+$), 185 ($M^+$-29), 171 ($M^+$-43, 100), 70 ($M^+$-144); $^1H$ nmr (deuteriodimethyl sulfoxide): δ 7.30 (broad, 2H), 3.62 (t, J = 6.6 Hz, 4H), 1.87 (t, J = 6.6 Hz, 4H); λmax absorption (chloroform) 337 nm, λmax emission (chloroform) 447 nm, stoke's shift 110 nm.

*Anal.* Calcd. for $C_{10}H_{10}N_6$: C, 56.07; H, 4.67; N, 39.25. Found: C, 56.24; H, 4.49; N, 39.54.

5-Dimethyalmino-6-(1-pyrrolidinyl)-pyrazine-2,3-dicarbonitrile (**6d**).

Compound **6d** was prepared by the above general procedure; mp 174-176°C (chloroform); ms m/z 242 ($M^+$), 227 ($M^+$-15); $^1H$ nmr (deuteriochloroform): δ 3.45 (t, J = 6.9 Hz, 4H), 3.37 (s, 6H), 1.94 (t, J = 6.9 Hz, 4H); λmax absorption (chloroform) 356 nm, λmax emission (chloroform) 475 nm, stoke's shift 119 nm.

*Anal.* Calcd. for $C_{12}H_{14}N_6$: C, 59.50; H, 5.79; N, 34.71. Found: C, 59.52; H, 5.62; N, 34.43.

5,6-Di-(1-pyrrolidinyl)-pyrazine-2,3-dicarbonitrile (**6e**).

Compound **6e** was prepared by the above general procedure; mp 207-209°C (chloroform); ms: m/z 268 ($M^+$), 225 ($M^+$-43), 70 (100); $^1H$ nmr (deuteriochloroform): δ 3.49 (t, J = 7.2 Hz, 4H), 3.47 (t, J = 7.2 Hz, 4H), 1.25 (t, J = 7.2 Hz, 8H); λmax absorption (chloroform) 360 nm, λmax emission (chloroform) 466 nm, stoke's shift 106 nm.

*Anal.* Calcd. for $C_{14}H_{16}N_6$: C, 62.69; H, 5.97; N, 31.34. Found: C, 62.32; H, 5.90; N, 31.50.

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