Synthetic Versatility of *N*-(Silylmethyl)imines: Water-Induced Generation of *N*-Protonated Azomethine Ylides of Nonstabilized Type and Fluoride-Induced Generation of 2-Azaallyl Anions

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N-(Silylmethyl)imines generate *N*-protonated azomethine ylides of nonstabilized type when treated with water in HMPA, which undergo stereospecific and regioselective cycloadditions with electron-poor olefins affording *N*-unsubstituted pyrrolidines. On the other hand, fluoride-induced desilylation of the imines leads to 2-azaallyl anions which are found to be synthetic equivalents of aminomethyl anion in the Michael additions with electron-poor olefins and nucleophilic additions with carbonyl compounds.

Since Vedejs and Martinez reported the first generation of azomethine ylides from *N*-(trimethylsilylmethyl)iminium salts,[1] this reaction has been applied to organic synthesis more frequently than any other methods known for the generation of azomethine ylide 1,3-dipoles. A variety of methodologies for the preparation of *N*-(silylmethyl)iminium salts were devised,[2] and this generation method has been successfully utilized as a key reaction in the synthesis of some natural products.[3]

To be noteworthy is that this method generates nonstabilized azomethine ylides which carry no substituents capable of stabilizing the ylide centers. Even the azomethine ylides carrying no substituents at the carbons are available according to the related reactions.[4] A variety of substituents such as alkyl,[5] acyl,[6] and silyl[7] can be introduced on the nitrogen.

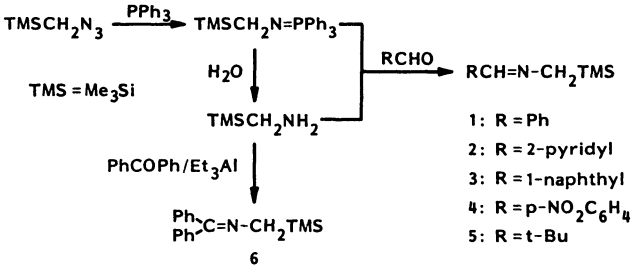
After our recent discovery of the general and convenient synthesis of *N*-(trimethylsilylmethyl)imines,[8] we have engaged in a research aiming at opening the synthetic utility of these imines. One attracting utilization is the generation of azomethine ylide 1,3-dipoles, and another is the generation of 2-azaallyl anions. So far there is no report available on the direct desilylation of *N*-(silylmethyl)imines leading to 2-azaallyl anions.[9]

The present article describes the water-induced generation of *N*-protonated azomethine ylides from *N*-(silylmethyl)imines,[10] and the desilylation of the imines without quaterization on the nitrogen leading to 2-azaallyl anions.

Results and Discussion

N-(Trimethylsilylmethyl)imines **1—5** derived from aldehydes are readily available by reactions of trimethylsilylmethyl azide with aldehydes in the presence of triphenylphosphine (Scheme 1).[8] As a good yield of trimethylsilylmethylamine is obtained from the reaction of the azide with triphenylphosphine and subsequent hydrolysis, condensations of this silylmethylamine with aldehydes can be also a convenient route to the *N*-(silylmethyl)imines **1—5**.

The azide method directly leads to *N*-(silylmethyl)imines by a simple one-flask procedure, but the imines have to be separated from triphenylphosphine oxide. This route can be conveniently applied to the synthesis of low-boiling or water-sensitive imines. On the other hand, the condensation method using trimethylsilylmethyamine needs one more step, in which the amine is separated from triphenylphosphine oxide by vacuum distillation. Accordingly, this condensation is favored when the imines can be hardly separated from triphenylphosphine oxide. Although benzophenone could not be converted into its imine **6** by either of the above two methods, **6** was successfully prepared by condensation of the silylmethylamine with benzophenone in the presence of triethylaluminum.



Scheme 1.

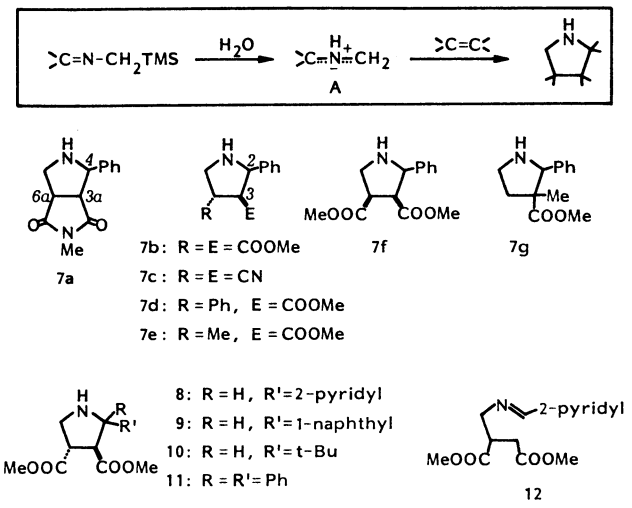
Water-Induced Generation of *N*-Protonated Azomethine Ylides of Nonstabilized Type. *N*-(Silylmethyl)imines react with water, slowly but cleanly at room temperature, in such a polar solvent as HMPA or DMF to generate *N*-protonated azomethine ylide 1,3-dipoles **A**. If electron-poor olefins are present, these ylides are captured as cycloadducts, *N*-unsubstituted pyrrolidines (Scheme 2).

N-(Benzylidene)trimethylsilylmethylamine **1** as an example was allowed to react with a variety of olefinic dipolarophiles, in HMPA in the presence of water and acetic acid for 12—24 h at room temperature, to give cycloadducts **7a—g** (Scheme 2 and Table 1). Water can be used in excess, but the use of more than five equivalents produces *N*-(benzylidene)methylamine as a tautomeric isomer of the corresponding *N*-protonated azomethine ylide. Less than one equivalent of acetic acid was employed, since acid catalyst was found to facilitate the ylide generation. Water, in this case,

Table 1. Water-Induced Cycloaddition of *N*-(Silylmethyl)imines with Olefins[a)]

Imine	Olefin	Solvent	Time/h	Conditions[b)]	Product	Yield/%[c)]	2,3-cis/2,3-trans[d)]
1	*N*-Methylmaleimide	HMPA	24	A	**7a**	100	1/2[e)]
1	Dimethyl fumarate	HMPA	24	A	**7b**	100	1/1
1	Fumaronitrile	HMPA	24	A	**7c**	80	7/5
1	Methyl cinnamate	HMPA	24	A	**7d**	72	3/1
1	Methyl crotonate	HMPA	24	A	**7e**	65	2/1
1	Dimethyl maleate	HMPA	24	A	**7f**	100	3/7
1	Methyl methacrylate	HMPA	24	A	**7g**	75	4/3[f)]
2	Dimethyl fumarate	THF	12	B	**8**	78	1/3
2	Dimethyl fumarate	HMPA	12	B	**12**	73	—
3	Dimethyl fumarate	HMPA	12	B	**9**	74	4/5
5	Dimethyl fumarate	HMPA	24	A	**10**	78	1/1
6	Dimethyl fumarate	HMPA	12	B	**11**	95	—

a) All reactions were carried out under nitrogen at room temperature. b) Each 1 mmol amounts of imines and olefins in 2 ml of solvent were allowed to react in the presence of: A: each 1 mmole of water and acetic acid or B: 1 mmol of water and a catalytic amount of acetic acid. c) Isolated yield. d) Determined by ^{1}H NMR. e) 3a,4-cis/3a,4-trans. f) 2,3-cis Isomer bears 3-ester cis to 2-phenyl.



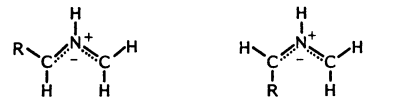
Scheme 2.

is not only a reagent neccessary for the generation of the ylide but also an inhibitor of polymerization of the dipolarophiles. When **1** is treated with *N*-methylmaleimide in very dry HMPA under nitrogen, the maleimide suffers from complete polymerization and **1** is quantitatively recovered.

Other *N*-(silylmethyl)imines **3** and **5**—**6** reacted with dimethyl fumarate under similar conditions to give the corresponding cycloadducts **9**—**11** (Scheme 2 and Table 1). Smooth generation of *N*-protonated azomethine ylide from **5** is quite interesting because this ylide is carrying no substituents which are capable of stabilizing the dipole centers.[11] Although similar reaction of the *N*-(silylmethyl)imine **2** bearing a 2-pyridyl substituent with dimethyl fumarate produced cycloadduct **8** when carried out in THF, the same reaction in HMPA afforded a Michael type product **12**. This difference will be discussed later.

The cycloadditions shown in Scheme 2 are exclusively stereospecific and regioselective, but awfully poor in stereoselectivity. In every case was formed an unseparable mixture of two stereoisomeric cycloadducts, endo and exo cycloadducts. Assignment of the stereostructures was based on $J_{3a\text{-}4}$ for **7a** or magnetic shielding of ester methyls by the adjacent phenyl moiety at the 2-position for **7b**, **7d**—**g**, and **8**—**9**. The 2-H of exo isomer (2,3-trans) of **7c** appeared in a lower field than that of endo isomer. Two isomers of **10** could not be assigned, but anyhow the isomer ratio was 1:1.

Two geometries are possible for the *N*-protonated azomethine ylide **A**, but *E*-isomer (*E*)-**A** should be much more stable than *Z*-isomer (*Z*)-**A** (Scheme 3).[12] Accordingly, two stereoisomers mentioned above are most likely to have been formed through endo and exo approaches of (*E*)-**A**.[13] Although the reason for such poor stereoselectivity can not be explained so far, there are some examples known for poor *endo*-selectivity of nonstabilized azomethine ylides.[14]



Scheme 3.

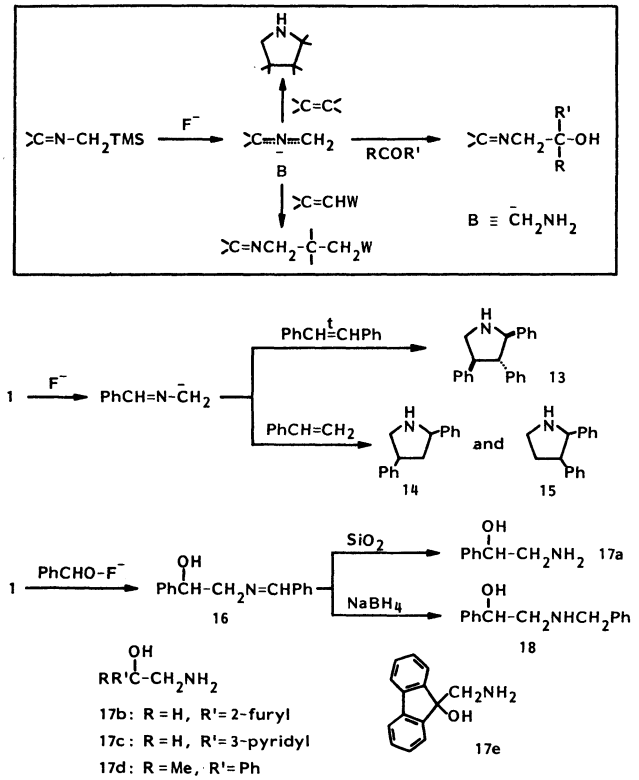
Fluoride-Induced Generation of 2-Azaallyl Anions. *N*-(Silylmethyl)imines are desilylated by a fluoride ion to generate 2-azaallyl anions **B**, which undergo cycloadditions with unactivated olefins, nucleophilic additions to carbonyl groups, or Michael additions to electron-deficient olefins (Scheme 4). Through these reactions, the anions **B** become synthetic equivalents of aminomethyl anion.

N-(Silylmethyl)imine **1** was treated with *trans*-stilbene in dry HMPA in the presence of cesium fluoride, at 80 °C for 3 d under nitrogen, to give 80% yield of 2,3,4-triphenylpyrrolidine **13** as single stereoisomer. On the basis of the very poor stereospecificity and stereoselectivity in a similar reaction of **1** with *cis*-stilbene,[15] its structure was tentatively assigned to be all-*trans*

Table 2. Nucleophilic Addition of 2-Azaallyl Anions Generated from *N*-(Silylmethyl)imines[a)]

Imine	Electrophile	Conditions[b)]	Product	Yield/%[c)]	Subsequent work-up[d)]
1	PhCHO	A	**16**	100	—
1	PhCHO	A	**17a**	88	A
1	2-Furancarbaldehyde	A	**17b**	73	A
1	3-Pyridinecarbaldehyde	A	**17c**	51	A
1	PhCOMe	A	**17d**	60	A
1	Fluorenone	A	**17e**	88	A
1	Dimethyl fumarate	B	**19a**	97	—
1	Dimethyl fumarate	B	**22a**	51	B
1	Methyl cinnamate	B	**22b**	60	B
1	Methyl methacrylate	B	**22c**	48	B
3	Benzylideneacetone	C	**23**	60	A
4	Dimethyl fumarate	C	**24**	100	—
6	Benzylideneacetone	D	**23**	77	A
6	Methyl acrylate	D	**25**	55	C

a) All reactions were carried out with equivalents of imines and electrophiles in the presence of TBAF (10 mol%). b) A: At room temperature for 48 h in DMF; B: At room temperature for 36 h in DMF in the presence of one equivalent of water; C: At 0 °C for 30 min in THF; D: At room temperature for 12 h in DMF in the presence of one equivalent of water. c) Isolated yield. d) A: Chromatographed over silica gel with MeOH–EtOAc (1:3); B: Reduced with $NaBH_4$ in MeOH at room temperature; C: Hydrolyzed with concd HCl in MeOH at room temperature and then acetylated with Ac_2O in the presence of pyridine at room temperature.



Scheme 4.

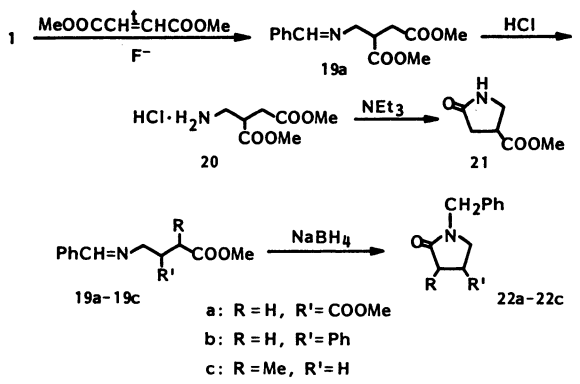
isomer that is thermodynamically most stable. Two regioisomeric cycloadducts **14** and **15** were obtained in the reaction of **1** with styrene under similar conditions, but their stereostructures could not be determined. In these reactions, a catalytic amount (0.1 equivalent) of cesium fluoride was sufficient.

As the imine **1** is inactive toward such unactivated olefins as stilbene and styrene in the presence of water, it is apparent that the reaction in the presence of cesium fluoride involves a reactive species other than *N*-protonated azomethine ylide **A**. 2-Azaallyl anion **B** will be the species involved. So we tried to capture **B** with aldehydes.

When **1** was treated with benzaldehyde in dry DMF in the presence of cesium fluoride at room temperature, a quantitative yield of 2-benzylideneamino-1-phenylethanol **16** was obtained (Scheme 4 and Table 2). This imine **16** was readily hydrolyzed into 2-amino-1-phenylethanol **17a** or reduced with sodium borohydride into its *N*-benzyl derivative **18**. The exclusive formation of **16** indicates that the 2-azaallyl anion from **1** undergoes highly regioselective nucleophilic addition with aldehydes at the carbon which was substituted with the silyl moiety. Thus, *N*-(silylmethyl)imine **1** can be a good reagent for nucleophilic aminomethylation. Therefore, similar reactions with some other carbonyl compounds were carried out. After the reactions were over, the crude reaction mixtures were subjected to column chromatography over silica gel to give hydrolyzed products, 2-aminoethanols **17b**—**e**.

Although some examples are known for the Michael addition reaction using ester-stabilized 2-azaallyl anion,[16] no nucleophilic aminomethylation using nonstabilized 2-azaallyl anion **B** has been reported so far.[17]

The 2-azaallyl anion generated from **1** and tetrabutylammonium fluoride was trapped with dimethyl fumarate at room temperature to give a regioselective Michael adduct **19a** in a quantitative yield (Scheme 5 and Table 2). One equivalent amount of water was used in this reaction, since otherwise the fumarate as a Michael acceptor readily polymerized. The adduct **19a** was hydrolyzed providing amino diester **20** which then cyclized into 2-pyrrolidinone **21** when treated with triethylamine, or it was reduced with sodium borohydride to give *N*-benzyl-2-pyrrolidinone **22a**

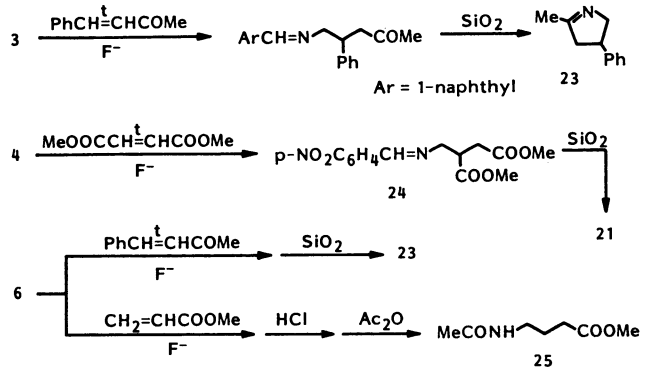


Scheme 5.

after spontaneous cyclization. Among these two sequences which look promising as a new synthetic method of 2-pyrrolidinones, the latter sequence seems more useful because all the procedures can be performed in the same flask. So the one-flask reaction was applied to some other Michael acceptors such as methyl cinnamate and methyl methacrylate to afford the corresponding *N*-benzyl-2-pyrrolidinones **22b** and **22c** (Table 2).[18]

One serious limitation is that olefins such as acrylates and methyl vinyl ketone polymerize under the reaction conditions even if water is present as an inhibitor. Such ready polymerization of olefins presumably results from the lack of stability of the 2-azaallyl anion from **1**. Therefore, several *N*-(silylmethyl)imines **3**, **4**, and **6** carrying anion-stabilizing substituents other than phenyl were examined.

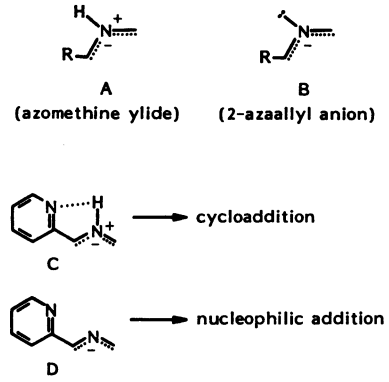
The imine **3** with a 1-naphthyl moiety was easily desilylated under very mild conditions. The anion generated underwent the Michael addition to benzylideneacetone followed by subsequent hydrolysis and cyclization providing 1-pyrroline **23** (Scheme 6 and Table 2). In this reaction, no water was needed. The 2-azaallyl anion generated from **4** also under mild conditions added to dimethyl fumarate in the absence of water to give a quantitative yield of **24**. However, the Michael addition using **3** is not highly regioselective,[19] and the anion from **4** undergoes ready oxidative coupling reaction especially if the Michael acceptor employed is not highly reactive.[20]



Scheme. 6.

So far the 2-azaallyl anion from **6** is most promising. With benzylideneacetone, 1-pyrroline **23** was obtained in 77% yield. The reaction with methyl acrylate produced 55% of methyl 4-acetamidopropanoate **25** after subsequent hydrolysis and acetylation (Scheme 6 and Table 2).

Thus, *N*-(silylmethyl)imines generate azomethine ylide 1,3-dipoles if desilylated after *N*-protonation and 2-azaallyl anions if directly desilylated. Although *N*-protonated azomethine ylides **A** and 2-azaallyl anions **B** are isoelectronic to each other, they show completely different chemical properties. Only structural difference is that the nonbonding electron pair on the nitrogen of **B** is used for the N–H bond in **A** (Scheme 7). This means that *N*-protonated azomethine ylides



Scheme 7.

A and 2-azaallyl anions **B** would be interconvertible to each other by protonation and deprotonation procedure. As described above, the reaction of imine **2** with dimethyl fumarate in THF in the presence of water produced pyrrolidine **8** which is a product expected from azomethine ylide **C**, whereas the same reaction in HMPA provided imine **12** expected from 2-azaallyl anion **D**. Probably the NH hydrogen of **C** is coordinating with the pyridine nitrogen so that the N–H bond may be weakened. In less polar solvent, THF, the hydrogen will be still sitting on the imine nitrogen, allowing the cycloaddition as azomethine ylide **C**. In highly polar HMPA, this hydrogen no longer stays on the imine nitrogen and hence the species involved is no longer azomethine ylide **C** but 2-azaallyl anion **D**. Nucleophilic addition is the reaction which actually took place.

Experimental

General. Melting points were determined on a Yanagimoto micro melting point apparatus and are uncorrected. IR spectra were taken with a JASCO IRA-1 or a JASCO A-702 spectrometer. ^{1}H NMR spectra were recorded on a Hitachi R-40 (90 MHz) or a JEOL FX-100 instrument (100 MHz) and ^{13}C NMR spectra on a JEOL FX-100 spectrometer at 25.05 MHz. Chemical shifts are expressed in parts per million downfield from tetramethylsilane as internal standard. Mass spectra were measured with a JEOL JMS-01SG-2 spectrometer at 70 eV of ionization energy. Ele-

mental analyses were performed on a Hitachi 026 CHN micro analyzer. Thin-layer chromatography (TLC) was accomplished on 0.2 mm precoated plates of silica gel 60F-254 (Merck) or of aluminum oxide 60 F-254 type-E (Merck). Visualization was made with ultraviolet light (254 and 365 nm) and iodine. For preparative column chromatography, Wakogel C-200, C-300 (Wako), or Kieselgel 60 (230—400 mesh, Merck) was used. Flash chromatography was carried out on an EYELA EF-10 apparatus using a column (20×180 mm) packed with Silicagel 60 (Merck, size: 0.04—0.063 mm). Gas liquid chromatography (GLC) was accomplished on a Yanaco G-2800 gas chromatography (Yanagimoto) with an ionization detector using a glass column (SE-30, 3×2000 mm). Micro vacuum distillation was performed with a Sibata GTO-250R Kugelrohr distilling apparatus. Solvents were evaporated with a Tokyo Rikakikai rotary evaporator type-V at about 50°C unless otherwise stated.

Preparation of *N*-(Silylmethyl)imines 1—6. The imines were prepared according to either of the following three methods: A: Imines **1**, **2**, and **5** were prepared according to the known method using trimethylsilylmethyl azide, triphenylphosphine, and the corresponding aldehydes.[8] B: A mixture of trimethylsilylmethylamine (40 mmol) and an aldehyde (44 mmol) was stirred in ethanol (10 ml) at room temperature. The ethanol was evaporated in vacuo and the residue was dissolved in dichloromethane (20 ml). The solution was dried on magnesium sulfate and evaporated in vacuo. Crude imines **2**—**4** thus obtained all in quantitative yields were purified through vacuum distillation. C: To a solution of Et_3Al (16% in hexane, 30 ml, 30 mmol) in dry benzene (40 ml) was added trimethylsilylmethylamine (3.09 g, 30 mmol) at room temperature. The mixture was heated under reflux under nitrogen for 0.5 h. The mixture was refluxed with benzophenone (3.64 g, 20 mmol) for 1.5 h, treated with ethanol (5 ml), and poured into an aqueous solution of sodium tartrate (10%). Organic materials were extracted with dichloromethane (100 ml), the extract was dried over magnesium sulfate, and evaporated in vacuo to give almost pure **6** (5.30 g, 99%, purity 99% (GLC)).

Imines **1** (89%), **2** (72% by method A; 88% by method B), and **5** (58%) are all known compounds.[8]

3: Colorless liquid; yield 82%; bp 115—118°C/27 Pa; IR (neat) 1630, 1245, and 850 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.12 (9H, s, TMS), 3.47 (2H, d, J=1.5 Hz, CH_2), 7.2—7.5 (3H, m, Ar), 7.6—7.9 (3H, m, Ar), 8.64 (1H, t, J=1.5 Hz, N=CH), and 8.7—8.9 (1H, m, Ar); MS m/z (rel intensity, %) 241 (M^+, 51), 240 (base peak), 168 (35), 167 (23), 141 (21), and 73 (99). HRMS Found: m/z 241.1212. Calcd for $C_{15}H_{19}NSi$: M, 241.1286.

4: Colorless liquid; yield 100%; bp 107—110°C/107 Pa; IR (neat) 1600, 1250, and 840 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.08 (9H, s, TMS), 3.44 (2H, d, J=1, 3 Hz, CH_2), 7.70, 8.12 (each 2H, br d, Ar), and 8.08 (1H, t, J=1.3 Hz, N=CH); MS m/z (rel intensity, %) 236 (M^+, 34), 235 (74), 219 (41), 189 (22), 117 (37), and 73 (base peak). HRMS Found: m/z 236.1021. Calcd for $C_{11}H_{16}N_2O_2Si$: M, 236.0976.

6: Colorless liquid; IR (neat) 1610, 1250, and 840 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.03 (9H, s, TMS), 3.26 (2H, s, CH_2), and 6.9—7.6 (10H, m, Ph); MS m/z (rel intensity, %) 267 (M^+, base peak), 165 (20), 91 (29), and 73 (38). HRMS Found: m/z 267.1503. Calcd for $C_{17}H_{21}NSi$: M, 267.1442.

General Procedure for the Water-Induced Cycloadditions of *N*-(Silylmethyl)imines with Olefins Leading to 7—11. A mixture of *N*-(silylmethyl)imine and olefin (each 1 mmol) in HMPA or THF (2 ml) was stirred, under nitrogen at room temperature, in the presence of water and acetic acid. Reaction conditions are listed in Tabel 1. After the reaction was completed, the mixture was poured into aqueous sodium hydroxide and extracted with dichloromethane (15 ml×2). The combined extracts were washed with water, dried over magnesium sulfate, and evaporated in vacuo. The residue was chromatographed over silica gel with benzene-ether. All the cycloadducts were obtained as mixtures of two stereoisomers, whose separation was unsuccessful. The results are summarized in Table 1.

7a: Colorless liquid; IR (neat) 3400, 1775, and 1700 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.11 (1H, s, NH), 2.7—3.8 (4H, m, 3a-, 6-, and 6a-H), 2.85 (1/3×3H, s, NMe), 2.98 (2/3×3H, s, NMe), 4.32 (1/3H, d, J=8.0 Hz, 4-H), 4.60 (2/3H, d, J=2.0 Hz, 4-H), and 7.1—7.5 (5H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=24.78, 25.07 (each q, NMe), 45.91, 46.62 (each d), 48.79, 48.96 (each t, 6-C), 49.32, 53.13 (each d), 64.76, 65.52 (each d, 4-C), 126.11, 126.59, 127.28, 127.75, 128.11 128.58 (each d), 137.79, 141.31 (each s), 175.66, 178.30, 178.77, and 179.18 (each s, CON); MS m/z (rel intensity, %) 230 (M^+, 50), 119 (56), 118 (base peak), and 106 (20). HRMS Found: m/z 230.1059. Calcd for $C_{13}H_{14}N_2O_2$: M, 230.1054.

7b: Colorless liquid; IR (neat) 3400 and 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.32 (1H, br s, NH), 3.0—3.9 (4H, m, 3-, 4-, and 5-H), 3.15 (1/2×3H, s, 3-COOMe), 3.63 (1/2×3H, s, COOMe), 3.70 (3H, s, COOMe), 4.27 (1/2H, d, J=7.0 Hz, 2-H), 4.50 (1/2H, d, J=8.0 Hz, 2-H), and 7.1—7.5 (5H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=47.14, 48.67, 50.20, 50.43, 50.90, 51.67, 51.78, 52.66, 54.89 (d), 65.87, 67.34 (each d, 2-C), 126.40, 127.05, 127.28, 127.64, 128.11 (each d), 138.37, 140.61 (each s), 172.31, 173.19, and 173.78 (each s, COOMe); MS m/z (rel intensity, %) 263 (M^+, 80), 232 (40), 204 (30), 177 (47), 144 (26), 119 (91), and 118 (base peak). Found: C, 63.89; H, 6.60; N, 5.15%. Calcd for $C_{14}H_{17}NO_4$: C, 63.87; H, 6.51; N, 5.32%.

7c: Colorless liquid; bp 150°C/400 Pa; IR (neat) 3350 and 2240 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.29 (1H, br, NH), 2.9—3.8 (4H, m, 3-, 4-, and 5-H), 4.25 (7/12H, d, J=9.0 Hz, 2-H), 4.46 (5/12H, d, J=7.0 Hz, 2-H), and 7.2—7.5 (5H, m, Ph); ^{13}C NMR (DMSO-d_6) δ=33.02, 33.09 (each d), 50.26, (t, 5-C), 63.94, 66.99 (each, d, 2-C), 118.48, 118.77, 119.71, 120.06 (each, s, CN), 126.81, 127. 05, 127.74, 128.11, 128.52 (each, d), 137.97, and 138.26 (each s); MS m/z (rel intensity, %) 197 (M^+, 28), 119 (36), 118 (base peak), 91 (40), 89 (31), and 77 (37). Found: C, 73.23; H, 5.70; N, 21.28%. Calcd for $C_{12}H_{11}N_3$: C, 73.07; H, 5.62; N, 21.31%.

7d: Colorless liquid; IR (neat) 3320 and 1720 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.60 (1H, br, NH), 2.9—4.0 (4H, m, 3-, 4-, and 5-H), 3.11 (3/4×3H, s, COOMe), 3.55 (1/4×3H, s, COOMe), 4.55 (1/4H, d, J=9.0 Hz, 2-H), 4.70 (3/4H, d, J=9.0 Hz, 2-H), and 7.0—7.5 (10H, m, Ph); MS m/z (rel intensity, %) 281 (M^+, 9), 131 (24), 119 (72), 118 (base peak), 117 (38), 115 (37), 103 (32), 91 (40), and 77 (30). Found: C, 77.04; H, 7.06; N, 4.72%. Calcd for $C_{18}H_{19}NO_2$: C, 76.84; H, 6.81; N, 4.98%.

7e: Colorless liquid; IR (neat) 3310 and 1725 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.10, 1.13 (3H, each d, J=6.0 Hz, 4-Me), 2.30 (1H, s, NH), 2.4—3.6 (4H, m, 3-, 4-, and 5-H), 3.16 (2/3×3H, s, COOMe), 3.61 (1/3×3H, s, COOMe), 4.44 (1/3H, d, J=8.0 Hz, 2-H), 4.46 (2/3H, d, J=8.0 Hz, 2-H), and 7.1—7.4 (5H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=18.14, 18.32 (each q, 4-Me), 37.40, 40.39 (each d, 4-C), 50.78, 51.55 (each q, COOMe), 54.25, 54.78 (each t, 5-C), 57.71, 60.35 (each d, 3-C),

65.17, 66.40 (each d, 2-C), 126.28, 126.64, 126.93, 127.40, 127.75, 128.05, 128.22 (each d), 140.08, 142.67 (each d), 173.31, and 174.37 (each s, COOMe); MS *m/z* (rel intensity, %) 219 (M^+, 40), 119 (76), and 118 (base peak); HRMS Found: *m/z* 219.1273. Calcd for $C_{13}H_{17}NO_2$: M, 219.1258.

7f: Colorless liquid; IR (neat) 3400 and 1740 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.33 (1H, s, NH), 3.1—3.5 (4H, m, 3-, 4-, and 5-H), 3.20 (3/10×3H, s, COOMe), 3.62, 3.63 (3H+7/10×3H, each s, COOMe), 4.39 (3/10H, d, *J*=6.0 Hz, 2-H), 4.59 (7/10H, d, *J*=6.0 Hz, 2-H), and 7.1—7.5 (5H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=47.67, 49.85, 51.08, 51.90, 55.07, 64.76, 67.28, 126.34, 126.46, 127.22, 127.40, 128.11, 128.40, 142.84, 172.14, 172.31, 172.61, and 172.84; MS *m/z* (rel intensity, %) 263 (M^+, 8), 144 (59), 143 (21), 119 (51), 118 (base peak), 117 (32), 115 (50), 104 (25), 91 (49), and 77 (31). Found:, C, 64.14; H, 6.58; N, 5.24%. Calcd for $C_{14}H_{17}NO$: C, 63.87; H, 6.51; N, 5.32%.

7g: Colorless liquid; bp 95 °C/532 Pa; IR (neat) 3320 and 1725 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.84 (3/7×3H, s, 3-Me), 1.37 (4/7×3H, s, 3-Me), 1.5—1.9 (1H, m), 2.2—2.7 (1H, m), 2.35 (1H, br s, NH), 2.9—3.5 (2H, m), 3.17 (4/7×3H, s, COOMe), 3.66 (3/7×3H, s, COOMe), 3.84 (4/7H, s, 2-H), 4.55 (3/7H, s, 2-H), and 7.1—7.3 (5H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=19.96, 22.90 (each q, 3-Me), 38.16, 38.75 (each t, 4-C), 44.74, 45.62 (each t, 5-C), 51.20, 51.96 (each q, COOMe), 54.89 (s, 3-C), 68.57, 74.15 (each d, 2-C), 126.58, 127.05, 127.28, 127.46, 127.87 (each d), 139.14, 140.20 (each s), 175.60, and 177.48 (each s, COOMe); MS *m/z* (rel intensity, %) 219 (M^+, 32), 119 (79), and 118 (base peak). Found: C, 71.46; H, 8.08; N, 6.64%. Calcd for $C_{13}H_{17}NO_2$: C, 71.20; H, 7.82; N, 6.39%.

8: Colorless liquid; IR (neat) 3400, 1730, and 1600 cm^{-1}; ^1H NMR ($CDCl_3$) δ=3.0—3.8 (4H, m, 3-, 4-, and 5-H), 3.20 (3/4×3H, s, COOMe), 3.32 (1H, s, NH), 3.66 (3H+3/4H, s, COOMe), 4.34 (1/4H, d, *J*=7.0 Hz, 2-H), 4.57 (3/4H, d, *J*=7.0 Hz, 2-H), 7.4—7.7 (3H, m, Py), and 8.40 (1H, br d, Py); MS *m/z* (rel intensity, %) 264 (M^+, 10), 145 (91), 132 (28), 126 (23), 120 (21), 119 (65), 118 (43), 117 (55), 105 (23), 92 (49), 79 (54), 78 (74), and 59 (base peak). Found: C, 59.93; H, 6.11; N, 10.32%. Calcd for $C_{13}H_{16}N_2O_4$: C, 59.08; H, 6.10; N, 10.60%.

9: Colorless liquid; IR (neat) 3400 and 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.28 (1H, br s, NH), 2.80 (4/9×3H, s, COOMe), 3.0—3.9 (4H, m, 3-, 4-, and 5-H), 3.56, 3.68 (each 5/9×3H, s, COOMe), 3.74 (4/9×3H, s, COOMe), 5.10 (4/9H, d, *J*=7.0 Hz, 2-H), 5.20 (5/9H, d, *J*=8.0 Hz, 2-H), and 7.3—8.2 (7H, m, Ar); MS *m/z* (rel intensity, %) 313 (M^+, 24), 194 (39), 193 (20), 169 (43), 168 (base peak), 167 (52), 166 (29), 165 (57), 154 (37), 153 (24), 141 (25), 139 (23), 128 (24), 127 (38), 115 (22), and 113 (22). Found: C, 69.05; H, 6.15; N, 4.68%. Calcd for $C_{18}H_{19}NO_4$: C, 68.99; H, 6.11; N, 4.47%.

10: Colorless liquid; IR (neat) 3400 and 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.93, 0.98 (each 1/2×9H, s, *t*-Bu), 1.96 (1H, br s, NH), 2.8—3.4 (6H, m, 2-, 3-, 4-, and 5-H), 3.65 and 3.67 (6H, each s, COOMe); ^{13}C NMR ($CDCl_3$) δ=26.54, 27.42 (each q, *t*-Bu), 32.41, 33.64 (each s, *q*-C), 48.55, 48.79, 49.14, 50.31, 51.02, 51.67, 52.02, 73.74 (d, 2-C), 74.50 (d, 2-C), 173.84, 174.25, 175.01, and 175.48 (each s, COOMe); MS *m/z* (rel intensity, %) 243 (M^+, 7), 186 (33), 154 (base peak), 126 (78), and 68 (38). Found: C, 59.01; H, 8.91; N, 5.81%. Calcd for $C_{12}H_{21}NO_4$: C, 59.24; H, 8.70; N, 5.76%.

11: Colorless needles; mp 140.5 °C; IR (KBr) 3400 and 1720 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.74 (1H, br, NH), 3.0—3.7 (3H, m, 4- and 5-H), 3.24, 3.47 (each 3H, s, COOMe), 4.35 (1H, d, *J*=5.0 Hz, 3-H), and 7.0—7.6 (10H, m, Ph); MS *m/z* (rel intensity, %) 339 (M^+, 5), 220 (25), 202 (49), 195 (34), 194 (base peak), 191 (21), 170 (36), 165 (55), 144 (46), 143 (49), 117 (21), 115 (43), 104 (29), 91 (36), and 77 (53). Found: C, 70.96; H, 6.28; N, 4.21%. Calcd for $C_{20}H_{21}NO_4$: C, 70.78; H, 6.24; N, 4.13%.

12: Colorless liquid; IR (neat) 1740 and 1590 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.72 (1H, t, *J*=6.5 Hz), 3.1—3.5 (2H, m), 3.62, 3.66 (each 3H, s, COOMe), 3.87 (2H, d, *J*=7.0 Hz, NCH_2), 7.0—7.9 (3H, m, Py), 8.25 (1H, br s, CH=N), and 8.50 (1H, br d, Py); MS *m/z* 264 (M^+). Found: C, 59.23; H, 6.12; N, 10.35%. Calcd for $C_{13}H_{16}N_2O_4$: C, 59.08; H, 6.10; N, 10.60%.

Reaction of 1 with *trans*-Stilbene Leading to 13. A mixture of **1** (191 mg, 1 mmol), *trans*-stilbene (180 mg, 1 mmol), and cesium fluoride (CsF, 15 mg, 0.1 mmol) in dry HMPA (2 ml) was heated under nitrogen at 80 °C for 3 d. The mixture was poured into aqueous sodium hydrogencarbonate and extracted with dichloromethane (15 ml×2). The dichloromethane was washed with water, dried over magnesium sulfate, and evaporated in vacuo. The residue was chromatographed over silica gel with hexane–ethyl acetate (2:1) to give **13** (239 mg, 80%): Colorless prisms; mp 64—67 °C; IR (KBr) 3340 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.20 (1H, s, NH), 3.1—3.8 (4H, m, 3-, 4-, and 5-H), 4.35 (1H, d, 2-H), and 6.8—7.4 (15H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=54.19 (d, 4-C), 54.60 (t, 5-C), 63.06 (d, 3-C), 71.04 (d, 2-C), 126.28, 126.64, 126.99, 127.28, 127.87, 128.22, 128.34, 128.87 (each d), 140.44, 142.55, and 143.02 (each s); MS *m/z* (rel intensity, %) 299 (M^+, base peak), 180 (21), 179 (25), 178 (25), 119 (25), 118 (27), and 91 (35). Found: C, 88.27; H, 7.11; N, 4.51%. Calcd for $C_{22}H_{21}N$: C, 88.25; H, 7.07; N, 4.68%.

Reaction of 1 with Styrene Leading to 14 and 15. A mixture of **1** (382 mg, 2 mmol), styrene (416 mg, 4 mmol), and CsF (30 mg, 0.2 mmol) was heated under nitrogen at 80 °C for 3 h. The same work-up as above gave **14** (152 mg, 34%) and **15** (71 mg, 16%).

14: Colorless prisms; mp 61—63.5 °C; IR (KBr) 3300 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.1—2.4 (2H, m, 3-H), 2.32 (1H, s, NH), 2.9—3.7 (3H, m, 4- and 5-H), 4.39 (1H, t, *J*=7.5 Hz, 2-H), and 7.1—7.5 (10H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=42.51 (t, 3-C), 44.80 (d, 4-C), 55.54 (t, 5-C), 62.47 (d, 2-C), 126.23, 126.46, 126.87, 127.28, 128.40 (each d), 144.01, and 144.90 (each s); MS *m/z* (rel intensity, %) 223 (M^+, 21), 119 (56), 118 (base peak), 115 (21), 91 (31), and 77 (24). Found: C, 86.05; H, 7.69; N, 6.32%. Calcd for $C_{16}H_{17}N$: C, 86.05; H, 7.67; N, 6.27%.

15: Colorless liquid; IR (neat) 3300 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.9—2.5 (2H, m, 4-H), 2.40 (1H, br s, NH), 2.9—3.5 (3H, m, 3- and 5-H), 4.05 (1H, d, *J*=8.5 Hz, 2-H), and 7.0—7.3 (10H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=35.13 (t, 4-C), 46.49 (t, 5-C), 53.94 (d, 3-C), 70.71 (d, 2-C), 126.21, 126.70, 126.94, 127.56, 128.16, 128.26 (each d), 142.63, and 142.78 (each s); MS *m/z* (rel intensity, %) 223 (M^+, 29), 119 (80), and 118 (base peak). Found: C, 86.18; H, 7.72; N, 6.45%. Calcd for $C_{16}H_{17}N$: C, 86.05; H, 7.67; N, 6.27%.

Reaction of 1 with Benzaldehyde Leading to 16. To a mixture of **1** (191 mg, 1 mmol) and benzaldehyde (106 mg, 1 mmol) in dry DMF (2 ml) was added at 0 °C tetrabutylammonium fluoride (TBAF, 1M solution in THF, 0.1 ml, 0.1 mmol). The mixture was stirred under nitrogen at room temperature for 2 d, poured into aqueous sodium hydrogencarbonate, and extracted with dichloromethane (15 ml×2). The conbined extracts were dried over magnesium sulfate and evaporated in vacuo to give crude **16** (195 mg, 100%): Colorless prisms (hexane); mp 114.5 °C; IR (KBr) 3400

and 1640 cm^{-1}; ^1H NMR ($CDCl_3$) δ=3.00 (1H, br, OH, exchanged with D_2O), 3.4—4.0 (2H, m, NCH_2), 4.95 (1H, dd, J=8.5 and 4.0 Hz, CH), 7.1—7.8 (10H, m, Ph), and 8.20 (1H, br s, CH=N); MS *m/z* (rel intensity, %) 194 (M^+, base peak), 91 (25), 89 (22), and 77 (31). Found: C, 80.10; H, 6.64; N, 6.15%. Calcd for $C_{15}H_{15}NO$: C, 79.97; H, 6.71; N, 6.22%.

General Procedure for the One-Pot Synthesis of 17. To a mixture of **1** (382 mg, 2 mmol) and carbonyl compounds (2 mmol) in dry DMF (4 ml) was added TBAF (1M in THF (1M=1 mol dm^{-3}), 0.2 ml) at 0 °C. The mixture was allowed to stir under nitrogen at room temperature for 2 d, treated with aqueous sodium hydrogencarbonate, and extracted with dichloromethane (20 ml×2). The combined extracts were dried over magnesium sulfate and evaporated in vacuo. The residue was filtered through a long column packed with silica gel using ethyl acetate–methanol (3:1) to give **17**. The results are summarized in Table 2.

17a: Colorless prisms; mp 54—56 °C (lit,[21] mp 57 °C); IR (KBr) 3200—3600 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.50 (3H, br s, OH and NH_2), 2.78 (2H, m, CH_2), 4.50 (1H, dd, J=7.2 and 4.6 Hz, CH), and 7.2—7.3 (5H, br s, Ph); MS *m/z* (rel intensity, %) 118 (23), 117 (16), 107 (19), 105 (30), 91 (47), 90 (13), 89 (18), 79 (75), 78 (37), and 77 (base peak).

17b: Colorless needles; mp 85—87.5 °C; IR (KBr) 2700—3300 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.70 (3H, br s, OH and NH_2), 2.88 (2H, d, J=6.0 Hz, CH_2), 4.51 (1H, t, J=6.0 Hz, CH), 6.12, 6.22, and 7.22 (each 1H, dd, 2-Furyl); MS *m/z* (rel intensity, %) 127 (M^+, 23), 98 (37), 97 (70), 69 (30), and 41 (base peak). Found: C, 56.84; H, 7.11; N, 10.95%. Calcd for $C_6H_9NO_2$: C, 56.68; H, 7.14; N, 11.02%.

17c: Colorless liquid; bp 140 °C/107 Pa; IR (neat) 2800—3400 cm^{-1}; ^1H NMR (DMSO-d_6) δ=2.67 (2H, d, J=5.5 Hz, CH_2), 3.10 (3H, br, OH and NH_2), 4.55 (1H, t, J=5.5 Hz, CH), 7.30, 7.70, 8.42, and 8.49 (each 1H, dd, dt, dd, and d, respectively, 3-Py); MS *m/z* (rel intensity, %) 109 (base peak), 108 (61), 80 (13), and 53 (10). HRMS Found: *m/z* 138.0793. Calcd for $C_7H_{10}N_2O$: M, 138.0788.

17d: Colorless liquid; bp 95 °C/13 Pa; IR (neat) 2800—3400 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.44 (3H, s, Me), 2.12 (3H, s, OH and NH_2), 2.75, 3.06 (each 1H, d, J=10.5 Hz, CH_2), and 7.1—7.5 (5H, m, Ph); MS *m/z* (rel intensity, %) 151 (M^+, 1), 121 (32), 105 (51), 91 (28), 78 (49), 77 (99), 51 (33), and 43 (base peak). HRMS Found: *m/z* 151.0999. Calcd for $C_9H_{13}NO$: M, 151.0996.

17e: Colorless needles; mp 134.5—135.5 °C; IR (KBr) 2700—3400 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.03 (3H, br, OH and NH_2), 2.74 (2H, s, CH_2), and 7.1—7.6 (8H, m, Ar); MS *m/z* (rel intensity, %) 211 (M^+, 9), 182 (24), 181 (82), 180 (25), 153 (base peak), 152 (35), and 151 (19). Found: C, 79.66; H, 6.25; N, 6.61%. Calcd for $C_{14}H_{13}NO$: C, 79.59; H, 6.20; N, 6.63%.

Reduction of 16 with Sodium Borohydride Leading to 18. To a solution of **16** (225 mg, 1mmol) in methanol (2 ml) was added little by little sodium borohydride (38 mg, 1 mmol) under cooling with ice. After 10 min, acetone (10 ml) was added and the mixture was evaporated in vacuo. The residue was treated with water (10 ml) and extracted with dichloromethane (20 ml). The extract was dried over magnesium sulfate and evaporated in vacuo to give **18** (159 mg, 70%): Colorless needles (hexane); mp 100—101 °C; IR (KBr) 2700—3200 and 1430 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.70 (2H, two d, J=7.4 and 5.2 Hz, CH_2), 3.28 (2H, br, OH and NH), 3.64 (2H, s, $PhCH_2$), 4.69 (1H, dd, J=7.4 and 5.2 Hz, CH), and 7.1—7.3 (10H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=53.41 (t, CH_2), 56.53 (t, $PhCH_2$), 71.83 (d, CH), 125.77, 126.99, 127.28, 128.06, 128.20, 128.35 (each d), 139.56, and 142.92 (each s); MS *m/z* (rel intensity, %) 227 (M^+, 5), 121 (base peak), 118 (23), 107 (28), 92 (70), 79 (40), and 77 (49). Found: C, 79.40; H, 7.54; N, 6.21%. Calcd for $C_{15}H_{17}NO$: C, 79.26; H, 7.54; N, 6.16%.

Reaction of 1 with Dimethyl Fumarate Leading to 19a. To a solution of **1** (382 mg, 2 mmol), dimethyl fumarate (288 mg, 2 mmol), and water (32 mg, 2 mmol) in DMF (2 ml) was added TBAF (1M in THF, 0.2 ml, 0.2 mmol) at 0 °C. The mixture was stirred at room temperature for 36 h and evaporated in vacuo. The residue was dissolved in dichloromethane, the dichloromethane was washed with water, dried over magnesium sulfate, and evaporated in vacuo to give **19a** (518 mg, 98%, purity: 99% by GLC): Colorless liquid; bp 145 °C/53 Pa; IR (neat) 1730 and 1640 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.72 (2H, m, CH_2), 3.27 (1H, m, CH), 3.63, 3.68 (each 3H, s, COOMe), 3.84 (2H, dd, J=6.5 and 1.5 Hz, NCH_2), 7.2—7.8 (5H, m, Ph), and 8.23 (1H, d, J=1.5 Hz, CH=N); MS *m/z* (rel intensity, %) 263 (M^+, 59), 232 (66), 204 (64), 203 (30), 195 (25), 190 (56), 158 (36), 118 (60), and 91 (base peak). Found: C, 63.73; H, 6.56; N, 5.49%. Calcd for $C_{14}H_{17}NO_4$: C, 63.86; H, 6.51; N, 5.32%.

Hydrolysis of 19a into 20 and Cyclization of 20 Leading to 21. To a solution of **19a** (616 mg, 2.3 mmol) in methanol (1 ml) was added a few drops of conc HCl. After 5 min at room temperature, diethyl ether (50 ml) was added to give colorless precipitate of **20** (331 mg, 68%). This hydrochloride **20** (300 mg, 1.4 mmol) was dissolved in methanol (5 ml) and triethylamine (1 ml) was added. The mixture was heated under reflux for 2 h. The methanol was evaporated in vacuo. To the resude was added dry diethyl ether (20 ml). The ether was dried over magnesium sulfate and evaporated in vacuo to give **21** (191 mg, 94%).

20: Colorless prisms (ethyl acetate–methanol); mp 178—179.5 °C; IR (KBr) 2800—3200, 1730, and 1595 cm^{-1}; ^1H NMR (DMSO-d_6) δ=2.4—3.3 (5H, m, CH_2 and CH), 3.58, 3.62 (each 3H, s, COOMe), and 8.35 (2H, br, NH); MS *m/z* (rel intensity, %) 176 (M^++1, 2), 144 (15), 115 (13), 114 (14), 102 (32), 70 (24), 56 (20), 55 (25), and 30 (base peak). Found: C, 39.84; H, 6.66; N, 6.64%. Calcd for $C_7H_{14}NO_4Cl$: C, 39.73; H, 6.67; N, 6.62%.

21: Colorless liquid; IR (neat) 3300 and 1800—1650 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.55 (2H, two d, J=8.5 and 7.0 Hz, 3-H), 3.0—3.8 (3H, m, 4- and 5-H), 3.72 (3H, s, COOMe), and 7.50 (1H, br, NH); MS *m/z* (rel intensity, %) 143 (M^+, 10), 116 (85), 113 (20), 101 (73), 100 (21), 87 (25), 84 (50), 83 (69), 70 (31), 59 (30), and 55 (base peak). HRMS Found: *m/z* 143.0599. Calcd for $C_6H_9NO_3$: M, 143.0582.

General Procedure for the One-Pot Synthesis of 22. To a mixture of **1** (382 mg, 2 mmol), electron-poor olefins (2 mmol), and water (2 mmol) was added TBAF (0.2 mmol) at 0 °C. The mixture was stirred at room temperature for 36 h and evaporated in vacuo. The residue was dissolved in methanol (4 ml) and sodium borohydride (76 mg, 2 mmol) was added. After 10 min, acetone was added and the mixture was evaporated in vacuo. The residue was treated with water (2 ml) and extracted with dichloromethane (20 ml×2). The combined extracts were dried over magnesium sulfate and evaporated in vacuo. The residue was heated under reflux in methanol for 0.5 h and the methanol was evaporated in vacuo. The crude product was chromatographed over silica gel with hexane–ethyl acetate (3:1) to give **22**. The results are summarized in Table 2.

22a: Colorless liquid; bp 150 °C/267 Pa; IR (neat) 1740 and

1680 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=2.75 (2H, two d, J=9.3 and 6.7 Hz, 3-H), 3.0—3.4 (1H, m, 4-H), 3.46 (2H, two d, J=7.9 and 6.3 Hz, 5-H), 3.64 (3H, s, COOMe), 4.44 (2H, s, $PhCH_2$), and 7.1—7.4 (5H, m, Ph); ^{13}C NMR ($CDCl_3$) δ=33.70 (t, 3-C), 35.52 (d, 4-C), 46.15, 48.12 (each t, 5-C and $PhCH_2$), 52.02 (q, COOMe), 127.34, 127.75, 128.34 (each d), 135.56 (s), 171.96, and 172.78 (each s, COOMe and CON); MS m/z (rel intensity, %) 233 (M^+, 47), 91 (base peak), 65 (34), and 55 (27). Found: C, 66.60; H, 6.64; N, 5.97%. Calcd for $C_{13}H_{15}NO_3$: C, 66.93; H, 6.48; N, 6.01%.

22b: Colorless liquid; bp 160°C/107 Pa; IR (neat) 1690 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=2.57, 2.89 (each 1H, dd, J=16.7 and 8.3 Hz, 3-H), 3.2—3.7 (3H, m, 4- and 5-H), 4.42, 4.56 (each 1H, d, J=14.5 Hz, $PhCH_2$), and 7.0—7.4 (10H, m, Ph); MS m/z (rel intensity, %) 251 (M^+, 78), 160 (24), 146 (22), 120 (21), 105 (98), and 91 (base peak). Found: C, 81.00; H, 6.79; N, 5.41%. Calcd for $C_{17}H_{17}NO$: C, 81.24; H, 6.82; N, 5.57%.

22c: Colorless liquid; bp 100°C/107 Pa; IR (neat) 1680 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=1.23 (3H, d, J=6.0 Hz, 3-Me), 1.58 (1H, dq, J=12.3, 8.5, 8.5, and 8.5 Hz, one of 4-H), 2.0—2.7 (2H, m, 3-H and the other of 4-H), 3.14, 3.19 (each 2H, d, J=8.5 Hz, 5-H), 4.42 (2H, s, $PhCH_2$), and 7.1—7.4 (5H, m, Ph); MS m/z (rel intensity, %) 189 (M^+, 85), 107 (27), 98 (42), 92 (22), and 91 (base peak). Found: C, 76.38; H, 7.84; N, 7.25%. Calcd for $C_{12}H_{15}NO$: C, 76.15; H, 7.99; N, 7.40%.

Reaction of 3 with Benzylideneacetone Leading to 23. To a mixture of **3** (482 mg, 1 mmol) and benzylideneacetone (292 mg, 2 mmol) in dry THF (2 ml) was added TBAF (1M in THF, 0.2 ml, 0.2 mmol) at 0°C. The mixture was stirred at 0°C for 30 min and poured into aqueous sodium hydrogencarbonate. Organic products were collected in dichloromethane, the dichloromethane was dried over magnesium sulfate, and evaporated in vacuo. The residue was chromatographed through a long column packed with silica gel using ethyl acetate–methanol (3:1) to give **23** (191 mg, 60%): Colorless liquid; IR (neat) 1650 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=2.05 (3H, s, 2-Me), 2.54 (1H, dd, J=17.5 and 7.5 Hz, one of 3-H), 2.96 (1H, m, the other of 3-H), 3.48 (1H, m, 4-H), 3.77, 4.24 (each 1H, m, 5-H), and 7.0—7.4 (5H, m, Ph); MS m/z (rel intensity, %) 159 (M^+, 28) and 55 (base peak). HRMS Found: m/z 159.1029. Calcd for $C_{11}H_{13}N$: M, 159.1047.

Reaction of 4 with Dimethyl Fumarate Leading to 24 and Then to 21. A mixture of **4** (572 mg, 2 mmol), dimethyl fumarate (288 mg, 2 mmol), and TBAF (1M in THF, 0.2 mmol) in dry THF (3 ml) was stirred at 0°C for 30 min, or the same mixture in ethanol (2 ml) was stirred at 0°C for 1 h. The resulting mixture was poured into aqueous sodium hydrogencarbonate and extracted with dichloromethane (15 ml×2). The combined extracts were dried over magnesium sulfate and evaporated in vacuo to give **24** in quantitative yields in both cases (^{1}H NMR ($CDCl_3$) δ=2.73 (2H, m, CH_2), 3.25 (1H, m, CH), 3.63, 3.68 (each 3H, s, COOMe), 3.89 (2H, dd, J=5.5 and 1.5 Hz, NCH_2), 7.78, 8.14 (each 2H, d, Ar), and 8.28 (1H, d, J=1.5 Hz, CH=N)). Crude **24** was chromatographed through a long column packed with silica gel using ethyl acetate–methanol (5:1) to give **21** (63% yield).

Reaction of 6 with Benzylideneacetone Leading to 23. A mixture of **6** (267 mg, 1 mmol), benzylideneacetone (146 mg, 1 mmol), TBAF (0.1 mmol), and water (18 mg, 1 mmol) in DMF (2 ml) was stirred at room temperature for 12 h. The same chromatographic work-up as above gave **23** (123 mg, 77%).

Reaction of 6 with Methyl Acrylate and Subsequent Hydrolysis and Acetylation Leading to 25. A mixture of **6** (267 mg, 1 mmol), methyl acrylate (86 mg, 1 mmol), TBAF (0.1 mmol), and water (1 mmol) in DMF (2 ml) was stirred at room temperature for 12 h. The mixture was poured into aqueous sodium hydrogencarbonate and extracted with dichloromethane (15 ml×2). The combined extracts were dried over magnesium sulfate and evaporated in vacuo. To the residue dissolved in methanol (2 ml) was added concentrated HCl (0.5 ml). The mixture was stirred at room temperature for 10 min, neutralized with aqueous sodium carbonate, and extracted with dichloromethane (20 ml). The dichloromethane was dried and evaporated in vacuo. The residue was dissolved in acetic anhydride (2 ml). After pyridine (1 ml) was added, the mixture was stirred at room temperature for 2 h and poured into ice water. Organic products were extracted with dichloromethane (15 ml), the extract was dried, and evaporated in vacuo. The residue was chromatographed over silica gel with ethyl acetate–ethanol (30:1) to give **25** (88 mg, 55%): Colorless liquid; IR (neat) 3300, 1725, and 1650 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=1.83 (1H, m, CH_2), 1.96 (3H, s, MeCO), 2.37 (2H, t, J=6.5 Hz, CH_2COOMe), 3.29 (2H, t, J=6.0 Hz, NCH_2), 3.67 (3H, s, COOMe), and 5.90 (1H, br, NH, exchanged with D_2O); MS m/z (rel intensity, %) 159 (M^+, 11), 116 (34), 86 (71), and 43 (base peak). HRMS Found: m/z 159.0874. Calcd for $C_7H_{13}NO_3$: M, 159.0895.

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19) 2-Methyl-5-(1-naphthyl)-4-phenyl-1-pyrroline was formed in 10% yield together with **23** in the reaction of **3** with benzylideneacetone, indicating that the 2-azaallyl anion generated from **3** can react at the both carbons.

20) The coupling product is quantitatively obtained in the reaction of **4** with TBAF in the absence of olefins, and was tentatively assigned as 1,2-bis(*p*-nitrobenzylideneamino)ethane (^1H NMR ($CDCl_3$) δ=4.00 (4H, s, CH_2), 7.75, 8.09 (each 2H, d, Ar), and 8.25 (2H, s, CH=N)).

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