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Various chloropyrazines and their *N*-oxides were submitted to the cross-coupling reaction with ethylenes, such as styrene, ethyl acrylate and acrylonitrile. While the chloro-phenylpyrazines and 2-chloropyrazine 1-oxides were sluggish in this reaction system, the expected products were obtained from almost all the 2-chloro-3,6-dialkylpyrazines and their 4-oxides in moderate to good yields.

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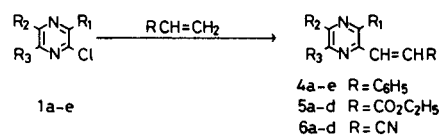
The carbon-carbon bond forming reaction using palladium catalysts has been extensively studied [1]. Introduction of alkenyl and alkynyl groups into the diazines like pyrimidine [2,3] and pyridazine [4] was performed with the aid of palladium catalysts. We have developed simple procedures for cyanation [5], alkynylation [6,7], methylation [8] and phenylation [9] of pyrazines using the palladium catalysts, and briefly reported the reaction of 2-chloro-3,6-dimethylpyrazine (**1a**) [10] with styrene [6]. By this catalytic system, (*Z*)- and (*E*)-3,6-dimethyl-2-styrylpyrazine, isolated from Argentine ant, *Iridomyrmex humilis* [11], was synthesized [6]. In the course of the studies on pyrazines, this paper reports the coupling reaction of some chloropyrazines with alkenes, such as styrene, ethyl acrylate and acrylonitrile, and presents full details of the work previously reported [6].

As already reported [6], by heating of **1a** with styrene in the presence of potassium acetate and tetrakis(triphenylphosphine)palladium in *N,N*-dimethylacetamide under

reflux for 15 hours, the expected (*E*)-3,6-dimethyl-2-styrylpyrazine (**4a**) was prepared in 95% yield. When the reaction time was reduced to 2 hours, the yield decreased to 24%. In the case of other 2-chloro-3,6-dialkylpyrazines **1b-d**, the reaction mixtures were heated evenly for 2 hours. The yields of the products were almost satisfactory, and the results were summarized in Table 1. The pmr spectra of the products **4b-d** suggested that the two ethylenic protons exist in the *trans* configuration (2H, AB quartet,  $J_{AB} = 16$  Hz).

On the other hand, 2-chlorophenylpyrazines, such as 2-chloro-3-methyl-5-phenylpyrazine (**1e**) [12] and 2-chloro-3,5-diphenylpyrazine (**1f**) [12], were sluggish in this reaction system. Namely, **1e** gave (*E*)-3-methyl-5-phenyl-2-styrylpyrazine (**4e**) only in 19% yield, and the formation of many products from **1f** was observed. In spite of replacing the catalyst with bis(triphenylphosphine)palladium dichloride, the yield of the aimed product from **1e** was not improved. The reaction of **1f** using bis(triphenylphos-

Table 1  
Reaction of Monochloropyrazines **1a-e** with Ethylenes



	Substrate			Product [a]	Product [d]	Product [e]
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Yield (%)	Yield (%)	Yield (%)
<b>1a</b> [10]	CH <sub>3</sub>	H	CH <sub>3</sub>	<b>4a</b> [6]	<b>5a</b>	<b>6a</b>
<b>1b</b> [16]	C <sub>2</sub> H <sub>5</sub>	H	C <sub>2</sub> H <sub>5</sub>	<b>4b</b>	<b>5b</b>	<b>6b</b>
<b>1c</b> [17]	<i>iso</i> -C <sub>3</sub> H <sub>7</sub>	H	<i>iso</i> -C <sub>3</sub> H <sub>7</sub>	<b>4c</b>	<b>5c</b>	<b>6c</b>
<b>1d</b> [13]	<i>iso</i> -C <sub>4</sub> H <sub>9</sub>	H	<i>iso</i> -C <sub>4</sub> H <sub>9</sub>	<b>4d</b>	<b>5d</b>	<b>6d</b>
<b>1e</b> [12]	CH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub>	H	<b>4e</b>		
<b>1e</b> [12]	CH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub>	H	<b>4e</b>	30 [b]	
<b>1e</b> [12]	CH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub>	H	<b>4e</b>	6 [c]	

[a] The reaction mixtures were refluxed for 2 hours in *N,N*-dimethylacetamide. [b] The reaction time was 15 hours. [c] The catalyst was bis(triphenylphosphine)palladium dichloride. [d] The reaction mixtures were heated at 130-140° for 15 hours in *N,N*-dimethylacetamide. [e] The reaction mixtures were heated at 100° for 15 hours in *N,N*-dimethylformamide. [f] The (*E*)-isomer. [g] Ratio of (*E*)- and (*Z*)-isomers **6b-d** and **6b'-6d'**.

phine)palladium dichloride was confined to afford many products. The addition of copper(I) iodide to this catalyst was ineffective on improvement of the yield. Namely, neither of the two catalysts was not effective for the reaction of **1f** with styrene.

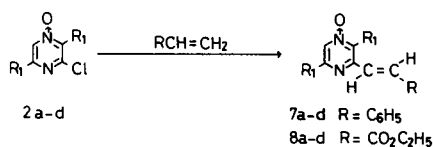
The reaction of 2-chloro-3,6-dialkylpyrazines **1a-d** with ethyl acrylate was carried out in the presence of tetrakis(triphenylphosphine)palladium by heating at 130-140° in a sealed tube for 15 hours in *N,N*-dimethylacetamide to give only the (*E*)-isomers. These results were shown in Table 1. The reaction of 2-chlorophenylpyrazines **1e,f** resulted in recovering the starting materials under the same conditions, and even by using bis(triphenylphosphine)palladium dichloride.

In the case of the reaction of **1a-d** with acrylonitrile, the reaction mixtures were heated at 100° for 15 hours in a sealed tube. As solvent, *N,N*-dimethylformamide was used, because the reaction in this solvent gave a better result than in *N,N*-dimethylacetamide. For instance, the yield of the product from 2-chloro-3,6-diisobutylpyrazine (**1d**) [13] was no more than 12% in *N,N*-dimethylacetamide, while 56% in *N,N*-dimethylformamide. From **1a**, the (*E*)-isomer was solely obtained, and the formation of a mixture of (*E*)- and (*Z*)-isomers was observed in all other cases. The (*E*)- and (*Z*)-isomers could be separated from each other by column chromatography.

The reaction of 2-chloro-3,6-dialkylpyrazine 1- and 4-oxides was also studied. As an example of 1-oxide, 2-chloro-3,6-diisobutylpyrazine 1-oxide [14] was submitted to the reaction with styrene, ethyl acrylate and acrylonitrile under reflux in *N,N*-dimethylacetamide in the presence of tetrakis(triphenylphosphine)palladium. However, the starting material was recovered in 60-80% yields in all cases.

Table 2

Reaction of Monochloropyrazine 4-Oxides **2a-d** with Ethylenes



Substrate	R <sub>1</sub>	Product [a]	Yield (%)	Product [b]	Yield (%)
<b>2a</b> [18]	CH <sub>3</sub>	<b>7a</b>	5	<b>8a</b>	38
<b>2b</b> [19]	C <sub>2</sub> H <sub>5</sub>	<b>7b</b>	34	<b>8b</b>	31
<b>2c</b> [20]	<i>iso</i> -C <sub>3</sub> H <sub>7</sub>	<b>7c</b>	19	<b>8c</b>	28
<b>2d</b> [13]	<i>iso</i> -C <sub>4</sub> H <sub>9</sub>	<b>7d</b>	25	<b>8d</b>	29

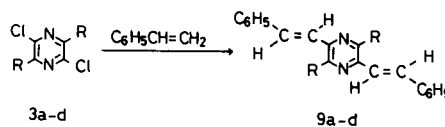
[a] The reaction mixtures were refluxed for 15 hours. [b] The reaction mixtures were heated at 130-140° for 15 hours.

The reaction of 2-chloro-3,6-dialkylpyrazine 4-oxides **2a-d** with styrene and ethyl acrylate, using tetrakis(triphenylphosphine)palladium, gave the expected products **7a-d** and **8a-d** though in poor yields, while the ones with acrylonitrile recovered the starting material in 80-90% yields. Although 2-chloro-3,6-diphenylpyrazine 4-oxide [15] was submitted to the reaction with styrene and ethyl acrylate, the starting material was recovered, even with any of the two palladium catalysts.

Next, some dichloropyrazines were submitted to this reaction. Treatment of 2,5-dichloro-3,6-dimethylpyrazine (**3a**) [10] with 2.4 equimolar styrene under reflux in *N,N*-dimethylacetamide for 2 hours gave a mixture of 2-chloro-3,6-dimethyl-5-styrylpyrazine (**9a'**) in 28% yield and 3,6-dimethyl-2,5-distyrylpyrazine (**9a**) in 13% yield. In order to improve the yield of **9a**, the reaction time was extended. In spite of heating for 15 hours, the yield was confined to 24%. However, from other dichloropyrazines **3b-d**, the expected products were obtained in satisfactory yields (Table 3). The reaction of **3a-d** with ethyl acrylate and acrylonitrile was investigated under various conditions, yet resulted in giving many products, which were not able to be purified.

Table 3

Reaction of Dichloropyrazines **3a-d** with Styrene



Substrate	R	Product	Yield (%)
<b>3a</b> [10]	CH <sub>3</sub>	<b>9a</b>	13 [a] (28) [a,b]
<b>3a</b> [10]	CH <sub>3</sub>	<b>9a'</b>	24
<b>3b</b> [17]	C <sub>2</sub> H <sub>5</sub>	<b>9b</b>	43
<b>3c</b> [17]	<i>iso</i> -C <sub>3</sub> H <sub>7</sub>	<b>9c</b>	60
<b>3d</b> [13]	<i>iso</i> -C <sub>4</sub> H <sub>9</sub>	<b>9d</b>	70

[a] The reaction mixtures were refluxed for 2 hours. [b] The product was (*E*)-5-chloro-3,6-dimethyl-2-styrylpyrazine.

The reaction of chloropyrazines with alkenes seems to be a little different from the one with alkynes. On the whole, the former reaction proceeds barely under the stronger conditions than the latter. However, the results presented in this paper represent that tetrakis(triphenylphosphine)palladium is an effective catalyst for the coupling reaction of 2-chloro-3,6-dialkylpyrazines and their *N*-oxides with some alkenes.

## EXPERIMENTAL

All melting and boiling points are uncorrected. Melting points were recorded on a Yanagimoto micro-melting point apparatus. All uv spectra

were taken in 95% ethanol using Hitachi Model 557 spectrometer, ir spectra on Shimadzu IR-400 spectrometer, and pmr spectra in deuteriochloroform using Varian EM-390 instrument with tetramethylsilane as an internal standard. Mass spectra were obtained with Hitachi M-80 spectrometer. For silica gel column chromatography, Wakogel C-200 (Wako Pure Chemical Industries, Ltd., Tokyo) was used. All experimentals were carried out in an argon atmosphere.

General Procedure for the Reaction of Monochloropyrazines **1a-e** with Ethylenes.

A mixture of a monochloropyrazine (2 mmoles), an ethylenic compound (3 mmoles of styrene and ethyl acrylate, and 10 mmoles of acrylonitrile), potassium acetate (294 mg, 3 mmoles) and tetrakis(triphenylphosphine)palladium (116 mg, 0.1 mmoles) in an appropriate solvent (5-10 ml) was treated under the conditions represented in Table 1. The solvent was removed by distillation *in vacuo*, and the residue was triturated with water (30 ml) and extracted with ether (10 ml x 3). The ethereal extract was dried over sodium sulfate and condensed to give crude products, which were purified by column chromatography on silica gel (15 g) and eluted with hexane including increasing amounts of ethyl acetate.

**(E)-3,6-Diethyl-2-styrylpyrazine (4b).**

This compound had the following physical properties: colorless oil, bp 114-119°/1 torr; uv:  $\lambda$  max 230.5 (log  $\epsilon$  = 3.97), 236.5 (3.95), 276 (4.17), 337 (4.28) nm; ir (liquid film): 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.30 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 1.33 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.83 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.93 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 7.16-7.83 (6H, m, benzene H and CH=CH), 7.97 (1H, d, J = 16 Hz, CH=CH), 8.33 (1H, s, pyrazine H) ppm; ms: m/e 238 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{16}\text{H}_{18}\text{N}_2$ : C, 80.63; H, 7.61; N, 11.76. Found: C, 80.53; H, 7.60; N, 11.86.

**(E)-3,6-Diisopropyl-2-styrylpyrazine (4c).**

This compound had the following physical properties: colorless oil, bp 108-112°/1 torr; uv:  $\lambda$  max 230.5 (log  $\epsilon$  = 4.03), 236 (3.99), 275.5 (4.23), 332.5 (4.32) nm; ir (liquid film): 960 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.32 (6H, d, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 1.35 (6H, d, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 3.13 (1H, m, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 3.48 (1H, m, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 7.33-7.87 (6H, m, benzene H and CH=CH), 8.00 (1H, d, J = 16 Hz, CH=CH), 8.43 (1H, s, pyrazine H) ppm; ms: m/e 266 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{18}\text{H}_{22}\text{N}_2$ : C, 81.16; H, 8.33; N, 10.52. Found: C, 81.27; H, 8.42; N, 10.44.

**(E)-3,6-Diisobutyl-2-styrylpyrazine (4d).**

This compound had the following physical properties: colorless oil, bp 140-145°/1 torr; uv:  $\lambda$  max 230.5 (log  $\epsilon$  = 4.11), 236.5 (4.00), 278 (4.26), 338 (4.33) nm; ir (liquid film): 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.00 (12H, d, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.17 (2H, m, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.70 (2H, d, J = 7 Hz,  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.85 (2H, d, J = 7 Hz,  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 7.20-7.83 (6H, m, benzene H and CH=CH), 8.00 (1H, d, J = 16 Hz, CH=CH), 8.30 (1H, s, pyrazine H) ppm; ms: m/e 294 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{20}\text{H}_{26}\text{N}_2$ : C, 81.58; H, 8.90; N, 9.52. Found: C, 81.68; H, 8.95; N, 9.31.

**(E)-3-Methyl-5-phenyl-2-styrylpyrazine (4e).**

This compound had the following physical properties: colorless prisms (from hexane), mp 105-106°; uv:  $\lambda$  max 232.5 (log  $\epsilon$  = 4.08), 237.5 (4.08), 295 (4.20), 355 (4.29) nm; ir (potassium bromide): 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  2.93 (3H, s,  $\text{CH}_3$ ), 7.33-8.00 (9H, m, benzene H and CH=CH), 8.00-9.43 (3H, m, benzene H and CH=CH), 9.13 (1H, s, pyrazine H) ppm; ms: m/e 272 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{19}\text{H}_{16}\text{N}_2$ : C, 83.79; H, 5.92; N, 10.29. Found: C, 83.50; H, 5.89; N, 10.20.

**(E)-2-(3,6-Dimethyl-2-pyrazinyl)acrylic Acid Ethyl Ester (5a).**

This compound had the following physical properties: colorless oil, bp 120-123°/2 torr; uv:  $\lambda$  max 247.5 (log  $\epsilon$  = 3.76), 312.5 (3.73) nm; ir (liquid

film): 1720 (C=O), 970 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.33 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.55 (3H, s,  $\text{CH}_3$ ), 2.67 (3H, s,  $\text{CH}_3$ ), 4.33 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 7.20 (1H, d, J = 16 Hz, CH=CH), 8.02 (1H, d, J = 16 Hz, CH=CH), 8.48 (1H, s, pyrazine H) ppm; m/e 206 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{11}\text{H}_{14}\text{N}_2\text{O}_2$ : C, 64.06; H, 6.84; N, 13.58. Found: C, 64.21; H, 6.76; N, 13.59.

**(E)-2-(3,6-Diethyl-2-pyrazinyl)acrylic Acid Ethyl Ester (5b).**

This compound had the following physical properties: colorless oil, bp 115-120°/2 torr; uv:  $\lambda$  max 248 (log  $\epsilon$  = 4.21), 311.5 (4.17) nm; ir (liquid film): 1720 (C=O), 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.27 (9H, t, J = 7 Hz,  $\text{COOCH}_2\text{CH}_3$  and 2 x  $\text{CH}_2\text{CH}_3$ ), 2.70 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.90 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 4.27 (2H, q, J = 7 Hz,  $\text{COOCH}_2\text{CH}_3$ ), 7.18 (1H, d, J = 16 Hz, CH=CH), 8.02 (1H, d, J = 16 Hz, CH=CH), 8.47 (1H, s, pyrazine H) ppm; ms: m/e 234 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{13}\text{H}_{18}\text{N}_2\text{O}_2$ : C, 66.64; H, 7.74; N, 11.96. Found: C, 66.62; H, 7.78; N, 12.06.

**(E)-2-(3,6-Diisopropyl-2-pyrazinyl)acrylic Acid Ethyl Ester (5c).**

This compound had the following physical properties: colorless oil, bp 129-133°/2 torr; uv:  $\lambda$  max 247 (log  $\epsilon$  = 4.03), 307.5 (3.92), 315 (3.95, shoulder) nm; ir (liquid film): 1730 (C=O), 980 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.22 (6H, d, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 1.25 (6H, d, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 1.27 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 3.02 (1H, m, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 3.28 (1H, m, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 4.18 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 7.07 (1H, d, J = 16 Hz, CH=CH), 7.88 (1H, d, J = 16 Hz, CH=CH), 8.37 (1H, s, pyrazine H) ppm; ms: m/e 262 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{15}\text{H}_{22}\text{N}_2\text{O}_2$ : C, 68.67; H, 8.45; N, 10.68. Found: C, 68.93; H, 8.43; N, 10.90.

**(E)-2-(3,6-Diisobutyl-2-pyrazinyl)acrylic Acid Ethyl Ester (5d).**

This compound had the following physical properties: colorless oil, bp 127-132°/1 torr; uv:  $\lambda$  max 249.5 (log  $\epsilon$  = 4.24), 313 (4.17) nm; ir (liquid film): 1720 (C=O), 970 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  0.97 (12H, d, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 1.33 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.07 (2H, m, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.65 (2H, d, J = 7 Hz,  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.83 (2H, d, J = 7 Hz,  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 4.32 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 7.18 (1H, d, J = 16 Hz, CH=CH), 8.07 (1H, d, J = 16 Hz, CH=CH), 8.43 (1H, s, pyrazine H) ppm; ms: m/e 290 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{17}\text{H}_{26}\text{N}_2\text{O}_2$ : C, 70.31; H, 9.02; N, 9.65. Found: C, 70.58; H, 9.15; N, 9.72.

**(E)-2-(3,6-Dimethyl-2-pyrazinyl)acrylonitrile (6a).**

This compound had the following physical properties: colorless prisms (from hexane), mp 103-104°; uv:  $\lambda$  max 246 (log  $\epsilon$  = 3.96), 307.5 (3.87, shoulder), 314.5 (3.88) nm; ir (potassium bromide): 2220 (C $\equiv$ N), 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  2.49 (3H, s,  $\text{CH}_3$ ), 2.58 (3H, s,  $\text{CH}_3$ ), 6.67 (1H, d, J = 16 Hz, CH=CH), 7.63 (1H, d, J = 16 Hz, CH=CH), 8.40 (1H, s, pyrazine H) ppm; ms: m/e 159 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_9\text{H}_9\text{N}_3$ : C, 67.90; H, 5.70; N, 26.40. Found: C, 67.77; H, 5.67; N, 26.34.

**(E)-2-(3,6-Diethyl-2-pyrazinyl)acrylonitrile (6b).**

This compound had the following physical properties: colorless oil, bp 92-95°/1 torr; uv:  $\lambda$  max 246.5 (log  $\epsilon$  = 4.26), 309 (4.16, shoulder), 315 (4.17) nm; ir (liquid film): 2230 (C $\equiv$ N), 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.32 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 1.33 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.85 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.97 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 6.88 (1H, d, J = 16 Hz, CH=CH), 7.87 (1H, d, J = 16 Hz, CH=CH), 8.63 (1H, s, pyrazine H) ppm; ms: m/e 187 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{11}\text{H}_{13}\text{N}_3$ : C, 70.56; H, 7.00; N, 22.44. Found: C, 70.51; H, 6.89; N, 22.64.

**(Z)-2-(3,6-Diethyl-2-pyrazinyl)acrylonitrile (6b').**

This compound had the following physical properties: colorless oil, bp 90-94°/1 torr; uv:  $\lambda$  max 245.5 (log  $\epsilon$  = 4.06), 308 (3.91), 316 (3.89, shoulder) nm; ir (liquid film): 2225 (C $\equiv$ N), 740 (*cis* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.27 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 1.40 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.92

(4H, q, J = 7 Hz, 2 x CH<sub>2</sub>CH<sub>3</sub>), 5.77 (1H, d, J = 12 Hz, CH=CH), 7.50 (1H, d, J = 12 Hz, CH=CH), 8.55 (1H, s, pyrazine H) ppm; ms: m/e 187 (M<sup>+</sup>).

Anal. Calcd. for C<sub>11</sub>H<sub>13</sub>N<sub>3</sub>: C, 70.56; H, 7.00; N, 22.44. Found: C, 70.50; H, 7.12; N, 22.53.

**(E)-2-(3,6-Diisopropyl-2-pyrazinyl)acrylonitrile (6c).**

This compound had the following physical properties: colorless oil, bp 108-112°/1 torr; uv: λ max 246 (log ε = 4.19), 308.5 (4.09), 314 (4.08) nm; ir (liquid film): 2225 (C≡N), 955 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 1.32 (12H, d, J = 7 Hz, 2 x CH(CH<sub>3</sub>)<sub>2</sub>), 3.25 (2H, m, = 7 Hz, 2 x CH(CH<sub>3</sub>)<sub>2</sub>), 6.83 (1H, d, J = 16 Hz, CH=CH), 7.90 (1H, d, J = 16 Hz, CH=CH), 8.62 (1H, s, pyrazine H) ppm; ms: m/e 215 (M<sup>+</sup>).

Anal. Calcd. for C<sub>13</sub>H<sub>17</sub>N<sub>3</sub>: C, 72.52; H, 7.96; N, 19.52. Found: C, 72.27; H, 7.99; N, 19.44.

**(Z)-2-(3,6-Diisopropyl-2-pyrazinyl)acrylonitrile (6c').**

This compound had the following physical properties: colorless oil, bp 82-87°/1 torr; uv: λ max 247 (log ε = 4.14), 308.5 (4.01, shoulder), 315 (4.02) nm; ir (liquid film): 2225 (C≡N), 750 (cis CH=CH) cm<sup>-1</sup>; pmr: δ 1.23 (6H, d, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 1.35 (6H, d, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 3.15 (2H, m, J = 7 Hz, 2 x CH(CH<sub>3</sub>)<sub>2</sub>), 5.62 (1H, d, J = 12 Hz, CH=CH), 7.43 (1H, d, J = 12 Hz, CH=CH), 8.42 (1H, s, pyrazine H) ppm; ms: m/e 215 (M<sup>+</sup>).

Anal. Calcd. for C<sub>13</sub>H<sub>17</sub>N<sub>3</sub>: C, 72.52; H, 7.96; N, 19.52. Found: C, 72.34; H, 7.96; N, 19.31.

**(E)-2-(3,6-Diisobutyl-2-pyrazinyl)acrylonitrile (6d).**

This compound had the following physical properties: colorless oil, bp 120-125°/1 torr; uv: λ max 247 (log ε = 4.14), 308.5 (4.01, shoulder), 315 (4.02) nm; ir (liquid film): 2240 (C≡N), 960 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 0.92 (12H, d, J = 7 Hz, 2 x CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.03 (2H, m, 2 x CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.58 (2H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.68 (2H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 6.65 (1H, d, J = 16 Hz, CH=CH), 7.63 (1H, d, J = 16 Hz, CH=CH), 8.35 (1H, s, pyrazine H) ppm; ms: m/e 243 (M<sup>+</sup>).

Anal. Calcd. for C<sub>15</sub>H<sub>21</sub>N<sub>3</sub>: C, 74.03; H, 8.70; N, 17.27. Found: C, 73.81; H, 8.74; N, 17.14.

**(Z)-2-(3,6-Diisobutyl-2-pyrazinyl)acrylonitrile (6d').**

This compound had the following physical properties: colorless oil, bp 118-123°/1 torr; uv: λ max 246.5 (log ε = 4.13), 308 (3.92), 313 (3.88, shoulder) nm; ir (liquid film): 2230 (C≡N), 750 (cis CH=CH) cm<sup>-1</sup>; pmr: δ 0.87 (6H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 0.90 (6H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.00 (2H, m, 2 x CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.65 (4H, d, J = 7 Hz, 2 x CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 5.62 (1H, d, J = 12 Hz, CH=CH), 7.33 (1H, d, J = 12 Hz, CH=CH), 8.33 (1H, s, pyrazine H) ppm; ms: m/e 243 (M<sup>+</sup>).

Anal. Calcd. for C<sub>15</sub>H<sub>21</sub>N<sub>3</sub>: C, 74.03; H, 8.70; N, 17.27. Found: C, 74.16; H, 8.77; N, 17.17.

**General Procedure for the Reaction of Monochloropyrazine 4-Oxides 2a-d with Ethylenes.**

A mixture of a monochloropyrazine 4-oxide (1.5 mmoles), an ethylenic compound (2.25 mmoles of styrene and ethyl acrylate), potassium acetate (220 mg, 2.25 mmoles) and tetrakis(triphenylphosphine)palladium (87 mg, 0.75 mmoles) in *N,N*-dimethylacetamide (5 ml) was treated under the conditions represented in Table 2. The reaction mixtures were worked up the same as described before.

**(E)-3,6-Dimethyl-2-styrylpyrazine 4-Oxide (7a).**

This compound had the following physical properties: colorless prisms (from methanol-water), mp 118-119°; uv: λ max 227.9 (log ε = 3.77), 236 (3.74, shoulder), 272.5 (4.10), 301 (3.72, shoulder), 347 (3.79), 358 (3.75, shoulder) nm; ir (potassium bromide): 975 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 2.48 (3H, s, CH<sub>3</sub>), 2.57 (3H, s, CH<sub>3</sub>), 7.22 (1H, d, J = 15 Hz, CH=CH), 7.30-7.50 (3H, m, benzene H), 7.50-7.73 (2H, m, benzene H), 7.88 (1H, d, J = 15 Hz, CH=CH), 7.97 (1H, s, pyrazine H) ppm; ms: m/e 226 (M<sup>+</sup>).

Anal. Calcd. for C<sub>14</sub>H<sub>14</sub>N<sub>2</sub>O: C, 74.31; H, 6.24; N, 12.38. Found: C, 74.10; H, 6.23; N, 12.33.

**(E)-3,6-Diethyl-2-styrylpyrazine 4-Oxide (7b).**

This compound had the following physical properties: colorless prisms (from hexane), mp 101-102°; uv: λ max 231 (log ε = 4.24), 237 (4.23, shoulder), 275 (4.59), 300 (4.29, shoulder), 347 (4.36), 359 (4.32, shoulder) nm; ir (potassium bromide): 960 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 1.27 (3H, t, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 1.33 (3H, t, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 2.73 (2H, q, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 3.10 (2H, q, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 7.15 (1H, d, J = 15 Hz, CH=CH), 7.27-7.52 (3H, m, benzene H), 7.52-7.72 (2H, benzene H), 7.92 (1H, d, J = 15 Hz, CH=CH), 7.95 (1H, s, pyrazine H) ppm; ms: m/e 254 (M<sup>+</sup>).

Anal. Calcd. for C<sub>16</sub>H<sub>18</sub>N<sub>2</sub>O: C, 75.56; H, 7.13; N, 11.02. Found: C, 75.66; H, 7.22; N, 10.91.

**(E)-3,6-Diisopropyl-2-styrylpyrazine 4-Oxide (7c).**

This compound had the following physical properties: colorless prisms (from methanol-water), mp 88-89°; uv: λ max 231 (log ε = 4.13), 236.5 (4.10, shoulder), 276.5 (4.47), 301.5 (4.16, shoulder), 346.5 (4.17), 359 (4.10, shoulder) nm; ir (potassium bromide): 960 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 1.33 (6H, d, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 1.48 (6H, d, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 2.97 (1H, m, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 2.97 (1H, m, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 3.95 (1H, m, J = 7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 7.28-7.50 (3H, m, benzene H), 7.32 (1H, d, J = 16.5 Hz, CH=CH), 7.50-7.70 (2H, m, benzene H), 7.87 (1H, d, J = 16.5 Hz, CH=CH), 7.90 (1H, s, pyrazine H) ppm; ms: m/e 282 (M<sup>+</sup>).

Anal. Calcd. for C<sub>18</sub>H<sub>22</sub>N<sub>2</sub>O: C, 76.56; H, 7.85; N, 9.92. Found: C, 76.32; H, 7.92; N, 9.84.

**(E)-3,6-Diisobutyl-2-styrylpyrazine 4-Oxide (7d).**

This compound had the following physical properties: colorless prisms (from methanol-water), mp 93-94°; uv: λ max 230 (log ε = 3.92), 238 (3.87, shoulder), 276 (4.19), 303 (3.86, shoulder), 348 (3.90), 362 (3.84, shoulder) nm; ir (potassium bromide): 965 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 0.97 (6H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 1.00 (6H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.18 (2H, m, 2 x CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.57 (2H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 2.97 (2H, d, J = 7 Hz, CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>), 7.22 (1H, d, J = 16 Hz, CH=CH), 7.27-7.47 (3H, m, benzene H), 7.47-7.67 (2H, m, benzene H), 7.88 (1H, d, J = 16 Hz, CH=CH), 7.88 (1H, s, pyrazine H) ppm; ms: m/e 310 (M<sup>+</sup>).

Anal. Calcd. for C<sub>20</sub>H<sub>26</sub>N<sub>2</sub>O: C, 77.38; H, 8.44; N, 9.03. Found: C, 77.57; H, 8.54; N, 9.00.

**(E)-2-(3,6-Dimethyl-4-oxido-pyrazin-2-yl)acrylic Acid Ethyl Ester (8a).**

This compound had the following physical properties: colorless prisms (from isopropyl ether), mp 142°; uv: λ max 254 (log ε = 4.04), 282 (3.43, shoulder), 332 (3.30) nm; ir (potassium bromide): 1720 (C=O), 970 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 1.33 (3H, t, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 2.47 (3H, s, CH<sub>3</sub>), 2.55 (3H, s, CH<sub>3</sub>), 4.28 (2H, q, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 7.08 (1H, d, J = 15 Hz, CH=CH), 7.78 (1H, d, J = 15 Hz, CH=CH), 8.03 (1H, s, pyrazine H) ppm; ms: 222 (M<sup>+</sup>).

Anal. Calcd. for C<sub>11</sub>H<sub>14</sub>N<sub>2</sub>O<sub>3</sub>: C, 59.45; H, 6.35; N, 12.60. Found: C, 59.48; H, 6.51; N, 12.66.

**(E)-2-(3,6-Diethyl-4-oxido-pyrazin-2-yl)acrylic Acid Ethyl Ester (8b).**

This compound had the following physical properties: colorless prisms (from hexane), mp 110-111°; uv: λ max 255.5 (log ε = 4.62), 287 (4.03, shoulder), 332.5 (3.85), 343.5 (3.79, shoulder) nm; ir (potassium bromide): 1720 (C=O), 970 (trans CH=CH) cm<sup>-1</sup>; pmr: δ 1.25 (3H, t, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 1.33 (3H, t, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 1.35 (3H, t, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 2.75 (2H, q, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 3.08 (2H, q, J = 7 Hz, CH<sub>2</sub>CH<sub>3</sub>), 4.30 (2H, q, J = 7 Hz, COOCH<sub>2</sub>CH<sub>3</sub>), 7.15 (1H, d, J = 16 Hz, CH=CH), 7.78 (1H, d, J = 16 Hz, CH=CH), 8.03 (1H, s, pyrazine H) ppm; ms: m/e 250 (M<sup>+</sup>).

Anal. Calcd. for C<sub>13</sub>H<sub>18</sub>N<sub>2</sub>O<sub>3</sub>: C, 62.38; H, 7.25; N, 11.19. Found: C, 62.44; H, 7.27; N, 11.34.

**(E)-2-(3,6-Diisopropyl-4-oxido-pyrazin-2-yl)acrylic Acid Ethyl Ester (8c).**

This compound had the following physical properties: colorless prisms

(from hexane), mp 119-120°; uv:  $\lambda$  max 257.5 (log  $\epsilon$  = 4.53), 291 (3.94, shoulder), 333 (3.71) nm; ir (potassium bromide): 1710 (C=O), 970 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.30 (6H, d, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 1.40 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 1.45 (6H, d, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 2.93 (1H, m, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 3.85 (1H, m, J = 7 Hz,  $\text{CH}(\text{CH}_3)_2$ ), 4.30 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 7.10 (1H, d, J = 16 Hz, CH=CH), 7.93 (1H, d, J = 16 Hz, CH=CH), 8.00 (1H, s, pyrazine H) ppm; ms: m/e 278 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{15}\text{H}_{22}\text{N}_2\text{O}_3$ : C, 64.72; H, 7.97; N, 10.07. Found: C, 65.02; H, 8.04; N, 10.04.

**(E)-2-(3,6-Diisobutyl-4-oxido-pyrazin-2-yl)acrylic Acid Ethyl Ester (8d).**

This compound had the following physical properties: colorless prisms (from hexane), mp 116-117°; uv:  $\lambda$  max 256.5 (log  $\epsilon$  = 4.36), 290 (3.78, shoulder), 334.5 (3.58), 345.5 (3.52, shoulder) nm; ir (potassium bromide): 1715 (C=O), 950 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  0.97 (12H, d, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 1.35 (3H, t, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 2.17 (2H, m, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.57 (2H, d, J = 7 Hz,  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.95 (2H, d, J = 7 Hz,  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 4.30 (2H, q, J = 7 Hz,  $\text{CH}_2\text{CH}_3$ ), 7.13 (1H, d, J = 16 Hz, CH=CH), 7.82 (1H, d, J = 16 Hz, CH=CH), 7.98 (1H, s, pyrazine H) ppm; ms: m/e 306 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{17}\text{H}_{26}\text{N}_2\text{O}_3$ : C, 66.64; H, 8.55; N, 9.14. Found: C, 66.77; H, 8.59; N, 8.98.

General Procedure for the Reaction of Dichloropyrazines **3a-d** with Styrene.

A mixture of a dichloropyrazine (2 mmoles), styrene (500 mg, 4.8 mmoles), potassium acetate (470 mg, 4.8 mmoles) and tetrakis(triphenylphosphine)palladium (232 mg, 0.2 mmole) in *N,N*-dimethylacetamide (5 ml) was refluxed for 15 hours. The reaction mixtures were worked up as same as described before.

**(E)-3,6-Dimethyl-2,5-distyrylpyrazine (9a).**

This compound had the following physical properties: pale yellow fine needles (from isopropyl ether), mp 220-222°; uv:  $\lambda$  max 226 (log  $\epsilon$  = 4.11), 237 (4.05, shoulder), 243.5 (3.95, shoulder), 294 (4.34), 302 (4.32, shoulder) nm; ir (potassium bromide): 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  2.70 (6H, s, 2 x  $\text{CH}_3$ ), 7.27-7.83 (12H, m, benzene H and 2 x CH=CH), 8.03 (2H, d, J = 16 Hz, 2 x CH=CH) ppm; ms: m/e 312 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{22}\text{H}_{20}\text{N}_2$ : C, 84.58; H, 6.45; N, 8.97. Found: C, 84.54; H, 6.40; N, 8.94.

**(E)-5-Chloro-3,6-dimethyl-2-styrylpyrazine (9a').**

This compound had the following physical properties: colorless fine needles (from methanol-water), mp 78-80°; uv:  $\lambda$  max 229 (log  $\epsilon$  = 3.96), 232 (3.94), 281.5 (4.23), 343 (4.30) nm; ir (potassium bromide): 960 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  2.67 (6H, s, 2 x  $\text{CH}_3$ ), 7.28 (1H, d, J = 16 Hz, CH=CH), 7.33-7.93 (5H, m, benzene H), 7.97 (1H, d, J = 16 Hz, CH=CH) ppm; ms: m/e 244 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{17}\text{H}_{13}\text{ClN}_2$ : C, 68.71; H, 5.35; N, 11.45. Found: C, 68.41; H, 5.35; N, 11.34.

**(E)-3,6-Diethyl-2,5-distyrylpyrazine (9b).**

This compound had the following physical properties: pale yellow prisms (from isopropyl ether), mp 203-204°; uv:  $\lambda$  max 226 (log  $\epsilon$  = 3.96), 237 (3.88, shoulder), 244 (3.78, shoulder), 294 (4.20), 302 (4.18, shoulder) nm; ir (potassium bromide): 955 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.40 (6H, t, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}_3$ ), 3.03 (4H, q, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}_3$ ), 7.23-7.95 (12H, m, benzene H and 2 x CH=CH), 8.05 (2H, d, J = 16 Hz, 2 x CH=CH) ppm; ms: m/e 340 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{24}\text{H}_{24}\text{N}_2$ : C, 84.66; H, 7.11; N, 8.23. Found: C, 84.67; H, 7.12; N, 8.23.

**(E)-3,6-Diisopropyl-2,5-distyrylpyrazine (9c).**

This compound had the following physical properties: pale yellow needles (from ethyl acetate), mp 219-221°; uv:  $\lambda$  max 226 (log  $\epsilon$  = 4.01), 235 (3.94, shoulder), 243 (3.82, shoulder), 293 (4.25), 302 (4.22, shoulder) nm; ir (potassium bromide): 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.33 (12H, d, J = 7 Hz, 2 x  $\text{CH}(\text{CH}_3)_2$ ), 3.35 (2H, m, J = 7 Hz, 2 x  $\text{CH}(\text{CH}_3)_2$ ), 7.03-7.63 (12H, m, benzene H and 2 x CH=CH), 7.80 (2H, d, J = 16 Hz, 2 x CH=CH) ppm; ms: m/e 368 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{26}\text{H}_{28}\text{N}_2$ : C, 84.74; H, 7.66; N, 7.60. Found: C, 84.57; H, 7.71; N, 7.78.

**(E)-3,6-Diisobutyl-2,5-distyrylpyrazine (9d).**

This compound had the following physical properties: pale yellow needles (from isopropyl ether), mp 170-170.5°; uv:  $\lambda$  max 225 (log  $\epsilon$  = 3.69), 237 (3.60, shoulder), 245 (3.47, shoulder), 295 (3.96), 305 (3.93, shoulder) nm; ir (potassium bromide): 965 (*trans* CH=CH)  $\text{cm}^{-1}$ ; pmr:  $\delta$  1.03 (12H, d, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.28 (2H, m, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 2.85 (4H, d, J = 7 Hz, 2 x  $\text{CH}_2\text{CH}(\text{CH}_3)_2$ ), 7.33-7.90 (12H, m, benzene H and 2 x CH=CH), 8.05 (2H, d, J = 16 Hz, 2 x CH=CH) ppm; ms: m/e 396 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{28}\text{H}_{32}\text{N}_2$ : C, 84.80; H, 8.13; N, 7.06. Found: C, 84.67; H, 8.18; N, 7.09.

REFERENCES AND NOTES

- [1] R. F. Heck, "Palladium Reagents in Organic Syntheses", Academic Press Inc., London, 1985.
- [2] T. Sakamoto, H. Arakida, K. Edo, and H. Yamanaka, *Heterocycles*, **16**, 965 (1981).
- [3] T. Sakamoto, M. Shiraiwa, Y. Kondo, and H. Yamanaka, *Synthesis*, 312 (1983).
- [4] A. Ohsawa, Y. Abe, and H. Igeta, *Chem. Pharm. Bull.*, **28**, 3488 (1980).
- [5] Y. Akita, M. Shimazaki, and A. Ohta, *Synthesis*, 974 (1981).
- [6] Y. Akita and A. Ohta, *Heterocycles*, **19**, 329 (1982).
- [7] Y. Akita, A. Inoue, and A. Ohta, *Chem. Pharm. Bull.*, **34**, 1447 (1986).
- [8] A. Ohta, A. Inoue, and T. Watanabe, *Heterocycles*, **22**, 2317 (1984).
- [9] A. Ohta, M. Ohta, and T. Watanabe, *Heterocycles*, **24**, 785 (1986).
- [10] R. A. Baxter and F. S. Spring, *J. Chem. Soc.*, 1179 (1947).
- [11] G. W. K. Cavil and E. Houghton, *Aust. J. Chem.*, **27**, 879 (1974).
- [12] A. Ohta, A. Imazeki, Y. Itoigawa, H. Yamada, C. Suga, C. Takagai, H. Sano, and T. Watanabe, *J. Heterocyclic Chem.*, **20**, 311 (1983).
- [13] A. Ohta, *Chem. Pharm. Bull.*, **16**, 1160 (1968).
- [14] A. Ohta, T. Ohwada, C. Ueno, M. Sumita, S. Masano, Y. Akita, and T. Watanabe, *Chem. Pharm. Bull.*, **27**, 1378 (1978).
- [15] A. Ohta, Y. Akita, and Y. Nakane, *Chem. Pharm. Bull.*, **27**, 2980 (1979).
- [16] H. Gainer, M. Kokorudz, and W. K. Langdon, *J. Org. Chem.*, **26**, 2360 (1961).
- [17] A. Ohta, S. Masano, M. Tsutsui, F. Yamamoto, S. Suzuki, M. Makita, H. Tamamura, and Y. Akita, *J. Heterocyclic Chem.*, **18**, 555 (1981).
- [18] R. A. Baxter, G. T. Newbold, and F. S. Spring, *J. Chem. Soc.*, 1859 (1948).
- [19] A. Ohta, Y. Akita, and M. Hara, *Chem. Pharm. Bull.*, **27**, 2027 (1979).
- [20] A. Ohta and M. Ohta, *Synthesis*, 216 (1985).