Table 2. Catalytic cocyclotrimerization of *N*-benzyldiz(propargyl) amine with phenylacetylene[a]

Entry	Catalyst	Yield (%)[b]
1	[(COD)Rh(DPPF)]ClO_4	27
2	[(COD)Rh(DPPE)]ClO_4	15
3	[(COD)Rh(FcNP)]ClO_4	19
4	$Rh(PPh_3)_3Cl$	10
5	$Cp^*Rh(CO)_2$	8
6	$Co_2(CO)_8$	7

[a]Reaction conditions: [catalyst] = 1 mol%; solvent = MeCN; reaction time = 4 h under reflux. [b]GC yield.

the more-electronegative nitrogen makes the *trans* Ir-olefin bond makes more labile toward substitution by incoming substrate which in turn undergoes intramolecular cyclization more easily.

As proposed by others,[10] the catalytic cycle may involve an initial oxidative addition of OH of the acid, nucleophilic attack of the carboxylate on the coordinated acetylene followed by reductive elimination to generate the lactone. These same cationic rhodium complexes (Table 1) were found to be poor catalyst, however, when applied to the cocyclotrimerization of N-benzyldi(propargyl)amine with phenylacetylene as presented in equation 2 (R = Ph; R' = benzyl). The results are shown in Table 2. As shown in the table rhodium and cobalt carbonyl complexes which are the well-known catalysts for cyclotrimerization of alkyne derivatives gave even poorer yields in this case.

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18. Crystal structure data for (COD)Ir(PPFA)·$2CH_3CH_2OH$: $a = 11.008(2)$, $b = 11.475(2)$, $c = 14.884(3)$ Å, $b = 108.19(2)°$, $V = 1784.5(7)$ Å^3, space group $P2_1$ (No. 4). The single crystals were obtained from ethanol solution. The structure was solved by Patterson method and subsequent difference Fourier techniques and refined by full-matrix least-squares for 473 parameters and 2887 observed reflections ($I \geq 3\sigma(I)$), $R = 0.040$, $R_W = 0.044$.

Synthesis of Plant Growth Promoting and Fungicidal 4-Quinolinone Metabolites of *Pseudomonas cepacia*

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A number of 2-alkyl-4-quinolinones have been isolated from both microorganisms and plants, and structurally related N-alkyl, N-oxide, or O-alkyl derivatives have been also found.[1,2] It was proposed that 2-heptyl-4-quinolinone (5) from a microbial fermentation broth was a condensation product of anthranilic acid and a fatty acid precursor.[3] However, biosynthetically different 3-alkyl 4-quinolinones have been isolated in small numbers.[4~8] The 4-quinolinone compounds ex-

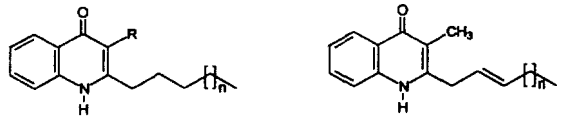

Figure 1.

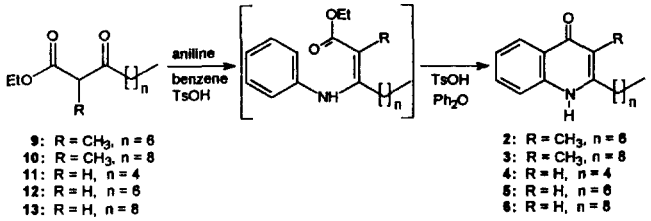

Figure 2.

hibit diverse biological activities as antibiotics,[6,7,9] electron transport inhibitors of the respiratory chain,[7,10] and lipoxygenase inhibitors.[11] Recently, we isolated 2-pentyl-3-methyl-4-quinolinone (**1**) and 2-heptyl-3-methyl-4-quinolinone (**2**), and 3-methyl-2-nonyl-4-quinolinone (**3**), new minor secondary metabolites of *Pseudomonas cepacia* collected from the red-pepper growing soil,[12] along with known 2-(2-heptenyl)-3-methyl-4-quinolinone (**7**) and 2-(2-nonenyl)-3-methyl-4-quinolinone (**8**).[4,6] They showed red-pepper growth promoting effect and antifungal activity against plant pathogens. We report the synthesis of newly isolated alkaloid metabolites, 2-alkyl-3-methyl-4-quinolinones (**2, 3**), and 2-alkyl-4-quinolinones (**4, 5, 6**) for further biological studies (Figure 1).

Several different synthetic methods for the construction of 4-quinolinone nucleus have been developed, *i.e.*, a Conrad-Limpach condensation of aniline with β-ketoester,[13,14] Niementowski cyclization starting from 2-nitrobenzoic acid,[15,16] and the reaction of isatoic anhydride with enolate followed by subsequent cyclization.[17]

For synthesis of 2-substituted-3-methyl-4-quinolinones we adapted the Conrad-Limpach condensation reaction,[13,14] although it is not very high yielding overall, but a short step reaction. As shown in Figure 2, a viable precursor for the quinolinone side chain is β-ketoesters. Among many synthetic routes[18~23] to β-ketoesters we found a Wierenga method[18] practically useful. Thus the acylacetates (**11, 12, 13**) were prepared from the corresponding acyl chloride and methylated[24] at the 2-position to give 2-acylpropionates (**9, 10**). The β-ketoesters were then condensed with aniline in the presence of *p*-toluenesulfonic acid and without isolation of the resulting enamine esters subsequently cyclized in diphenyl ether at 200 ℃. Although the reaction became deep brown, the high-boiling diphenyl ether was efficiently removed by silica gel chromatography with elution of ethyl acetate/hexane and trituration of a methanol eluate with ethyl acetate afforded the 4-quinolinones (**2-6**) in 60-69% overall yield. Replacement of diphenyl ether with xylene at lower reaction temperature were not successful.[25] The spectral data of compound **2** and **3** were identical to those of authentic natural products and confirmed the structure of natural products. Their biological activities are presently under evaluation.

Experimental

Melting points were measured on an Electrothermal's IA 9100 digital melting point apparatus and are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker AMX 500 NMR spectrometer at 500 MHz and 125.77 MHz, respectively. High and low resolution mass spectra were obtained using a JEOL HX110A-HX110A Tandem HR mass spectrometer by electron impact. Infrared spectra were recorded on a Shimazu IR-408 infrared spectrophotometer. Ultraviolet spectra were recorded on a Hitachi U-3300 ultraviolet spectrophotometer. Analytical thin-layer chromatography (TLC) was carried out on Merck plastic plates precoated with silica gel 60 F254 (0.2 mm layer thickness) and visualized using UV lamp or charring solution (anisaldehyde and sulfuric acid in methanol). Chromatography was performed on Merck silica gel 60 (70-230 mesh). High performance liquid chromatography was conducted using a Young-in HPLC 9500 system.

General Method for Synthesis of 4-Quinolinones. A solution of β-ketoester (20 mmol), aniline (20 mmol), and *p*-toluenesulfonic acid (0.02 g) in bezene (50 mL) was heated to reflux with stirring for 5 h. The water formed was removed by using a Dean-Stark apparatus. The reaction mixture was concentrated and diluted with diphenyl ether (2 mL) and added to a diphenyl ether (50 mL) at 200 ℃ in a dropwise fashion. The reaction mixture was stirred at the temperature for 30 min. The reaction mixture was cooled, diluted with EtOAc, and chromatographed on a silica gel with 1 : 1 hexane/EtOAc to remove diphenyl ether and followed by methanol elution to afford the main product. Concentration, trituration with EtOAc, and filtration afforded the 4-quinolinone as a yellowish solid. An analytical sample was obtained as a white crystalline solid by recrystallization from aqueous MeOH.

2-Heptyl-3-methyl-4-quinolinone (2). Obtained as a white solid in 65% yield starting from ethyl 2-methyl-3-oxodecanoate (**9**) which was prepared according to the literature method[18] using potassium monoethyl malonate, *n*-butyllithium, and octanoyl chloride in dry THF, and followed by methylation[24] : mp 227-228 ℃; EIMS m/z 257 [M$^+$]; HREIMS m/z (rel. int.) 257.1774 [M$^+$] (74) (calcd 257.1780 for $C_{17}H_{23}NO$), 200.1075 (78), 186.0916 (61), 173.0817 (100), 144.0816 (11); UV (MeOH) 215, 239, 322, 335 nm; IR (KBr) 3355, 2900, 1632, 1608, 1603, 1590, 1552, 1500, 1479, 1369, 1358, 1252, 995, 751, 690 cm^{-1}; ^{1}H NMR (CD_3OD) δ 0.89 (t, 3H, J=7.0 Hz), 1.30-1.35 (m, 4H), 1.34-1.42 (m, 2H), 1.40-1.46 (m, 2H), 1.68-1.73 (m, 2H), 2.15 (s, 3H), 2.81 (t, 2H, J=8.0 Hz), 7.33 (ddd, 1H, J=8.2, 6.9, 1.1 Hz), 7.53 (ddd, 1H, J=8.4, 1.1, 0.6 Hz), 7.62 (ddd, 1H, J=8.4, 6.9, 1.4 Hz), 8.22 (ddd, 1H, J=8.2, 1.4, 0.6 Hz) ppm; ^{13}C NMR (CD_3OD) δ 179.6, 153.3, 140.6, 132.6, 126.2, 124.47, 124.42, 118.6, 116.2, 33.4, 32.9, 30.5, 30.1, 29.9, 23.6, 14.3, 10.8 ppm.; HPLC Rt 6.7 min (same as the natural product,[12] Phenomenex μ-Bondapak C-18, 3.9×300 mm, UV 225 nm, 1 mL/min, 75 : 25 MeOH/H_2O).

3-Methyl-2-nonyl-4-quinolinone (3). Obtained as a white solid in 60% yield starting from ethyl 2-methyl-3-oxododecanoate (**10**)[18,24] : mp 215-216 ℃; EIMS m/z 285 [M$^+$];

HREIMS m/z (rel. int.) 285.2091 [M^+] (32) (calcd 285.2093 for $C_{19}H_{27}NO$), 200.1071 (41), 186.0915 (68), 173.0846 (100), 144.0832 (14); UV (MeOH) 214, 239, 322, 335 nm; IR (KBr) 3350, 2830, 1639, 1608, 1593, 1557, 1503, 1481, 1397, 1360, 1000, 758, 694 cm^{-1}; ^1H NMR (CD_3OD) δ 0.88 (t, 3H, J=7.1 Hz), 1.27-1.34 (m, 8H), 1.32-1.38 (m, 2H), 1.38-1.46 (m, 2H), 1.70-1.73 (m, 2H), 2.15 (s, 3H), 2.81 (t, 2H, J=8.0 Hz), 7.33 (ddd, 1H, J=8.2, 6.9, 1.0 Hz), 7.53 (dd, 1H, J=8.4, 1.0 Hz), 7.62 (ddd, 1H, J=8.4, 6.9, 1.4 Hz), 8.22 (dd, 1H, J=8.2, 1.4 Hz) ppm; ^{13}C NMR (CD_3OD) δ 179.6, 153.3, 140.6, 132.6, 126.2, 124.47, 124.42, 118.6, 116.2, 33.4, 33.0, 30.6, 30.5, 30.4, 30.3, 30.0, 23.7, 14.4, 10.8 ppm; HPLC Rt 11.5 min (same as the natural product,[12] Phenomenex μ-Bondapak C-18, 3.9×300 mm, UV 225 nm, 1 mL/min, 75 : 25 MeOH/H_2O).

2-Pentyl-4-quinolinone (4). Obtained as a white solid in 69% yield starting from ethyl 3-oxooctanoate (**11**)[18] : mp 139-140 ℃ (lit[9] 141-142 ℃, lit[15] 134-138 ℃); EIMS m/z (rel. int.) 215 [M^+] (17), 186 (8), 172 (26), 159 (100), 130 (12), 44 (29); UV (MeOH) 213, 234, 315, 327 nm; IR (KBr) 3350, 2900, 1628, 1592, 1548, 1495, 1473, 1439, 1315, 1249, 798, 750 cm^{-1}; ^1H NMR (CD_3OD) δ 0.92 (t, 3H, J=7.0 Hz), 1.37-1.42 (m, 4H), 1.76-1.78 (m, 2H), 2.70 (t, 2H, J=7.7 Hz), 6.22 (s, 1H), 7.37 (ddd, 1H, J=8.2, 7.0, 1.1 Hz), 7.57 (ddd, 1H, J=8.4, 1.1, 0.4 Hz), 7.62 (ddd, 1H, J=8.4, 7.0, 1.5 Hz), 8.20 (ddd, 1H, J=8.2, 1.5, 0.4 Hz) ppm; ^{13}C NMR (CD_3OD) δ 180.7, 157.1, 141.6, 133.4, 126.0, 125.5, 125.0, 119.0, 108.9, 35.0, 32.4, 29.8, 23.4, 14.2 ppm.

2-Heptyl-4-quinolinone (5). Obtained as a white solid in 75% yield starting from ethyl 3-oxodecanoate (**12**)[18] : mp 141-142 ℃ (lit[14]. 138-141 ℃); EIMS m/z (rel. int.) 243 [M^+] (21), 172 (43), 159 (100), 130 (9); UV (MeOH) 213, 234, 315, 327 nm; IR (KBr) 3400, 2870, 1633, 1595, 1556, 1510, 1476, 1447, 1388, 1195, 1131, 763 cm^{-1}; ^1H NMR (CD_3OD) δ 0.89 (t, 3H, J=7.0 Hz), 1.29-1.34 (m, 4H), 1.32-1.43 (m, 4H), 1.76 (quintet, 2H, J=7.7 Hz), 2.71 (t, 2H, J=7.7 Hz), 6.22 (s, 1H), 7.38 (ddd, 1H, J=8.2, 7.0, 1.1 Hz), 7.57 (ddd, 1H, J=8.4, 1.1, 0.3 Hz), 7.62 (ddd, 1H, J=8.4, 7.0, 1.5 Hz), 8.20 (ddd, 1H, J=8.2, 1.5, 0.3 Hz) ppm; ^{13}C NMR (CD_3OD) δ 180.7, 157.1, 141.6, 133.4, 126.0, 125.5, 125.0, 119.0, 108.9, 35.0, 32.8, 30.2, 30.1, 30.0, 23.6, 14.3 ppm.

2-Nonyl-4-quinolinone (6). Obtained as a white solid in 72% yield starting from ethyl 3-oxododecanoate (**13**)[18] : mp 131-132 ℃ (lit[14]. 129-132 ℃); EIMS m/z (rel. int.) 271 [M^+] (20), 172 (58), 159 (100), 130 (10); UV (MeOH) 213, 234, 315, 327 nm; IR (KBr) 2800, 1638, 1593, 1552, 1503, 1473, 1444, 1353, 1327, 1137, 762 cm^{-1}; ^1H NMR (CD_3OD) δ 0.87 (t, 3H, J=7.0 Hz), 1.22-1.33 (m, 8H), 1.32-1.43 (m, 4H), 1.76 (quintet, 2H, J=7.7 Hz), 2.71 (t, 2H, J=7.7 Hz), 6.22 (s, 1H), 7.38 (ddd, 1H, J=8.2, 7.0, 1.1 Hz), 7.57 (ddd, 1H, J=8.4, 1.1, 0.5 Hz), 7.62 (ddd, 1H, J=8.4, 7.0, 1.5 Hz), 8.20 (ddd, 1H, J=8.2, 1.5, 0.5 Hz) ppm; ^{13}C NMR (CD_3OD) δ 180.7, 157.1, 141.6, 133.4, 126.0, 125.5, 125.0, 119.0, 108.9, 35.0, 33.0, 30.5, 30.4, 30.3, 30.1, 30.1, 23.7, 14.3 ppm.

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Efficient Synthetic Methods for (η^5-C_5H_5)$(CO)_2$Cr≡C(C_6H_4Me-4)

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Since the first transition metal alkylidyne complex was reported by Fischer and coworkers in 1973,[1] its chemistry has been extensively investigated in various aspects, *i.e.*, precursors for synthetic use,[2] active catalysts for alkyne me-