Reaction of the Morita–Baylis–Hillman Acetates of 2-Azidobenzaldehydes with Triethyl Phosphite: Synthesis of 1-Diethylphosphono-1,2-dihydroquinolines and 3-Acetoxymethylquinolines

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Abstract: A simple synthesis of 1-diethylphosphono-1,2-dihydroquinolines and 3-acetoxymethylquinolines from the reaction of several Morita–Baylis–Hillman acetates of 2-azidobenzaldehydes with triethyl phosphite has been described.

Key words: quinoline, triethyl phosphite, Morita–Baylis–Hillman acetate, Michaelis–Arbuzov rearrangement, iminophosphorane

The quinoline ring system is an important structural unit in naturally occurring quinoline alkaloids, therapeutics, and synthetic analogues with interesting biological activities.[1] Among them, 1,2-dihydroquinolines have received substantial attention due to their potential biological activities arising from their antioxidant properties,[2] as well as being general synthetic building blocks of some other biologically active compounds.[3] However, synthetic methods of 1,2-dihydroquinolines are limited.[4,5] Dihydroquinolines can be prepared most often by the addition reaction of nucleophiles to the quinolinium salts[5] and by the S_NAr reaction of the cinnamylamine derivatives, which are readily obtainable from the Morita–Baylis–Hillman acetates having an *ortho*-halogen.[6] Recently, an efficient one-step synthesis of 1-arylsulfonyl-1,2-dihydroquinoline and 1,2,3,4-tetrahydroquinoline rings using tandem Michael–aldol cyclization reaction between N-protected *ortho*-aminobenzaldehydes and α,β-unsaturated carbonyl compounds in the presence of a quaternary ammonium salt was reported.[7]

The Morita–Baylis–Hillman (MBH) reaction is one of the most powerful carbon–carbon bond forming reaction.[8] Much attention has recently been focused on the intra-[9–12] and intermolecular S_N2' reaction[13] of the acetates, imines or bromo derivatives of the MBH adducts. The intramolecular reaction of the MBH adducts in synthesis of chromenes,[9] benzothiopyrans,[10] coumarins[11] and quinolines[6,12] have been reported.

Basavaiah and Pandiaraju[14] had found that the nucleophilic attack of triethyl phosphite (TEP) on the MBH acetates provided allylphosphonates after thermal Michaelis–Arbuzov (MA) rearrangement.[15] In continuation of our interest in the synthesis of heterocyclic compounds using the MBH reaction,[16] we have envisioned that 1,2-dihydroquinoline derivatives bearing *N*-diethylphosphoryl group might in principle be obtained from the MBH acetates having *ortho*-iminophosphoranyl group via the construction of a C–N bond through the intramolecular S_N2' reaction followed by the MA rearrangement. To the best of our knowledge, there is no report in the literature for the synthesis of 1-dialkylphosphono-1,2-dihydroquinolines.

Accordingly, we first selected methyl 3-acetoxy-3-(2-azidophenyl)-2-methylenepropanoate (**4a**),[16b] the MBH acetate obtained from methyl acrylate and 2-azidobenzaldehyde, as a substrate for performing three consecutive reactions, i.e., the Staudinger reaction,[17] the intramolecular S_N2' reaction and then MA rearrangement, with TEP in refluxing toluene. This reaction led to the formation of the desired 3-carbomethoxy-1-diethylphosphono-1,2-dihydroquinoline (**7a**) in 79% yield and 3-acetoxymethyl-2-methoxyquinoline (**9a**) in 4% yield. Reaction of the MBH acetate **4b** having an electron-withdrawing nitro group at the 5-position with TEP afforded the corresponding 1,2-dihydroquinoline derivatives **7b** (59%) and quinoline **9b** (16%). Similar reaction of the acetate **4c** bearing an electron-donating methoxy group at the 5-position gave exclusively the 1-diethylphosphono-1,2-dihydroquinoline **7c** in excellent yield (91%) within three hours. When the reactions of the MBH acetates of methyl vinyl ketone (MVK) **4d–f** were run at room temperature, however, the products were found to be the 3-acetoxymethyl-2-methylquinolines **9d–f** (60–72%)[18] as the sole isolated products regardless of aromatic substituents. In the reaction of the MBH acetates of acrylonitrile **4g–i** the expected 3-cyano-1-diethylphosphono-1,2-dihydroquinolines **7g–i** (57–63%) were obtained (Table 1 and Scheme 1). Also, an attempt was made to isolate the intermediate iminophosphorane **5b** (80%) and transform it into **7b** (65%) and **9b** (22%) in refluxing toluene for 19 hours. On changing the MBH acetate **4b** to the MBH propanoate **4j**, (1,2-dihydroquinolinyl)phosphonate **7b** (46%) and 2-methoxy-6-nitro-3-propanoyloxymethylquinoline (**9j**; 16%) were produced, as expected (Scheme 2).

The reaction mechanism could be proposed as shown in Scheme 1. Generation of iminophosphorane **5** by the reaction of azide with TEP followed by the S_N2' displacement of acetate group affords the dihydroquinoline intermediate **6**. In the next step acetate ion attacks an ethyl group of the phosphonium salt **6** to result in the formation of the di-

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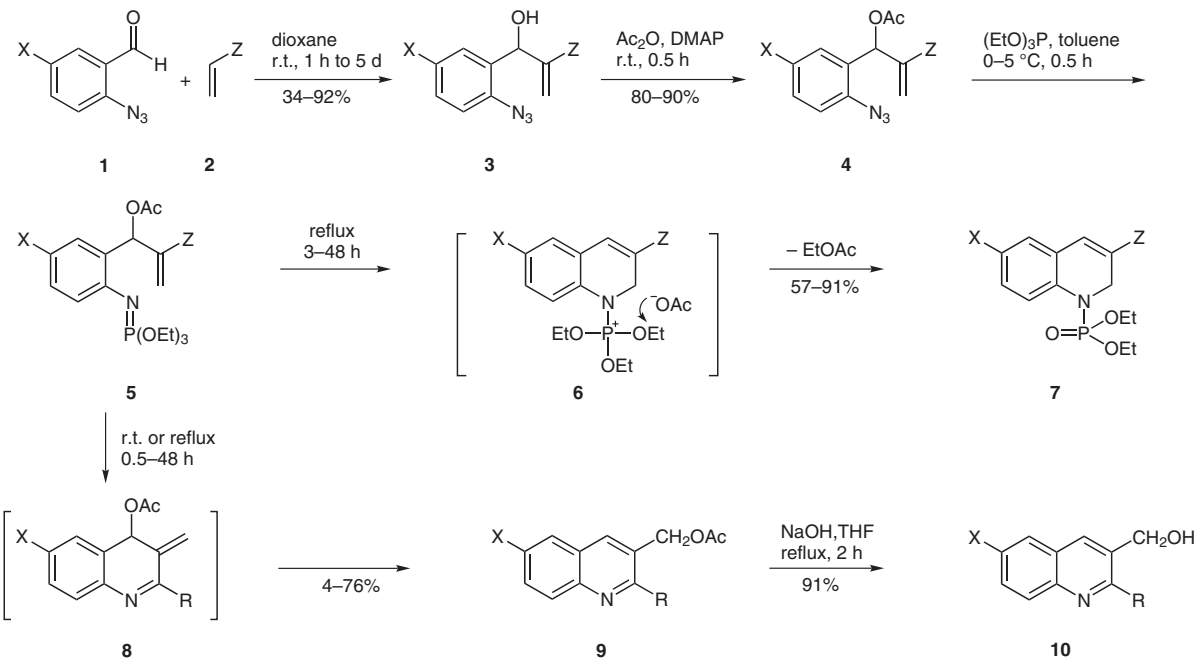
Table 1 Quinolines **7** and **9** Prepared

Reactant	Time (h)[a]	Product (yield, %)	
4a	10	**7a** (79)	**9a** (4)
4b	48	**7b** (59)	**9b** (16)
4c	3	**7c** (91)	–
4d	.5[b]	–	**9d** (60)
4e	2[b]	–	**9e** (70)
4f	4[b]	–	**9f** (76)
4g	24	**7g** (63)	–
4h	48	**7h** (57)	–
4i	24	**7i** (60)	–

[a] Reflux temperature.
[b] Room temperature.

ethyl (1,2-dihydroquinolinyl)phosphonate **7** and ethyl acetate by the well-known MA rearrangement. The formation of acetoxymethylquinoline derivatives **9** are attributed to the aza-Wittig olefination giving **8** followed by the aromatization via migration of acetoxy group under the reaction conditions.[18]

The structures **7** and **9** were established on the basis of spectroscopic data. Compound **7a**, for instance, had the molecular formula $C_{15}H_{20}NO_3P$, as indicated by HRMS and EIMS spectra and the base ion peak was observed at m/z = 188 [M^+ – $PO(OEt)_2$]. The ^1H NMR spectrum showed a characteristic peak at δ = 4.49 as doublet of doublet for the C2-methylene protons, and the C4-methine proton and methyl protons resonated in δ = 7.53 and 3.87 as two singlets. The characteristic signal found in the ^{31}P NMR spectra appeared at δ = 20.86. Compound **9a** had the molecular formula $C_{13}H_{13}NO_3$, as indicated by HRMS and EIMS spectra and the base ion peak was observed at m/z = 188 [$M^+ - COCH_3$] again. In the ^1H NMR spectrum, the signals from the methylene protons, C4-aromatic pro-

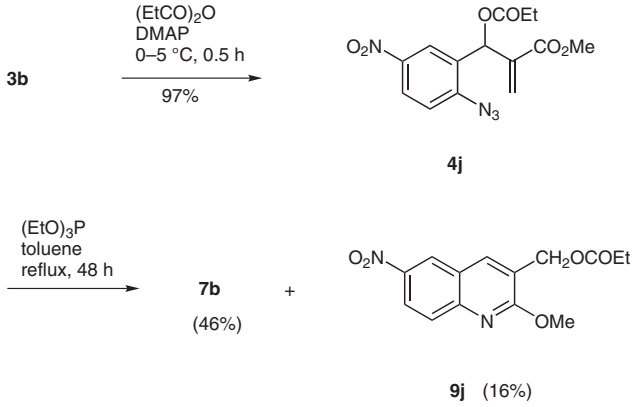


1, **2**, **3**, **4**, **5**, **6**, **7**, **8**, **9**, **10**

1	X	3, 4, 5, 7	X	Z	9, 10	X	R
a	H	**a**	H	CO_2Me	**a**	H	OMe
b	NO_2	**b**	NO_2	CO_2Me	**b**	NO_2	OMe
c	OMe	**c**	OMe	CO_2Me	**c**	OMe	OMe
		d	H	COMe	**d**	H	Me
		e	NO_2	COMe	**e**	NO_2	Me
		f	OMe	COMe	**f**	OMe	Me
		g	H	CN			
		h	NO_2	CN			
		i	OMe	CN			

Scheme 1

ton and two methyl protons appeared as four singlets at δ = 5.24, 7.99, 2.18 and 4.11 ppm. The ^{13}C NMR spectrum showed carbonyl carbon and C2-carbon signals at δ = 170.79 and 159.99 ppm, respectively. These ^{1}H and ^{13}C NMR values are in good agreement with those reported for a similar system.[18,19] In addition, hydrolysis of **9b** with sodium hydroxide in refluxing aqueous tetrahydrofuran gave alcohol **10b**. On examining the ^{1}H NMR spectrum of **10b** we identified *O*-methyl peak at δ = 4.16 ppm, methylene peak at δ = 4.82 ppm, OH peak at δ = 2.33 ppm, and C4-aromatic peak at δ = 8.16 ppm as all singlets.



Scheme 2

In conclusion, we have successfully synthesized several 1,2-dihydroquinoline derivatives and 3-acetoxymethylquinoline derivatives from the reaction of the MBH acetates of 2-azidobenzaldehydes derived from methyl acrylate, MVK and acrylonitrile with TEP, thus demonstrating the efficacy of the Morita–Baylis–Hillman adducts in organic synthesis.

Silica gel 60 (70–230 mesh ASTM) used for column chromatography was supplied by E. Merck. Analytical TLC was carried out on Merck silica gel 60 F_{254} TLC plates. Melting points were taken using an Electrothermal melting point apparatus and are uncorrected. Microanalyses were obtained using a Carlo Erba EA 1180 element analyzer. Electron impact (EI) and high resolution mass spectra (HRMS) were obtained using a Jeol SX 102 mass spectrometer. IR spectra were recorded on a Nicolet Magna 550 FTIR spectrometer. The ^{1}H, ^{13}C and ^{31}P NMR spectra were measured on a Gemini 300 spectrometer using $CDCl_3$ at 300 MHz, 75 MHz and 121 MHz, respectively. All chemical shifts are reported in ppm relative to TMS or $(PhO)_3PO$. The coupling constants (*J*) are expressed in Hz.

Methyl acrylate, MVK, acrylonitrile, DABCO, DMAP and TEP were obtained from Aldrich and were used without further purification. The known MBH adducts **3a**, **3d** and **3g**, MBH acetates **4a**, **4d**, **4g**,[16b] 2-azido-5-nitrobenzaldehyde[20] and 5-methoxy-2-nitrobenzaldehyde[21] were prepared according to the literature procedures. Petroleum ether (PE) used refers to the fraction boiling in the range 30–60 °C.

2-Azido-5-methoxybenzaldehyde (1c)

A mixture of 5-methoxy-2-nitrobenzaldehyde (9.06 g, 50 mmol) and NaN_3 (6.50 g, 100 mmol) in HMPA (100 mL) was stirred for 70 h at 60 °C. The reaction mixture was diluted with H_2O (300 mL) and extracted with EtOAc (3 × 100 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (7:1) to afford recovered starting aldehyde (4.80 g, 53%) and the desired **1c** (1.86 g, 21%) as a pale-yellow needle-like solid after crystallization with Et_2O–PE; mp 81 °C.

IR (KBr): 2876, 2858, 2134, 2096, 1686, 1610, 1493, 1291 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 3.84 (s, 3 H, CH_3), 7.19–7.21 (m, 2 H, arom), 7.36–7.37 (m, 1 H, arom), 10.32 (s, 1 H, CHO).

^{13}C NMR ($CDCl_3$): δ = 55.68, 110.64, 120.26, 123.39, 127.34, 135.74, 156.74, 188.17.

Anal. Calcd for $C_8H_7N_3O_2$: C, 54.24; H, 3.98; N, 23.72. Found: C, 54.11; H, 3.85; N, 23.60.

Methyl 3-(2-Azido-5-nitrophenyl)-3-hydroxy-2-methylenepropanoate (3b)

A mixture of 2-azido-5-nitrobenzaldehyde (**1b**; 1.92 g, 10 mmol), methyl acrylate (2.70 mL, 30 mmol) and DABCO (1.12 g, 10 mmol) was stirred without solvent for 1 h at r.t. The reaction mixture was diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (3:1) to afford **3b** (2.56 g, 92%) as a yellow solid after crystallization with Et_2O–PE; mp 74–76 °C.

IR (KBr): 3517, 2119, 1693, 1586, 1518, 1342, 1285 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 3.35 (d, *J* = 5.5 Hz, 1 H, OH), 3.79 (s, 3 H, OCH_3), 5.71 (s, 1 H, CH), 5.82 (d, *J* = 5.5 Hz, 1 H, CH), 6.39 (s, 1 H, CH), 7.28 (d, *J* = 8.4 Hz, 1 H, arom), 8.24 (dd, *J* = 2.6, 8.4 Hz, 1 H, arom), 8.42 (d, *J* = 2.6 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 52.21, 67.23, 118.38, 123.85, 124.39, 127.36, 133.44, 139.88, 143.78, 144.56, 166.49.

Anal. Calcd for $C_{11}H_{10}N_4O_5$: C, 47.49; H, 3.62; N, 20.14. Found: C, 47.31; H, 3.50; N, 19.92.

Methyl 3-(2-Azido-5-methoxyphenyl)-3-hydroxy-2-methylenepropanoate (3c)

A mixture of 2-azido-5-methoxybenzaldehyde (**1c**; 1.77 g, 10 mmol), methyl acrylate (2.70 mL, 30 mmol), triethanolamine (1.06 mL, 8 mmol) and DABCO (1.12 g, 10 mmol) in THF (10 mL) was stirred for 4 d at r.t. The reaction mixture was diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (4:1) to afford **3c** (1.63 g, 62%) as a brown oil.

IR (KBr): 3479, 2122, 1722, 1631, 1607, 1494, 1438, 1287 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 3.29 (d, *J* = 5.2 Hz, 1 H, OH), 3.77 (s, 3 H, OCH_3), 3.80 (s, 3 H, OCH_3), 5.65 (s, 1 H, CH), 5.78 (d, *J* = 5.2 Hz, 1 H, CH), 6.32 (s, 1 H, CH), 6.88 (dd, *J* = 2.7, 8.9 Hz, 1 H, arom), 7.03 (d, *J* = 2.7 Hz, 1 H, arom), 7.08 (d, *J* = 8.9 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 52.09, 55.56, 67.90, 113.24, 114.70, 119.12, 126.64, 129.53, 133.03, 140.77, 156.97, 166.93.

Anal. Calcd for $C_{12}H_{13}N_3O_4$: C, 54.75; H, 4.98; N, 15.96. Found: C, 54.61; H, 4.73; N, 15.82.

3-[1-(2-Azido-5-nitrophenyl)-1-hydroxy]methyl-3-buten-2-one (3e)

A mixture of 2-azido-5-nitrobenzaldehyde (**1b**; 1.92 g, 10 mmol), MVK (2.50 mL, 30 mmol) and DABCO (0.22 g, 2 mmol) in dioxane (15 mL) was stirred for 1.5 h at 0–5 °C. The reaction mixture was diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 × 30 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was

chromatographed on silica gel eluting with hexane–EtOAc (5:1) to afford **3e** (1.31 g, 50%) as a yellow solid after crystallization with Et_2O–PE; mp 98–99 °C.

IR (KBr): 3490, 2131, 1759, 1607, 1587, 1515, 1344, 1283 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.41 (s, 3 H, CH_3), 3.47 (d, *J* = 5.0 Hz, 1 H, OH), 5.84 (d, *J* = 5.0 Hz, 1 H, CH), 5.86 (s, 1 H, CH), 6.26 (s, 1 H, CH), 7.27 (d, *J* = 8.8 Hz, 1 H, arom), 8.21 (dd, *J* = 2.4, 8.8 Hz, 1 H, arom), 8.36 (d, *J* = 2.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 26.56, 66.83, 177.73, 118.97, 123.87, 124.68, 127.82, 133.78, 144.15, 147.86, 200.13.

Anal. Calcd for $C_{11}H_{10}N_4O_4$: C, 50.38; H, 3.84; N, 21.37. Found: C, 50.25; H, 3.67; N, 21.18.

3-[1-(2-Azido-5-methoxyphenyl)-1-hydroxy]methyl-3-buten-2-one (3f)

A mixture of 2-azido-5-methoxybenzaldehyde (**1c**; 0.89 g, 5 mmol), MVK (1.25 mL, 15 mmol) and DMAP (0.12 g, 0.2 mmol) in DMF (10 mL) was stirred for 36 h at r.t.[22] The reaction mixture was diluted with H_2O (10 mL) and extracted with EtOAc (3 × 20 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (3:1) to afford **3f** (0.42 g, 34%) as an oil.

IR (KBr): 3421, 2124, 1675, 1607, 1286, 1233 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.38 (s, 3 H, CH_3), 3.59 (br s, 1 H, OH), 3.79 (s, 3 H, OCH_3), 5.78 (d, *J* = 4.9 Hz, 1 H, CH), 5.79 (s, 1 H, CH), 6.18 (s, 1 H, CH), 6.87 (dd, *J* = 3.0, 8.9 Hz, 1 H, arom), 7.02 (d, *J* = 3.0 Hz, 1 H, arom), 7.06 (d, *J* = 8.9 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 26.32, 55.49, 67.33, 113.17, 114.43, 119.00, 127.24, 129.27, 133.32, 148.69, 156.91, 200.45.

Anal. Calcd for $C_{12}H_{13}N_3O_3$: C, 58.29; H, 5.30; N, 16.99. Found: C, 58.05; H, 5.21; N, 16.76.

3-(2-Azido-5-nitrophenyl)-3-hydroxy-2-methylenepropanenitrile (3h)

A mixture of 2-azido-5-nitrobenzaldehyde (**1b**; 1.92 g, 10 mmol), acrylonitrile (2.35 mL, 30 mmol) and DABCO (1.12 g, 10 mmol) in dioxane (15 mL) was stirred for 5 d at r.t. The reaction mixture was diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 × 30 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (5:1) to afford **3h** (1.62 g, 66%) as a yellow solid after crystallization with Et_2O–PE; mp 82–83 °C.

IR (KBr): 3521, 2223, 2131, 1610, 1590, 1522, 1486, 1340 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.65 (d, *J* = 4.9 Hz, 1 H, OH), 5.64 (d, *J* = 4.9 Hz, 1 H, CH), 6.14 (s, 1 H, CH), 6.20 (s, 1 H, CH), 7.32 (d, *J* = 8.5 Hz, 1 H, arom), 8.29 (dd, *J* = 2.4, 8.5 Hz, 1 H, arom), 8.45 (d, *J* = 2.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 68.51, 116.21, 118.71, 123.72, 124.19, 125.37, 131.34, 131.72, 143.74, 144.84.

Anal. Calcd for $C_{10}H_7N_5O_3$: C, 48.98; H, 2.88; N, 28.56. Found: C, 48.73; H, 2.75; N, 28.39.

3-(2-Azido-5-methoxyphenyl)-3-hydroxy-2-methylenepropanenitrile (3i)

A mixture of 2-azido-5-methoxybenzaldehyde (**1c**; 0.89 g, 5 mmol), acrylonitrile (0.99 mL, 15 mmol) and DABCO (0.12 g, 1 mmol) in dioxane (10 mL) was stirred for 5 d at r.t. The reaction mixture was diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (3:1) to afford **3i** (0.39 g, 34%) as a yellow solid after crystallization with Et_2O–PE; mp 65–66 °C.

IR (KBr): 3451, 2225, 2135, 1610, 1493, 1470, 1295 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.85 (d, *J* = 5.2 Hz, 1 H, OH), 3.82 (s, 3 H, OCH_3), 5.52 (d, *J* = 5.2 Hz, 1 H, CH), 6.05 (s, 1 H, CH), 6.08 (s, 1 H, CH), 6.94 (dd, *J* = 3.1, 8.8 Hz, 1 H, arom), 7.04 (d, *J* = 3.1 Hz, 1 H, arom), 7.11 (d, *J* = 8.8 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 55.64, 69.51, 113.02, 115.74, 116.73, 119.44, 124.98, 129.36, 130.66, 130.97, 157.15.

Anal. Calcd for $C_{11}H_{10}N_4O_2$: C, 57.39; H, 4.38; N, 24.34. Found: C, 57.22; H, 4.27; N, 24.15.

Methyl 3-Acetoxy-3-(2-azido-5-nitrophenyl)-2-methylenepropanoate (4b)

To a stirred solution of **3b** (1.39 g, 5 mmol) in CH_2Cl_2 (10 mL) were added Ac_2O (0.71 mL, 7.5 mmol) and DMAP (0.12 g, 1 mmol) at r.t. After stirring at r.t. for 30 min the reaction mixture was diluted with 10% aq $NaHCO_3$ solution and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (3:1) to afford **4b** (1.44 g, 90%) as a yellow solid after crystallization with Et_2O; mp 79–80 °C.

IR (KBr): 2129, 1752, 1711, 1635, 1587, 1355, 1297 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.15 (s, 3 H, CH_3), 3.76 (s, 3 H, OCH_3), 5.79 (s, 1 H, CH), 6.51 (s, 1 H, CH), 6.89 (s, 1 H, CH), 7.30 (d, *J* = 8.4 Hz, 1 H, arom), 8.21 (d, *J* = 2.6 Hz, 1 H, arom), 8.25 (dd, *J* = 2.6, 8.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.84, 52.22, 67.48, 118.74, 124.15, 124.98, 128.18, 130.32, 137.40, 144.42, 144.69, 164.91, 169.11.

Anal. Calcd for $C_{13}H_{12}N_4O_6$: C, 48.75; H, 3.78; N, 17.49. Found: C, 48.63; H, 3.67; N, 17.30.

Methyl 3-Acetoxy-3-(2-azido-5-methoxyphenyl)-2-methylenepropanoate (4c)

The procedure was the same as described above using **3c** (1.32 g, 5 mmol) to afford **4c** (1.22 g, 80%) as a white solid after crystallization with PE; mp 79 °C.

IR (KBr): 2118, 1751, 1709, 1635, 1605, 1493, 1299 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.12 (s, 3 H, CH_3), 3.75 (s, 3 H, OCH_3), 3.79 (s, 3 H, OCH_3), 5.64 (s, 1 H, CH), 6.43 (s, 1 H, CH), 6.85 (d, *J* = 2.7 Hz, 1 H, arom), 6.86 (s, 1 H, CH), 6.90 (dd, *J* = 2.7, 8.5 Hz, 1 H, arom) 7.10 (d, *J* = 8.5 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.90, 52.12, 55.54, 68.38, 113.94, 114.44, 119.41, 127.66, 129.90, 130.39, 138.36, 156.70, 165.35, 169.25.

Anal. Calcd for $C_{14}H_{15}N_3O_5$: C, 55.08; H, 4.95; N, 13.76. Found: C, 54.89; H, 4.90; N, 13.62.

3-[1-Acetoxy-1-(2-azido-5-nitrophenyl)]methyl-3-buten-2-one (4e)

The procedure was the same as described above using **3e** (1.31 g, 5 mmol) to afford **4e** (1.37 g, 90%) as an orange solid after crystallization with PE; mp 112–113 °C.

IR (KBr): 2124, 1738, 1673, 1585, 1515, 1483, 1373 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.13 (s, 3 H, CH_3), 2.38 (s, 3 H, CH_3), 6.00 (s, 1 H, CH), 6.36 (s, 1 H, CH), 6.92 (s, 1 H, CH), 7.28 (d, *J* = 8.8 Hz, 1 H, arom), 8.13 (d, *J* = 2.7 Hz, 1 H, arom), 8.23 (dd, *J* = 2.4, 8.8 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.35, 26.10, 66.97, 118.18, 119.47, 123.59, 124.58, 125.28, 130.68, 144.55, 145.52, 169.11, 197.05.

Anal. Calcd for $C_{13}H_{12}N_4O_5$: C, 51.32; H, 3.98; N, 18.41. Found: C, 51.19; H, 3.76; N, 18.27.

3-[1-Acetoxy-1-(2-azido-5-methoxyphenyl)]methyl-3-buten-2-one (4f)

The procedure was the same as described above using **3f** (0.49 g, 2 mmol) to afford **4f** (0.48 g, 83%) as an oil.

IR (KBr): 2122, 1746, 1681, 1609, 1495, 1369, 1289, 1230 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.10 (s, 3 H, CH_3), 2.36 (s, 3 H, CH_3), 3.78 (s, 3 H, OCH_3), 5.84 (s, 1 H, CH), 6.27 (s, 1 H, CH), 6.81 (d, *J* = 3.1 Hz, 1 H, arom), 6.88 (dd, *J* = 3.1, 8.5 Hz, 1 H, arom), 6-90 (s, 1 H, CH), 7.09 (d, *J* = 8.5 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.84, 26.14, 55.42, 67.62, 114.05, 114.21, 119.36, 127.04, 130.22, 135.12, 146.26, 156.59, 169.17, 197.02.

Anal. Calcd for $C_{14}H_{15}N_3O_4$: C, 58.13; H, 5.23; N, 14.53. Found: C, 57.89; H, 5.07; N, 14.38.

3-Acetoxy-3-(2-azido-5-nitrophenyl)-2-methylenepropanenitrile (4h)

The procedure was the same as described above using **3h** (1.23 g, 5 mmol) to afford **4h** (1.22 g, 85%) as a yellow solid after crystallization with EtOAc; mp 94–95 °C.

IR (KBr): 2234, 2131, 1759, 1607, 1587, 1515, 1485, 1344 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.24 (s, 3 H, CH_3), 6.15 (s, 2 H, 2 × CH), 6.59 (s, 1 H, CH), 7.33 (d, *J* = 8.8 Hz, 1 H, arom), 8.31 (dd, *J* = 2.4, 8.8 Hz, 1 H, arom), 8.39 (d, *J* = 2.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.77, 68.50, 115.44, 118.86, 120.76, 123.33, 125.60, 128.08, 133.79, 143.96, 144.64, 168.85.

Anal. Calcd for $C_{12}H_9N_5O_3$: C, 50.18; H, 3.16; N, 24.38. Found: C, 50.03; H, 3.01; N, 24.09.

3-Acetoxy-3-(2-azido-5-methoxyphenyl)-2-methylenepropanenitrile (4i)

The procedure was the same as described above using **3i** (0.46 g, 2 mmol) to afford **4i** (0.44 g, 81%) as a yellow solid after crystallization with Et_2O–PE; mp 84–85 °C.

IR (KBr): 2229, 2134, 2103, 1740, 1609, 1497, 1294 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.19 (s, 3 H, CH_3), 3.82 (s, 3 H, OCH_3), 6.07 (s, 2 H, 2 × CH), 6.55 (s, 1 H, CH), 6.95 (dd, *J* = 2.7, 8.8 Hz, 1 H, arom), 7.05 (d, *J* = 2.7 Hz, 1 H, arom), 7.11 (d, *J* = 8.8 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.88, 55.63, 69.30, 112.99, 115.57, 115.98, 119.37, 121.71, 127.86, 129.59, 132.99, 157.05, 169.02.

Anal. Calcd for $C_{13}H_{12}N_4O_3$: C, 57.35; H, 4.44; N, 20.58. Found: C, 57.20; H, 4.29; N, 20.47.

1-Diethylphosphono-1,2-dihydroquinolines 7 and 3-Acetoxymethylquinolines 9; General Procedure

To a stirred solution of **4** (4 mmol) in toluene (5 mL) was slowly added $(EtO)_3P$ (0.82 mL, 4.8 mmol) in toluene (5 mL) at 0–5 °C. The reaction mixture was stirred at r.t. for 30 min, and then at reflux temperature for the time indicated in Table 1. The reaction mixture was concentrated under reduced pressure and the residue was chromatographed on silica gel eluting with hexane–EtOAc (6:1 → 3:1) to afford **7** and/or **9** as a solid after crystallization with Et_2O or PE.

3-Carbomethoxy-1-diethylphosphono-1,2-dihydroquinoline (7a)

White solid; yield: 79%; mp 31–32 °C.

IR (KBr): 1721, 1640, 1600, 1567, 1487, 1435 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 1.31 (td, *J* = 0.9, 7.3 Hz, 6 H, CH_3), 3.87 (s, 3 H, OCH_3), 3.98–4.20 (m, 4 H, OCH_2), 4.49 (dd, *J* = 1.2, 7.6 Hz, 2 H, NCH_2), 7.08 (dd, *J* = 7.3, 7.6 Hz, 1 H, arom), 7.25 (d, *J* = 7.6 Hz, 1 H, arom), 7.31 (dd, *J* = 7.6, 8.2 Hz, 1 H, arom), 7.49 (d, *J* = 8.2 Hz, 1 H, arom), 7.53 (s, 1 H, C4-H).

^{13}C NMR ($CDCl_3$): δ = 15.92, 43.20, 51.92, 62.80, 120.63, 123.19, 125.16, 125.58, 129.04, 130.53, 134.91, 139.68, 165.29.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 20.86.

EIMS: *m*/*z* (%) = 325 (55) [M^+], 310 (24), 268 (40), 188 (100).

HRMS (EI): *m*/*z* calcd for $C_{15}H_{20}NO_5P$: 325.1080; found: 325.1085.

3-Acetoxymethyl-2-methoxyquinoline (9a)

White solid; yield: 4%; mp 69–70 °C.

IR (KBr): 1736, 1629, 1575, 1478, 1464, 1251 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 4.11 (s, 3 H, OCH_3), 5.24 (s, 2 H, CH_2), 7.39 (dd, *J* = 7.9, 8.2 Hz, 1 H, arom), 7.62 (dd, *J* = 7.0, 7.9 Hz, 1 H, arom), 7.73 (d, *J* = 7.0 Hz, 1 H, arom), 7.85 (d, *J* = 8.2 Hz, 1 H, arom), 7.99 (s, 1 H, C4-H).

^{13}C NMR ($CDCl_3$): δ = 20.99, 53.63, 61.38, 120.33, 124.21, 125.41, 126.96, 127.45, 129.56, 136.93, 146.20, 159.99, 170.79.

EIMS: *m*/*z* (%) = 231 (51) [M^+], 188 (100), 142 (12).

HRMS (EI): *m*/*z* calcd for $C_{13}H_{13}NO_3$: 231.0896; found: 231.0892.

3-Carbomethoxy-1-diethylphosphono-6-nitro-1,2-dihydroquinoline (7b)

Yellow solid; yield: 59%; mp 99–100 °C.

IR (KBr): 1716, 1656, 1606, 1578, 1513, 1488, 1330, 1281 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 1.32 (td, *J* = 0.9, 7.0 Hz, 6 H, CH_3), 3.86 (s, 3 H, OCH_3), 4.03–4.22 (m, 4 H, OCH_2), 4.52 (dd, *J* = 1.2, 6.0 Hz, 2 H, NCH_2), 7.49 (s, 1 H, C4-H), 7.61 (d, *J* = 9.2 Hz, 1 H, arom), 8.10 (d, *J* = 1.2 Hz, 1 H, arom), 8.11 (dd, *J* = 2.4, 9.2 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 15.96, 43.63, 52.24, 63.66, 120.54, 124.20, 125.25, 125.64, 126.77, 133.03, 142.74, 145.82, 164.51.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 19.45.

EIMS: *m*/*z* (%) = 370 (28) [M^+], 355 (17), 341 (15), 313 (32), 255 (13), 233 (100).

HRMS (EI): *m*/*z* calcd for $C_{15}H_{19}N_2O_7P$: 370.0931; found: 370.0919.

3-Acetoxymethyl-2-methoxy-6-nitroquinoline (9b)

White solid; yield: 16%; mp 144–145 °C.

IR (KBr): 1744, 1632, 1580, 1528, 1496, 1474, 1406, 1339, 1240 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.22 (s, 3 H, CH_3), 4.15 (s, 3 H, OCH_3), 5.25 (s, 2 H, CH_2), 7.91 (d, *J* = 9.2 Hz, 1 H, arom), 8.11 (s, 1 H, C4-H), 8.38 (dd, *J* = 2.4, 9.2 Hz, 1 H, arom), 8.67 (d, *J* = 2.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.83, 54.24, 60.62, 123.14, 123.28, 123.69, 123.99, 128.23, 136.98, 143.90, 149.19, 162.08, 170.45.

EIMS: *m*/*z* (%) = 276 (17) [M^+], 233 (100), 217 (12), 187 (19).

HRMS (EI): *m*/*z* calcd for $C_{13}H_{12}N_2O_5$: 276.0747; found: 276.0743.

3-Carbomethoxy-1-diethylphosphono-6-methoxy-1,2-dihydroquinoline (7c)

White solid; yield: 91%; mp 124–126 °C.

IR (KBr): 1709, 1638, 1609, 1572, 1495, 1436 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 1.26 (t, *J* = 7.0 Hz, 6 H, CH_3), 3.80 (s, 3 H, OCH_3), 3.82 (s, 3 H, OCH_3), 3.93–4.14 (m, 4 H, OCH_2), 4.41 (d, *J* = 8.5 Hz, 2 H, NCH_2), 6.75 (d, *J* = 2.7 Hz, 1 H, arom), 6.84 (dd, *J* = 2.7, 8.9 Hz, 1 H, arom), 7.36 (d, *J* = 8.9 Hz, 1 H, arom), 7.46 (s, 1 H, C4-H).

^{13}C NMR ($CDCl_3$): δ = 15.99, 43.33, 52.02, 55.52, 62.73, 113.43, 116.12, 121.94, 126.18, 126.72, 132.76, 134.86, 155.45, 165.34.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 21.30.

EIMS: *m*/*z* (%) = 355 (21) [M$^+$], 298 (8), 218 (100).

HRMS (EI): *m*/*z* calcd for $C_{16}H_{22}NO_6P$: 355.1186; found: 355.1183.

3-Acetoxymethyl-2-methylquinoline (9d)
Pink solid; yield: 60%; mp 94–95 °C (Lit.[18] 94–95 °C).

IR (KBr): 1736, 1620, 1607, 1564, 1490, 1425, 1366, 1241 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 2.16 (s, 3 H, CH_3), 2.76 (s, 3 H, CH_3), 5.29 (s, 2 H, CH_2), 7.51 (dd, *J* = 8.1, 8.1 Hz, 1 H, arom), 7.70 (dd, *J* = 8.4, 8.4 Hz, 1 H, arom), 7.80 (d, *J* = 8.1 Hz, 1 H, arom), 8.03 (d, *J* = 8.4 Hz, 1 H, arom), 8.09 (s, 1 H, C4-H).

^{13}C NMR ($CDCl_3$): δ = 20.85, 22.84, 63.86, 126.05, 126.61, 127.45, 127.64, 128.37, 129.67, 136.05, 147.41, 157.73, 170.61.

EIMS: *m*/*z* (%) = 215 (18) [M$^+$], 155 (100).

HRMS (EI): *m*/*z* calcd for $C_{13}H_{13}NO_2$: 215.0947; found: 215.0948.

3-Acetoxymethyl-2-methyl-6-nitroquinoline (9e)
White solid; yield: 70%; mp 158–159 °C.

IR (KBr): 1752, 1620, 1571, 1509, 1480, 1448, 1345, 1238 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 2.20 (s, 3 H, CH_3), 2.81 (s, 3 H, CH_3), 5.32 (s, 2 H, CH_2), 8.15 (d, *J* = 9.5 Hz, 1 H, arom), 8.28 (s, 1 H, C4-H), 8.47 (dd, *J* = 2.4, 9.2 Hz, 1 H, arom), 8.78 (d, *J* = 2.7 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 20.75, 23.17, 63.02, 122.94, 124.15, 125.37, 130.11, 136.56, 145.06, 149.22, 162.72, 170.40.

EIMS: *m*/*z* (%) = 260 (12) [M$^+$], 200 (100), 192 (10), 154 (11).

HRMS (EI): *m*/*z* calcd for $C_{13}H_{12}N_2O_4$: 260.0798; found: 260.0790.

3-Acetoxymethyl-6-methoxy-2-methylquinoline (9f)
White solid; yield: 76%; mp 105–106 °C.

IR (KBr): 1738, 1610, 1497, 1458, 1376, 1252 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 2.16 (s, 3 H, CH_3), 2.71 (s, 3 H, CH_3), 3.92 (s, 3 H, OCH_3), 5.26 (s, 2 H, CH_2), 7.06 (d, *J* = 2.7 Hz, 1 H, arom), 7.34 (dd, *J* = 2.7, 9.2 Hz, 1 H, arom), 7.92 (d, *J* = 9.2 Hz, 1 H, arom), 7.99 (s, 1 H, C4-H).

^{13}C NMR ($CDCl_3$): δ = 16.06, 22.51, 55.43, 63.76, 104.98, 121.97, 122.50, 127.65, 129.68, 134.99, 143.37, 154.98, 157.34, 170.71.

EIMS: *m*/*z* (%) = 245 (48) [M$^+$], 185 (100), 170 (10).

HRMS (EI): *m*/*z* calcd for $C_{14}H_{15}NO_3$: 245.1053; found: 245.1050.

3-Cyano-1-diethylphosphono-1,2-dihydroquinoline (7g)
Yellow oil; yield: 63%.

IR (KBr): 2209, 1622, 1600, 1565, 1487, 1453, 1392, 1259 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 1.29 (td, *J* = 0.9, 7.2 Hz, 6 H, CH_3), 3.98–4.18 (m, 4 H, OCH_2), 4.29 (dd, *J* = 1.2, 8.5 Hz, 2 H, NCH_2), 7.08 (dd, *J* = 7.3, 7.6 Hz, 1 H, arom), 7.17 (d, *J* = 7.6 Hz, 1 H, arom), 7.21 (s, 1 H, C4-H), 7.31 (dd, *J* = 7.3, 8.2 Hz, 1 H, arom), 7.44 (d, *J* = 8.2 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 15.97, 44.17, 63.19, 105.38, 117.05, 121.08, 123.71, 124.47, 128.63, 131.33, 139.04, 140.09.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 20.13.

EIMS: *m*/*z* (%) = 292 (39) [M$^+$], 263 (13), 235 (34), 155 (100).

HRMS (EI): *m*/*z* calcd for $C_{14}H_{17}N_2O_3P$: 292.0978; found: 292.0980.

3-Cyano-1-diethylphosphono-6-nitro-1,2-dihydroquinoline (7h)
Yellow solid; yield: 57%; mp 65–67 °C.

IR (KBr): 2221, 1632, 1607, 1573, 1512, 1483, 1392, 1347, 1280 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 1.34 (t, *J* = 7.0 Hz, 6 H, CH_3), 4.05–4.24 (m, 4 H, OCH_2), 4.42 (d, *J* = 6.4 Hz, 2 H, NCH_2), 7.23 (s, 1 H, C4-H), 7.60 (d, *J* = 9.4 Hz, 1 H, arom), 8.05 (s, 1 H, arom), 8.16 (dd, *J* = 2.7, 9.2 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 15.92, 44.34, 63.91, 107.31, 115.96, 120.89, 123.82, 123.95, 126.04, 138.22, 142.82, 144.89.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 18.77.

EIMS: *m*/*z* (%) = 337 (36) [M$^+$], 308 (14), 280 (54), 200 (100), 138 (55), 111 (31).

HRMS (EI): *m*/*z* calcd for $C_{14}H_{16}N_3O_5P$: 337.0829; found: 337.0822.

3-Cyano-1-diethylphosphono-6-methoxy-1,2-dihydroquinoline (7i)
Yellow oil; yield: 60%.

IR (KBr): 2210, 1625, 1606, 1569, 1493, 1465, 1392, 1258 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 1.29 (t, *J* = 7.0 Hz, 6 H, CH_3), 3.80 (s, 3 H, OCH_3), 3.97–4.16 (m, 4 H, OCH_2), 4.28 (d, *J* = 9.5 Hz, 2 H, NCH_2), 6.70 (d, *J* = 2.7 Hz, 1 H, arom), 6.88 (dd, *J* = 2.7, 8.9 Hz, 1 H, arom), 7.18 (s, 1 H, C4-H), 7.35 (d, *J* = 8.9 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 15.96, 44.28, 55.54, 63.06, 106.37, 112.80, 117.03, 122.55, 125.48, 125.56, 132.08, 139.94, 155.76.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 20.60.

EIMS: *m*/*z* (%) = 322 (33) [M$^+$], 265 (12), 185 (100).

HRMS (EI): *m*/*z* calcd for $C_{15}H_{19}N_2O_4P$: 322.1084; found: 322.1081.

Methyl 3-Acetoxy-3-(5-nitro-2-triethoxyiminophosphoranylidene)phenyl-2-methylenepropanoate (5b)
To a stirred solution of **4b** (1.28 g, 4 mmol) in toluene (5 mL) was slowly added $(EtO)_3P$ (0.82 mL, 4.8 mmol) in toluene (5 mL) at 0–5 °C. The reaction mixture was stirred at r.t. for 30 min and concentrated under reduced pressure. The residue was chromatographed on silica gel eluting with hexane–EtOAc (1:1) to afford **5b** (1.47 g, 80%) as an oil.

IR (KBr): 1742, 1727, 1633, 1596, 1580, 1495, 1384, 1318, 1023 cm^{-1}.

^{1}H NMR ($CDCl_3$): δ = 1.34 (td, *J* = 0.6, 7.0 Hz, 9 H, CH_3), 2.12 (s, 3 H, CH_3), 3.74 (s, 3 H, OCH_3), 4.14 (qd, *J* = 7.0, 7.3 Hz, 6 H, OCH_2), 5.64 (s, 1 H, CH), 6.41 (s, 1 H, CH), 6.87 (d, *J* = 8.8 Hz, 1 H, arom), 7.24 (s, 1 H, CH), 8.00 (dd, *J* = 2.7, 8.8 Hz, 1 H, arom), 8.09 (dd, *J* = 2.7, 3.1 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 15.98, 21.03, 52.14, 64.61, 68.96, 121.05, 123.25, 123.69, 124.96, 130.47, 138.77, 138.98, 154.38, 165.82, 169.57.

^{31}P NMR [$CDCl_3$/$(PhO)_3PO$]: δ = 16.77.

Anal. Calcd for $C_{19}H_{27}N_2O_9P$: C, 49.78; H, 5.94; N, 6.11. Found: C, 49.60; H, 5.85; N, 5.90.

3-Carbomethoxy-1-diethylphosphono-6-nitro-1,2-dihydroquinoline (7b) and 3-Acetoxymethyl-2-methoxy-6-nitroquinoline (9b)
A stirred solution of iminophosphorane **5b** (1.37 g, 3 mmol) in toluene (10 mL) was heated at reflux temperature for 19 h and the solvent was evaporated in vacuo. The residue was chromatographed on

silica gel eluting with hexane–EtOAc (3:1) to afford **7b** (0.72 g, 65%) and **9b** (0.18 g, 22%) as solids.

Methyl 3-(2-Azido-5-nitrophenyl)-2-methylene-3-propanoyloxypropanoate (4j)

To a stirred solution of **3b** (1.39 g, 5 mmol) in CH_2Cl_2 (10 mL) was added propionic anhydride (0.96 mL, 7.5 mmol) and DMAP (0.12 g, 1 mmol) at r.t. After stirring at r.t. for 30 min the reaction mixture was diluted with 10% aq $NaHCO_3$ solution and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried over anhyd $MgSO_4$ and the solvent was evaporated in vacuo. The resulting mixture was chromatographed on silica gel eluting with hexane–EtOAc (3:1) to afford **4j** (1.62 g, 97%) as a yellow oil.

IR (KBr): 2130, 1746, 1723, 1634, 1611, 1588, 1528, 1346, 1297 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 1.17 (t, *J* = 7.6 Hz, 3 H, CH_3), 2.43 (q, *J* = 7.6 Hz, 2 H, CH_2), 3.76 (s, 3 H, OCH_3), 5.78 (d, *J* = 1.2 Hz, 1 H, CH), 6.50 (s, 1 H, CH), 6.89 (s, 1 H, CH), 7.31 (d, *J* = 8.9 Hz, 1 H, arom), 8.21 (d, *J* = 2.4 Hz, 1 H, arom), 8.25 (dd, *J* = 2.4, 8.9 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 8.85, 27.31, 52.17, 67.32, 118.76, 124.06, 124.94, 128.19, 130.43, 137.50, 144.41, 144.68, 164.94, 172.60.

Anal. Calcd for $C_{14}H_{14}N_4O_6$: C, 50.30; H, 4.22; N, 16.76. Found: C, 50.07; H, 4.09; N, 16.53.

3-Carbomethoxy-1-diethylphosphono-6-nitro-1,2-dihydroquinoline (7b) and 2-Methoxy-6-nitro-3-propanoyloxymethylquinoline (9j)

To a stirred solution of **4g** (1.34 g, 4 mmol) in toluene (5 mL) was slowly added $(EtO)_3P$ (0.82 mL, 4.8 mmol) in toluene (5 mL) at 0–5 °C. The reaction mixture was stirred at r.t. for 30 min, and then at reflux temperature for 48 h. The reaction mixture was concentrated under reduced pressure and the residue was chromatographed on silica gel eluting with hexane–EtOAc (5:1) to afford **7b** (0.68 g, 46%) and **9j** (0.19 g, 16%) as solids.

9j

White solid; mp 127–128 °C.

IR (KBr): 1742, 1631, 1618, 1583, 1530, 1496, 1404, 1343, 1187 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 1.24 (t, *J* = 7.6 Hz, 3 H, CH_3), 2.51 (q, *J* = 7.6 Hz, 2 H, CH_2), 4.15 (s, 3 H, OCH_3), 5.26 (s, 2 H, CH_2), 7.89 (d, *J* = 9.2 Hz, 1 H, arom), 8.09 (s, 1 H, C4-H), 8.37 (dd, *J* = 2.4, 9.2 Hz, 1 H, arom), 8.66 (d, *J* = 2.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 9.07, 27.47, 54.21, 60.53, 123.12, 123.25, 123.63, 123.97, 128.16, 136.81, 143.77, 149.10, 162.03, 173.91.

Anal. Calcd for $C_{14}H_{14}N_2O_5$: C, 57.93; H, 4.86; N, 9.65. Found: C, 57.81; H, 4.77; N, 9.46.

3-Hydroxymethyl-2-methoxy-6-nitroquinoline (10b)

A mixture of **9b** (0.14 g, 0.5 mmol) and NaOH (0.02 g, 0.5 mmol) in THF (3 mL) and H_2O (1 mL) was stirred at reflux temperature for 2 h. The reaction mixture was concentrated under reduced pressure and the residue was partitioned between H_2O (3 mL) and CH_2Cl_2 (20 mL). The solvent was removed after drying over anhyd $MgSO_4$ and the residue was crystallized with PE to afford **10b** (0.11 g, 91%) as a yellow solid; mp 160–161 °C.

IR (KBr): 3266, 1629, 1580, 1527, 1476, 1402 cm^{-1}.

^1H NMR ($CDCl_3$): δ = 2.33 (br s, 1 H, OH), 4.16 (s, 3 H, OCH_3), 4.82 (s, 2 H, CH_2), 7.91 (d, *J* = 9.2 Hz, 1 H, arom), 8.16 (s, 1 H, C4-H), 8.38 (dd, *J* = 2.4, 9.2 Hz, 1 H, arom), 8.67 (d, *J* = 2.4 Hz, 1 H, arom).

^{13}C NMR ($CDCl_3$): δ = 54.18, 60.45, 122.95, 123.97, 124.06, 127.50, 128.18, 136.01, 143.86, 148.99, 162.35.

Anal. Calcd for $C_{11}H_{10}N_2O_4$: C, 56.41; H, 4.30; N, 11.96. Found: C, 56.32; H, 4.21; N, 11.79.

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References

(1) (a) Michael, J. P. *Nat. Prod. Rep.* **1997**, *14*, 605. (b) Balasubramanian, M.; Keay, J. G. In *Comprehensive Heterocyclic Chemistry II*, Vol. 5; Katritzky, A. R.; Rees, C. W.; Scriven, E. F. V., Eds.; Pergamon: Oxford, **1996**, 245–300. (c) Jones, G. In *Comprehensive Heterocyclic Chemistry II*, Vol. 5; Katritzky, A. R.; Rees, C. W.; Screven, E. F. V., Eds.; Pergamon: Oxford, **1996**, 167–243.

(2) (a) Tetsuya, A.; Takayuki, D.; Koji, F. Jpn. Patent, 04282370, **1992**; *Chem. Abstr.* **1993**, *118*, 147472u. (b) Uchida, M.; Chihiro, M.; Morita, S.; Yamashita, H.; Yamasaki, K.; Kanbe, T.; Yabuuchi, Y.; Nakagawa, K. *Chem. Pharm. Bull.* **1990**, *38*, 534. (c) Epstein, S. S.; Saporoschetz, I. B.; Small, M.; Park, W.; Mantel, N. *Nature (London)* **1965**, *208*, 655.

(3) (a) Engler, T. A.; Lynch, K. O. Jr.; Chai, W.; Meduna, S. P. *Tetrahedron Lett.* **1995**, *36*, 2713. (b) Engler, T. A.; La Tessa, K. O.; Iyenger, R.; Chai, W.; Agrios, K. *Bioorg. Med. Chem.* **1996**, *4*, 1755.

(4) (a) Yavari, I.; Ramazani, A.; Esmaili, A. A. *J. Chem. Res., Synop.* **1997**, 208. (b) Williamson, N. M.; March, D. R.; Ward, A. D. *Tetrahedron Lett.* **1995**, *36*, 7721. (c) Kobayashi, K.; Nakahashi, R.; Shimizu, A.; Kitamura, T.; Morikawa, O.; Konishi, H. *J. Chem. Soc., Perkin Trans. 1* **1999**, 1547. (d) Yavari, I.; Esmaili, A. A.; Ramazani, A.; Bolbol–Amiri, A. R. *Monatsh. Chem.* **1997**, *128*, 927. (e) Kikugawa, Y.; Kuramoto, M.; Saito, I.; Yamada, S.-I. *Chem. Pharm. Bull.* **1972**, *21*, 1914. (f) Johnson, W. S.; Buell, B. G. *J. Am. Chem. Soc.* **1952**, *74*, 4517. (g) Kobayashi, K.; Nagato, S.; Kawakita, M.; Morikawa, O.; Konishi, H. *Chem. Lett.* **1995**, 575. (h) Kouznetsov, V.; Palma, A.; Ewert, C.; Varlamov, A. *J. Heterocycl. Chem.* **1998**, *35*, 761. (i) Schweizer, E. E.; Smucker, L. D. *J. Org. Chem.* **1966**, *31*, 3146. (j) Arisawa, M.; Theeraladanon, C.; Nishida, A.; Nakagawa, M. *Tetrahedron Lett.* **2001**, *42*, 8029.

(5) (a) Grignon-Dubois, M.; Diaba, F.; Grellier–Marly, M.-C. *Synthesis* **1994**, 800. (b) Diaba, F.; Houerou, C. L.; Grignon-Dubois, M.; Gerval, P. *J. Org. Chem.* **2000**, *65*, 907. (c) Diaba, F.; Lewis, I.; Grignon-Dubois, M.; Navarre, S. *J. Org. Chem.* **1996**, *61*, 4830. (d) Grignon-Dubois, M.; Diaba, F. *J. Chem. Res., Synop.* **1998**, 660. (e) Maeda, M. *Chem. Pharm. Bull.* **1990**, *38*, 2577. (f) Mani, N. S.; Chen, P.; Jones, T. K. *J. Org. Chem.* **1999**, *64*, 6911. (g) Muren, J. F.; Weissman, A. *J. Med. Chem.* **1971**, *14*, 49.

(6) (a) Kim, J. N.; Lee, H. J.; Lee, K. Y.; Kim, H. S. *Tetrahedron Lett.* **2001**, *42*, 3737. (b) Kim, J. N.; Kim, H. S.; Gong, J. H.; Chung, Y. M. *Tetrahedron Lett.* **2001**, *42*, 8341.

(7) Makino, K.; Hara, O.; Takiguchi, Y.; Katano, T.; Asakawa, Y.; Hatano, K.; Hamada, Y. *Tetrahedron Lett.* **2003**, *44*, 8925.

(8) For reviews of the Morita–Baylis–Hillman reaction, see: (a) Drewes, S. E.; Roos, G. H. P. *Tetrahedron* **1988**, *44*, 4653. (b) Basavaiah, D.; Rao, P. D.; Hyma, R. S. *Tetrahedron* **1996**, *52*, 8001. (c) Ciganek, E. In *Organic Reactions*, Vol. 51; Paquette, L. A., Ed.; Wiley: New York,

1997, 201. (d) Langer, P. *Angew. Chem. Int. Ed.* **2000**, *39*, 3049. (e) Kim, J. N.; Lee, K. Y. *Curr. Org. Chem.* **2002**, *6*, 627. (f) Basavaiah, D.; Rao, A. J.; Satyanarayana, T. *Chem. Rev.* **2003**, *103*, 811.
(9) (a) Kaye, P. T.; Nocanda, X. W. *J. Chem. Soc., Perkin Trans. 1* **2000**, 1331. (b) Kaye, P. T.; Nocanda, X. W. *J. Chem. Soc., Perkin Trans. 1* **2002**, 1318.
(10) Kaye, P. T.; Nocanda, X. W. *Synthesis* **2001**, 2389.
(11) Kaye, P. T.; Musa, M. A.; Nocanda, X. W. *Synthesis* **2003**, 531.
(12) (a) Familoni, O. B.; Kaye, P. T.; Klass, P. J. *Chem. Commun.* **1998**, 2563. (b) Kim, J. N.; Lee, K. Y.; Kim, H. S.; Kim, T. Y. *Org. Lett.* **2000**, *2*, 343.
(13) Hong, W. P.; Lee, K.-J. *Synthesis* **2005**, 33; and references cited therein.
(14) Basavaiah, D.; Pandiaraju, S. *Tetrahedron* **1996**, *52*, 2261.
(15) (a) Michaelis, A.; Kaehne, R. *Chem. Ber.* **1898**, *31*, 1048. (b) Arbuzov, A. E. *J. Russ. Phys. Chem. Soc.* **1906**, *38*, 687. (c) Bhattacharya, A. K.; Thyagarajan, G. *Chem. Rev.* **1981**, *81*, 415.
(16) (a) Song, Y. S.; Lee, C. H.; Lee, K.-J. *J. Heterocycl. Chem.* **2003**, *40*, 939. (b) Lee, C. H.; Song, Y. S.; Cho, H. I.; Yang, J. W.; Lee, K.-J. *J. Heterocycl. Chem.* **2003**, *40*, 1103. (c) Ko, S. H.; Lee, K.-J. *J. Heterocycl. Chem.* **2004**, *41*, 613. (d) Lee, C. H.; Lee, K.-J. *Synthesis* **2004**, 1941.
(17) Staudinger, H.; Meyer, J. *Helv. Chim. Acta* **1919**, *2*, 635.
(18) (a) For the known compound **9d**, see: Basavaiah, D.; Reddy, R. M.; Kumaragurubaran, N.; Sharada, D. *Tetrahedron* **2002**, *58*, 3693. (b) The efforts on the isolation of compounds **7d–f** were unsuccessful.
(19) Suginome, M.; Fukuda, T.; Ito, Y. *Org. Lett.* **1999**, *1*, 1977.
(20) Fusco, R.; Bianchetti, G.; Pocar, D.; Ugo, R. *Gazz. Chim. Ital.* **1962**, *92*, 1040; *Chem. Abstr.* **1963**, *58,* 73330.
(21) Iyobe, A.; Uchida, M.; Kamata, K.; Hotei, Y.; Kusama, H.; Harada, H. *Chem. Pharm. Bull.* **2001**, *49*, 822.
(22) Shi, M.; Li, C.-Q.; Jiang, J.-K. *Tetrahedron* **2003**, *59*, 1181.