# X=Y-ZH COMPOUNDS AS POTENTIAL 1,3-DIPOLES. PART 30.<sup>1</sup> CYCLOADDITION OF ARYLIDENE IMINES OF α-AMINO ESTERS TO ACETYLENIC DIPOLAROPHILES AND PYRROLE FORMING REARRANGEMENTS.<sup>2</sup>

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Abstract: Arylidene imines of  $\alpha$ -amino esters undergo cycloaddition to ethyl phenylpropiolate, methyl propiolate and dimethyl acetylenedicarboxylate (ADE) on heating in toluene (110°C) or o-xylene (135-145°C). The reactions proceed via stereospecific azomethine ylide formation and give single 3-pyrroline cycloadducts in moderate to good yield. Reaction of certain of the imines with 2 mol. of ADE leads to a pyrroles formed by rearrangement. The mechanism of the rearrangement is discussed.

The facile generation of novel "NH" azomethine ylides by 1,2-prototropy in imines of α-amino acids and esters (1) (Scheme 1) is well established.<sup>3</sup> Azomethine ylide formation occurs stereospecifically giving (2) under kinetic control.<sup>4</sup> The extensive use of aziridines as precursors of azomethine ylides, via a thermal conrotatory ring opening, stemming from the early pioneering work of Heine, Huisgen and Padwa<sup>5</sup> led us to suggest that aziridines would be expected to participate in the Scheme 1 equilibria.<sup>6</sup> We have never detected such intermediates but a recent report disclosed that the reaction of certain arylidene imines of  $\alpha$ -amino esters with acyl chlorides leads to the formation of isolable Nacylaziridines.<sup>7</sup> A wide range of other electron-withdrawing substituents can replace the carboxylic acid/ester molety in (1) and give rise to analogous dipoles.<sup>8</sup> Typically the uncatalysed thermal 1.2prototropy occurs on heating the imines at ca. 80-140°C in a suitable solvent. However, we showed some time ago that azomethine ylide formation from (1) is markedly accelerated by both weak Lewis and Bronsted acid catalysts.<sup>9</sup> More recently we reported that a wide range of metal salts [Ag(I), Li(I), Zn(II), Mg(II), Co(II), Mn(II), Ti(IV)} in combination with triethylamine and a polar solvent enable these azomethine ylides to be rapidly generated and trapped at room temperature.<sup>10,11</sup> The Ti(IV) catalysed processes show an interesting and synthetically useful reversal of the normal cycloaddition regiochemistry (Scheme 2)<sup>12</sup>

We have previously reported details of the cycloaddition of (1) to maleate and fumarate esters, and to cyclic dipolarophiles.<sup>4,6</sup> We now report related studies with acetylenic dipolarophiles. These studies were completed before we developed the metal ion catalysed methodology.<sup>10</sup>

#### Ethyl Phenylpropiolate as Dipolarophile

The reaction of imines, or the imine molety of heterocycles such as pyridine or thiazole, with acetylenes, and in particular dimethyl acetylenedicarboxylate (ADE), is well documented. The former

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reaction leads to dihydropyridines<sup>13</sup> whilst the latter lead to a wide variety of products via zwitterionic intermediates.<sup>14</sup> In the light of these literature precedents we were therefore delighted to observe that ethyl phenylpropiolate reacts with imines (3a-c) on heating in o-xylene in a sealed tube at 130-145°C over 48h to give 3-pyrrolines (4a-c) in good yield (69-83%) (Table 1). The reaction is, moreover, both regio and stereo-specific for (3a) and (3b). A small amount of a second isomer was detected (p.m.r.) in the case of (3c) but not isolated. The tendency of 1,3-diarylazomethine ylides to stereomutate, when dipolarophiles less active than maleimides are used, has been noted previously<sup>4</sup> and is believed to be the source of the second isomer from (3c).

### Methyl Propiolate as Dipolarophile

An analogous series of cycloadducts (4d-h) (45-69%) was obtained from imines (3c-g) on heating with methyl propiolate in toluene at 100°C in a sealed tube for 24-48h (Table 1). The regiochemistry of the cycloadducts is assigned on the basis of the 3-H/5-H coupling constants (4,  $R^2$ =H). Coupling constants for CH-CH=C are 6.5-11.5 Hz, whereas 4-bond allylic coupling constants for CH-C=CH are 1.5 - 2.5 Hz.<sup>15</sup> The J<sub>3-H/5-H</sub> coupling constants for (4d-h) are 1.92 - 2.06 Hz. The effect of weak Lewis acids in catalysing the cycloaddition of (3c) and methyl propiolate has been previously discussed.<sup>9</sup>

Table 1 3 - Pyrrolines (4) derived from the reaction of imines (3a-g) with ethyl phenylpropiolate<sup>a</sup> or methyl propiolate.<sup>b</sup>

Imine	Solvent <sup>a</sup>	Reaction Time (h)	3-Pyrroline	Yield(%)
3a	xylene	48	4a	82
3b	xylene	48	4b	83
3c	xylene	48	4c	69
3c	toluene	24	4d	69 <sup>C</sup>
3d	toluene	24	4e	45
Зө	toluene	36	4f	61
3f	toluene	48	4g	52
Зg	toluene	48	<b>4</b> h	58

- a. Reactions carried out under nitrogen in dry o-xylene in a sealed tube at 135-145°C with equimolar quantities of reactants.
- b. Reactions carried out under nitrogen in dry toluene in a sealed tube at 100°C using 2 mol. of methyl propiolate.
- c. Previously reported in reference 9.

It proved difficult to purify pyrrolines (4g) and (4h), and these were therefore characterised by oxidation with dichlorodicyano-p-quinone (DDQ) in benzene at room temperature.<sup>6</sup> The initial oxidation product, the pyrrolenine (5), was not detected. The products were the pyrroles (6a) and (6b) which



arise from (5) via facile 1,5-sigmatropic ester rearrangements.



### ADE as Dipolarophile

Reaction of imines (3) with ADE in boiling toluene gave the corresponding cycloadducts (7) in variable yield (Table 2). A few of the later reactions were carried out in sealed tubes (Table 2) and proceeded with substantially improved yields. In a number of these reactions by-products were apparent. Closer examination of some of the by-products showed they were niether dihydropyridines nor decomposition products of ADE. Thus imine (3a) and ADE gave, in addition to (7, R=H, R<sup>1</sup>=Me), the Michael adduct (8a)(17%), whilst imine (3, R=H, R<sup>1</sup>=p-MeOC<sub>6</sub>H<sub>4</sub>) gave (9a)(19%) and (10a)(5%) as by-products. Formation of by-products was sensitive to the reaction conditions. Thus imine (3g) and ADE give a good yield of (7, R=NO<sub>2</sub>, R<sup>1</sup>=Ph) in a sealed tube reaction (Table 2) but under normal reflux conditions the yield is reduced to 47% and , in addition, pyrrole (9b) (12%) is produced.



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lmine(3)		Reaction Time (h)	3-Pyn	roline(7)	Yield(%)
R	R <sup>1</sup>		R	R <sup>1</sup>	
н	Me	48	н	Me	48 <sup>a</sup>
н	i-Pr	72	н	i-Pr	34
н	CH <sub>2</sub> SCH <sub>2</sub> Ph	48	н	CH <sub>2</sub> SCH <sub>2</sub> Ph	45
Н	Ph	48	н	Ph	53
н	p-CIC <sub>6</sub> H <sub>4</sub>	48	н	p-CIC <sub>6</sub> H <sub>4</sub>	55
Н	p-MeOC <sub>6</sub> H <sub>4</sub>	14	н	p-MeOC <sub>6</sub> H <sub>4</sub>	32 <sup>b</sup>
NO2	Ph	72	NO <sub>2</sub>	Ph	66 <sup>C</sup>
CN	Ph	24	CN	Ph	71 <sup>C</sup>
CF3	Ph	8	CF3	Ph	68 <sup>C</sup>
_d ັ	Ph	24	_e 、	Ph	70 <sup>C</sup>
CI	Ph	48	CI	Ph	21
Me	Ph	48	Me	Ph	54
MeO	Ph	48	MeO	Ph	16
NO2	p-CIC <sub>6</sub> H₄	48	NO2	p-CIC <sub>6</sub> H <sub>4</sub>	43
MeŌ	p-CIC <sub>6</sub> H <sub>4</sub>	48	MeÖ	p-CIC6H4	38
NO2	p-MeOC <sub>6</sub> H <sub>4</sub>	48	NO <sub>2</sub>	p-MeOC <sub>6</sub> H <sub>4</sub>	58

Table 2. 3-Pyrrolines (7) derived from the reaction of imines (3) (1 mol) with ADE (1 mol) in boiling toluene.

a. In addition Michael adduct (8a)(17%) was obtained.

b. In addition (9a)(19%) and (10a)(5%) were obtained.

c. Reaction carried out in dry toluene in a sealed tube under argon.

d. Pentamethylbenzaldehyde imine.

e. 5-Pentamethylphenyl derivative.

The formation of the by-products (8)-(10) prompted a more detailed study of the reaction of the imines (3) and the 3-pyrrolines (7) with ADE. When methyl arylidenephenylglycinates (3,  $R^1$ =Ph) were heated (toluene, 110°C) with ADE (2.2 mol) for 24-48h, in a sealed tube, conversion to the corresponding pyrrole (9) and substituted maleate ester (10) occured in good yield (Table 3). The stereochemistry of the maleates (10a-d) was established by n.O.e. studies, e.g. irradiation of H<sub>A</sub> in (10b) gives a 22% enhancement of the signal of the ortho-phenyl protons. Careful monitoring of these reactions (p.m.r.) indicated that the 3-pyrroline (7) was an intermediate. This was confirmed by reacting (7) with ADE (1 mol) in toluene (110°C) when identical products were obtained to those derived from (3,  $R^1$ =Ph) and ADE (2 mol) (Table 3). Interestingly, (7, R=H,  $R^1$ =Ph) gave a ca. 1:1 mixture of the pyrrole (9a) and Michael adduct (8b). Michael adduct (8b) was not, however, an intermediate in the

formation of (9a) since it was thermally stable on heating at 140°C in xylene. Similar Michael adducts (12a-c) are the sole products (67-71% yield) when pyrrolines (4d-f) are reacted with methyl propiolate in toluene at 110°C in a sealed tube. The stereochemistry of the N-vinyl substituent is assigned on the basis of coupling constants (J<sub>AB</sub> 13.6 Hz) and n.O.e. data. Thus for (12a) irradiation of 5-H caused enhancements of 23% and 25% in the signals for H<sub>A</sub> and H<sub>B</sub> respectively. The Michael adducts (12a-c) do not rearrange to pyrroles on heating to 140°C.

**Table 3** Pyrroles (9) derived from the reaction of imines (3,  $R^1$ =Ph) or pyrrolines (7) with acetylenic esters.<sup>a</sup>

Imine/Pyrroline	Acetylenic Ester(mol) <sup>b</sup>	Time(h)	Pyrrole	Yield(%) <sup>C</sup>
7, R=H, R <sup>1</sup> =Ph	ADE(1.1)	24	9a	44 <sup>d</sup>
7, R=NO <sub>2</sub> , R <sup>1</sup> ≞Ph	ADE(1.05)	24	9b	65
3, R=CF3 R <sup>1</sup> =Ph	ADE(2.2)	24	9c	69 <sup>0</sup>
11	ADE(2.2)	24	9c	65 <sup>f</sup>
3, R=CF <sub>3</sub> , R <sup>1</sup> =Ph	ADEE(2.2)	48	9d	81 <sup>g</sup>
7, R=CN, R <sup>1</sup> =Ph	ADE(1.05)	24	9e	80
3, R=CN, R <sup>1</sup> =Ph	ADEE(2.2)	24	9f	69
7, R=CN, R <sup>1</sup> ≖Ph	ADEE(1.05)	24	9g	72

a. All reactions carried out in toluene at 110°C in a sealed tube under argon.

b. ADE = dimethyl acetylenedicarboxylate; ADEE = diethyl acetylenedicarboxylate.

- c. Isolated yield.
- d. Michael adduct (8b) (28%) also obtained. Yields of (9a) and (8b) estimated from the p.m.r. spectrum of a mixture.
- e. In addition (10d) was isolated.
- f. In addition (10b) (42%) was isolated.
- g. In addition (10c) was isolated.

# Mechanisation of the Pyrrole Forming Rearrangement.

The mechanism of the pyrrole forming rearrangement needs to account for the following observations: (i) 3-pyrrolines (7) are intermediates but Michael adducts (8) are not, (ii) the rearrangement is promoted by electron withdrawing para-substituents in the 5-aryl group in (7), (iii) imines (3e) and (11) react with ADE (2.2 mol) to give the same pyrrole (9c) but different olefins, i.e. (3e) gives (10d) and (11) gives (10b). This together with the structure of pyrroles derived from imines (3) and ADEE (2.2 mol) (Table 3) establishes that the original imine ester group is **not** present in the pyrrole (9), and (iv) only one ester group from the second mol. of acetylenic ester is incorporated into the product as shown by the final entry in Table 3. A mechanism which does not conflict with (i) - (iv) is presented in Scheme 3.



The first intermediate is the zwitterion (13) in which abstraction by the carbanion of the 5-H is faster than proton transfer from nitrogen to the carbanion. The effect of electron withdrawing substituents in the 5-Ar group is to lower the  $pk_a$  of 5-H and promote the former process. Zwitterions of type (13) have been implicated in a related three carbon ring expansion process<sup>16</sup> and in zwitterionic amino-Claisen rearrangements.<sup>17</sup> Literature precedents also exist for the 1,7-electrocyclisation (8 $\pi$ -electron processes)<sup>18</sup> and the 1,5-dipolar cyclisation (14, arrows).<sup>19</sup>

Experimental Experimental details were as previously noted.<sup>4</sup> Petroleum ether refers to the fraction with b.p. 40-60°C.

Imines Imines were known compounds prepared by literature methods<sup>4,6</sup> except as noted below. <u>Methyl N-pentamethylbenzylidenephenylglycinate</u> Prepared by method A<sup>4</sup> from phenylglycine methyl 6474

ester hydrochloride and pentamethylbenzaldehyde. The *product* was obtained as a colourless fluffy powder from ether-petroleum ether, m.p. 90-91°C. (Found: C, 77.95; H, 7.8; N, 4.2.  $C_{21}H_{25}NO_2$  requires C, 78.0: H, 7.8; N, 4.35%);  $v_{max}$ (nujol) 1740 and 1640 cm<sup>-1</sup>;  $\delta$  8.8(s, 1H, CH=N), 7.5(m, 5H, ArH), 4.7(s, 1H, PhCH), 6.2(s, 3H, OMe) and 7.3-8.2(overlapping singlets, 15H, 5 x Me).

<u>Methyl N-4-methoxybenzylidene-4-chlorophenylglycinate (3, R=MeO, R<sup>1</sup> = 4-ClC<sub>6</sub>H<sub>4</sub>)</u>. Prepared by method A<sup>4</sup> from 4-chlorophenylglycine methyl ester hydrochloride and 4-methoxybenzaldehyde. The *product* (76%) crystallised from ether-petroleum ether as colourless needles, m.p. 78-80°C. (Found: C, 64.5; H, 5.15; N, 4.3. C<sub>17</sub>H<sub>16</sub> ClNO<sub>3</sub> requires C, 64.25; H, 5.05; N, 4.4%);  $v_{max}$ (nujol) 1735 and 1635 cm<sup>-1</sup>;  $\delta$  8.25(s, 1H, CH=N), 7.75(d, 2H, ArH), 7.4(AB, 4H, ArH), 6.9(d, 2H, ArH), 5.1(s, 1H, ArCH), and 3.8 and 3.7(2 x s, 2 x 3H, OMe).

<u>Methyl N-4-nitrobenzylidene-4-methoxyphenylglycinate(3, R=NO<sub>2</sub>, R<sup>1</sup>=4-MeOC<sub>6</sub>H<sub>4</sub>)</u>. Prepared by method A<sup>4</sup> from 4-methoxyphenylglycine methyl ester hydrochloride and 4-nitrobenzaldehyde. The *product* (27%) crystallised from ether-petroleum ether as pale yellow needles, m.p. 38-40°C (Found: C, 62.25; H, 4.9; N, 8.3. C<sub>17</sub>H<sub>16</sub>N<sub>2</sub>O<sub>5</sub> requires C, 62.2; H, 4.95; N, 8.55%); v<sub>max</sub> (nujol) 1755, 1710 and 1620 cm<sup>-1</sup>;  $\delta$  8.45(s, 1H, CH=N), 8.2 and 7.2(2 x AB, 2 x 4H, ArH), 5.3(s, 1H, ArCH), and 3.8 and 3.75(2 x s, 2 x 3H, OMe).

<u>Ethyl N-4-trifluorobenzylidenephenylglycinate</u>. Prepared by method B<sup>4</sup> from phenylglycine ethyl ester hydrochloride and 4-trifluoromethylbenzaldehyde. The *product* (71%) was a colourless oil, b.p. 123°C/0.05 mmHg(Found: C, 64.2; H, 4.7; N, 4.15.  $C_{18}H_{16}F_3NO_2$  requires C, 64.5; H, 4.75; N, 4.2%);  $v_{max}$ (film) 3060, 3030, 2980, 1735, 1640, 1615, 845 and 700 cm<sup>-1</sup>;  $\delta$  8.20(s, 1H, CH=N), 8.0-7.1(m, 9H, ArH), 5.2(s, 1H, PhCH), 4.25(q, 2H, CH<sub>2</sub>Me) and 1.25(t, 3H, CH<sub>2</sub>Me); m/z(%) 335(M<sup>+</sup>, 1), 263(33), 262(100), 159(11) and 91(7).

# Ethyl Phenylpropiolate Cycloadducts

<u>Methyl 4-ethoxycarbonyl-2-methyl-3,5-diphenyl-3-pyrroline-2-carboxylate (4a)</u>. A solution of methyl Nbenzylidinealaninate (380mg, 2 mmol) and ethyl phenylpropiolate (348 mg, 2 mmol) in o-xylene (2ml) was flushed with nitrogen prior to being sealed in a glass tube (freeze-thaw procedure). The mixture was heated at 135°C for 48h. The tube was allowed to attain room temperature, opened, and the solvent removed to give a pale yellow paste. Crystallisation and recrystallisation from ether-petroleum ether gave (4a) as pale yellow prisms (600mg; 82%), m.p. 97-99°C (Found: C, 72.25; H, 6.4; N, 3.7.  $C_{22}H_{23}NO_4$  requires: C, 72.3; H, 6.35; N, 3.85%);  $v_{max}$ (nujol) 3320, 1725 and 1710 cm<sup>-1</sup>;  $\delta$  7.6-7.0(m, 10H, ArH), 5.4(s, 1H, 5-H), 3.8(m, 2H, C $\underline{H}_2$ Me), 3.65(s, 3H, OMe), 2.7(br s, 1H, NH), 1.55(s, 3H, Me) and 0.75(t, 3H, CH<sub>2</sub>Me).

<u>Methyl 4-ethoxycarbonyl-2-ethyl-3,5-diphenyl-3-pyrroline-2-carboxylate (4b)</u>. A solution of methyl N-benzylidine-α-aminobutyrate (410mg, 2 mmol) and ethyl phenylpropiolate (348 mg, 2 mmol) in o-xylene (2.5ml) was heated at 135°C for 48h. (sealed tube, nitrogen flush). After work-up as above, the *product* was obtained as pale yellow prisms (630mg, 83%), m.p. 67-70°C, from ether-petroleum ether at -20°C (Found: C, 72.75; H, 6.6; N, 3.55.  $C_{23}H_{25}NO_4$  requires: C, 72.8; H, 6.65; N, 3.7%),  $v_{max}$ (nujol) 3365 and 1720 cm<sup>-1</sup>; δ 7.7-7.0(m, 10H, ArH), 5.4(s, 1H, 5-H), 3.85(m, 2H, OCH<sub>2</sub>Me), 3.65(s, 3H, OMe),

# 3.0(br s, 1H, NH), 1.5-0.9(m, 5H, CH<sub>2</sub>CH<sub>2</sub>Me) and 0.76(t, 3H, OCH<sub>2</sub>Me).

Methyl 4-ethoxycarbonyl-2,3,5-triphenyl-3-pyrroline-2-carboxylate (4c). A solution of methyl N-benzylidinephenylglycinate (500mg; 2 mmol) and ethyl phenylpropiolate (348mg, 2 mmol) in o-xylene (2ml) (sealed tube, nitrogen flush) was heated at 145° for 48h. Work up as above gave a pale yellow oil which resisted crystallisation. Preparative t.l.c. of the oil (silica) eluting with 1:1 ether-petroleum ether gave the *product* (590mg, 69%) as colourless prisms, m.p. 62-64°C from petroleum ether at-20° (Found: C, 75.9; H, 6.0; N, 3.15.  $C_{27}H_{25}NO_4$  requires: C, 75.9; H, 5.85; N, 3.3%);  $v_{max}$ (nujol) 3400 and 1720 cm<sup>-1</sup>; δ 7.35(m, 13H, ArH), 6.95(m, 2H, ArH), 5.55(s, 1H, 5-H), 3.82(m, 2H, CH<sub>2</sub>Me), 3.65(s, 3H, OMe), and 0.76(t, 3H, CH<sub>2</sub>Me); m/z(%) 427(M<sup>+</sup>, 2), 368(100), 322(12) and 295(40).

### Methyl Propiolate Cycloadducts.

Reaction times and yields are collected in Table 1.

<u>Dimethyl</u> <u>2-phenyl-5-(4<sup>/</sup>-methoxyphenyl)-3-pyrroline-2,4-dicarboxylate</u> (4e). Methyl N-4<sup>/</sup> methoxylbenzylidene phenylglycinate (849mg, 3 mmol) and methyl propiolate (504 mg, 6 mmol) were dissolved in dry toluene (10ml) and the solution was heated at 100°C under a nitrogen atmosphere in a sealed tube for 24 h. The solvent was evaporated under reduced pressure to leave a thick yellow gum which was triturated with ether-pentane and set aside in the refrigerator for 24 h during which the product crystallised as colourless needles, m.p. 171°C (Found: C, 68.7; H, 5.85; N, 3.7.  $C_{21}H_{21}NO_5$  requires C, 68.65; H, 5.75; N, 3.8%);  $v_{max}$  3360, 2960, 1720, 1715, 1630, 1605, 830, 780 and 700 cm<sup>-1</sup>;  $\delta$  7.59-6.78(m, 10H, ArH and 3-H), 5.24(d, 1H, 5-H, J 1.95Hz), and 3.79, 3.78 and 3.63(3 x s, 3 x 3H, 3 x OMe); m/z(%) 336(M -OMe, 3), 308 (100) 276(62), 249(28) and 234(20).

<u>Dimethyl 2-phenyl-5-(4<sup>/</sup>-trifluoromethylphenyl)-3-pyrroline-2,4-dicarboxylate (4f)</u>. Obtained as colourless prisms from ether, m.p. 70°C, after chromatography of the crude product on silica eluting with 2:3 v/v ether-pentane. (Found: C, 62.35; H, 4.45; N, 3.3.  $C_{21}H_{18}F_3NO_4$  requires C, 62.2; H, 4.45; N, 3.45%);  $v_{max}$  3390, 2950, 1725, 1715, 1635, 1610, 1440, 1325, 835, 785, 770, 760 and 700 cm<sup>-1</sup>;  $\delta$  7.63-7.26(m, 10H, ArH and 3-H), 5.35(d, 1H, 5-H, J 1.99Hz), 3.80, 3.65(2 x s, 2 x 3H, 2 x OMe) and 3.17(br s, 1H, NH); m/z(%) 405(M<sup>+</sup>, 0.5), 404(2), 347(21), 346(100), 328(1), 315(15), 316(66), 287(79), 268(5) and 77(13).

<u>Dimethyl 2-phenyl-5-(4<sup>*l*</sup>-cyanophenyl)-3-pyrroline-2,4-dicarboxylate (4g)</u>. Obtained as an impure pale yellow gum which was characterised by oxidation to the corresponding pyrrole (below).  $\delta$  7.76-7.17(m, 10H, ArH and 3-H), 5.34(d, 1H, 5-H, J 1.95Hz), 3.79 and 3.63(2 x s, 2 x 3H, 2 x OMe) and 2.74(br s, 1H, NH); m/z(%) 361(M-1; 0.5), 279(21), 278(100), 246(50), and 219(33).

<u>Dimethyl</u> 2-phenyl-5-(4<sup>/</sup>-cyanophenyl)-1H-pyrrole-3,4-dicarboxylate (6a). Dimethyl 2-phenyl-5(4<sup>/</sup>-cyanophenyl)-3-pyrroline-2,4-dicarboxylate (362mg, 1 mmol) and DDQ(227mg, 1 mmol) were dissolved in dry benzene and the mixture stirred overnight at room temperature. The hydroquinone precipitated during the reaction and was removed by filtration. The filtrate was evaporated to dryness and the residual gum triturated with ether. The resulting solid was crystallised from methanol to give the *product* (300 mg, 83%) as colourless plates, m.p. 167-169°C (Found: C, 69.85; H, 4.45; N, 7.83.  $C_{21}H_{16}N_2O_4$  requires C, 70.0; H, 4.5; N, 7.75%);  $v_{max}$  3250, 2940, 2220, 1725, 1680, 1605, 1485, 1455, 1440,

1220, 785 and 760 cm<sup>-1</sup>;  $\delta$  8.93(br s, 1H, NH), 7.65-7.39(m, 9H, ArH), and 3.82 and 3.79(2 x s, 2 x 3H, 2 x OMe); m/z(%) 360(M<sup>+</sup>, 100), 329(42), 316(10), 301(22), 286(22) and 77(6).

<u>Dimethyl 2-phenyl-5-(4<sup>/</sup>-nitrophenyl)-3-pyrroline-2,4-dicarboxylate (4h)</u>. Obtained as a yellow gum which was characterised by oxidation to the corresponding pyrrole (below).  $v_{max}$  3360, 2920, 2840, 1720, 1635, 1600, 1520, 850, 820, 730 and 700 cm<sup>-1</sup>;  $\delta$  8.24-7.28(m, 10H, ArH and 3-H), 5.44(d, 1H, 5-H, J 2.0Hz), 3.82 and 3.65(2 x s, 2 x 3H, 2 x OMe); m/z(%) 383(M + 1, 4), 323(100), 291(61), 264(21), 245(10), 233(13), 218(21) and 77(7).

<u>Dimethyl</u> <u>5-(4<sup>/</sup>-nitrophenyl)2-phenyl-1H-pyrrole-3,4-dicarboxylate</u> (6b). Dimethyl 2-phenyl-5-(4<sup>/</sup>-nitrophenyl)-3-pyrroline-2,4-dicarboxylate(382mg, 1 mmol) and DDQ(227 mg, 1 mmol) were reacted in benzene in an analogous manner to that described above. The resulting yellow solid was crystallised from methanol-ether to give the *product* (300 mg, 79%) as bright yellow prisms, m.p. 198-199°C (Found: C, 63.35; H, 4.3; N, 7.4.  $C_{20}H_{16}N_2O_6$  requires C, 63.15; H, 4.25; N, 7.35%);  $v_{max}$  3260, 3020, 1735, 1710, 1600, 860, 855, 790, 770, 725, 710 and 700 cm<sup>-1</sup>;  $\delta$  8.86(br s, 1H, NH), 8.29-7.36(m, 9H, ArH), and 3.82 and 3.79(2 x s, 2 x 3H, 2 x OMe); m/z(%) 380(M<sup>+</sup>, 100), 350(29), 349(47), 303(12), 258(2) and 77(6).

### ADE Cycloadducts

Reaction times and yields are collected in Table 2.

<u>Trimethyl 2-methyl-5-phenyl-3-pyrroline-2,3,4-tricarboxylate (7, R=H, R'=Me)</u>. A solution of methyl Nbenzylidene alaninate (3.82g, 20 mmol) and ADE(2.84g, 20 mmol) in toluene (50 ml) was stirred and boiled under reflux for 48h. Removal of the solvent under reduced pressure gave a brown gum which was chromatographed on silica eluting with increasing percent of ether in petroleum ether. Elution with 3:7 v/v ether-petroleum ether gave a pale yellow oil which crystallised from ether-petroleum ether at -20°C to give the *product* (3.2g, 48%), m.p. 79-80°C, as colourless prisms (Found: C, 61.0; H, 5.9; N, 4.25.  $C_{17}H_{19}NO_6$  requires C, 61.25; H, 5.75; N, 4.2%);  $v_{max}$ (nujol) 3450, 1730 and 1720 cm<sup>-1</sup>;  $\delta$ 8.0(m, 2H, ArH), 7.65(m, 3H, ArH), 5.0(d, 1H, 5-H), 3.8, 3.75 and 3.7(3 x s, 3 x 3H, OMe) and 1.95(s, 3H, Me); m/z(%) 333(M<sup>+</sup>, 2), 274(50) and 242(100).

Elution with 1:1 ether-petroleum ether gave an orange oil which was triturated with ether-petroleum ether at 0°C. The resulting solid crystallised from ether-petroleum ether to afford trimethyl 1-[(1<sup>/</sup>,2<sup>/</sup>-dimethyoxycarbonyl)ethenyl]-2-methyl-5-phenyl-3-pyrroline-2,3,4-tricarboxlate (8) (1.6g, 17%) as colourless prisms, m.p. 139-141°C (Found: C, 58.3; H, 5.35; N, 3.05.  $C_{23}H_{25}NO_{10}$  requires C, 58.1: H, 5.3; N, 2.95%);  $v_{max}$  1750, 1720, 1700 and 1580 cm<sup>-1</sup>;  $\delta$  7.4(m, 5H, ArH), 5.94(s, 1H, olefinic H), 4.75(s, 1H, 5-H), 4.0, 3.8, 3.6, 3.55 and 3.35(5 x s, 5 x 3H, OMe) and 1.8(s, 3H, Me); m/z(%) 475(M<sup>+</sup>,2), 444(4), 416(27) and 384(100).

<u>Trimethyl 2-isopropyl-5-phenyl-3-pyrroline-2,3,4-tricarboxylate (7,R=H,R<sup>1</sup>=i-Pr)</u>. Colourless plates from ether-petroleum ether, m.p. 58-60°C (Found: C, 62.95; H, 6.45; N, 3.65.  $C_{19}H_{23}NO_6$  requires C, 63.15; H, 6.4; N, 3.9%);  $v_{max}$  3360, 1720 and 1655 cm<sup>-1</sup>;  $\delta$  7.3(s, 5H, ArH), 5.1(s, 1H, 5-H), 3.85, 3.8 and 3.55(3 x s, 3 x 3H, OMe), 2.75(br s, 1H, NH), 2.5(m, 1H, CHMe<sub>2</sub>), and 0.9(2 x d, 6H, CHMe<sub>2</sub>); m/z(%) 361(M<sup>+</sup>, 3), 318(83), and 302(100).

Trimethyl 2-phenylmethylthiomethyl-5-phenyl-3-pyrroline-2.3.4-tricarboxylate (7, R=H,  $R'=CH_2SCH_2Ph$ ). Colourless prisms from ether-petroleum ether at -20°C, m.p. 63-65°C (Found: C, 63.05; H, 5.55; N, 3.24. C<sub>24</sub>H<sub>25</sub>NO<sub>6</sub>S requires C, 63.3; H, 5.55; N, 3.05%); δ 7.4(s, 5H, ArH), 5.3(s, 1H, 5-H), 3.85(s, 2H, SCH<sub>2</sub>Ar), 3.75(s, 6H, 2 x OMe), 3.55(s, 3H, OMe), 3.15(dd, 2H, CH<sub>2</sub>S) and 2.65(br s, 1H, NH); m/z(%) 424(M-OMe, 2), 396(3), 364(4), 318(100), 286(72), 274(88), 254(28) and 242(62).

<u>Trimethyl 2.5-diphenyl-3-pyrroline-2,3,4-tricarboxylate (7, R=H, R<sup>/</sup>=Ph)</u>. Colourless needles from dichloromethane-petroleum ether, m.p. 135-137°C (Found: C, 66.9; H, 5.5; N, 3.8.  $C_{22}H_{21}NO_6$  requires C, 66.85; H, 5.35; N, 3.55%);  $v_{max}$  3360, 1730, 1710 and 1665 cm<sup>-1</sup>;  $\delta$  7.35(s, 10H, ArH), 5.33(s, 1H, 5-H), 3.8, 3.75 and 3.6(3 x s, 3 x 3H, OMe), and 3.2(br, s, 1H, NH); m/z(%) 394(M-1, 6), 336(100), 304(93) and 277(29).

<u>Trimethyl 2-(4-chlorophenyl)-5-phenyl-3-pyrroline-2,3,4-tricarboxylate (7, R=H, R<sup>/</sup>=p-ClC<sub>6</sub>H<sub>4</sub>)</u>. Colourless needles from ether-petroleum ether, m.p. 106-107<sup>o</sup>C (Found: C, 61.65; H, 4.9; N, 2.95.  $C_{22}H_{20}CINO_6$  requires C, 61.45; H, 4.65; N, 3.25%);  $v_{max}$ (nujol) 3380, 1730 and 1710 cm<sup>-1</sup>;  $\delta$  7.5(m, 9H, ArH), 5.35(s, 1H, 5-H), 3.85, 3.8 and 3.6(3 x s, 3 x 3H, OMe) and 3.7(br s, 1H, NH); m/z(%) 370(M -  $CO_2$ Me, 30), 338(32) and 311(100).

<u>Trimethyl</u> 2-(4-methoxyphenyl)-5-phenyl-3-pyrroline-2,3,4-tricarboxylate (7, R=H,  $R'=p-MeOC_6H_4$ ). Obtained as colourless prisms, m.p. 90-93°C, from ether-petroleum ether after separation of the reaction mixture by preparative t.l.c. (silica) eluting with 1:1 v/v ether-petroleum ether ( $R_f$  0.47). (Found: C, 64.95; H, 5.6; N, 3.15.  $C_{23}H_{23}NO_7$  requires C, 64.95; H, 5.5; N, 3.2%);  $v_{max}$ (nujol) 3280, 1700 and 1680 cm<sup>-1</sup>;  $\delta$  7.4(br s, 5H, ArH), 7.1(AB, 4H, ArH), 5.35(s, 1H, 5-H), 3.85, 3.8 and 3.6(3 x s, 3 x 3H, OMe), and 3.2(br s, 1H, NH); m/z(%) 425(M<sup>+</sup>, 3), 393(2), 366(100), 334(91) and 307(42).

A second slower moving band (R<sub>f</sub> 0.38) from the preparative t.l.c. afforded <u>trimethyl 5-phenylpyrrole-2,3,4-tricarboxylate(19%)</u>, m.p. 164-165°C, as colourless prisms from dichlormethane-ether at -20°C (Found: C, 60.55; H, 4.75; N, 4.4. C<sub>16</sub>H<sub>15</sub>NO<sub>6</sub> requires C, 60.55; H, 4.65; N, 4.4%); v<sub>max</sub> 3280, 1745, 1725 and 1680 cm<sup>-1</sup>;  $\delta$  9.7(br s, 1H, NH), 7.7-7.2(m, 5H, ArH) and 3.95, 3.75 and 3.7(3 x s, 3 x 3H, OMe); m/z(%) 317(M<sup>+</sup>, 18), 316(100), 284(81) and 254(67),

A third band from the preparative t.l.c. ( $R_f$  0.26) afforded <u>dimethyl 4-methoxyphenylmaleate(5%)</u>, m.p. 145-148°C, as yellow prisms from ether-petroleum ether (Found: C, 62.45; H, 5.9.  $C_{13}H_{14}O_5$  requires C, 62.4; H, 5.65%);  $v_{max}$  1735(sh), 1720 and 1680 cm<sup>-1</sup>;  $\delta$  7.45(m, 4H, ArH) and 3.9, 3.75 and 3.6(3 x s, 3 x 3H, OMe).

<u>Trimethyl 2-phenyl-5-(4<sup>/</sup>-nitrophenyl)-3-pyrroline-2,3,4-tricarboxylate (7, R=NO<sub>2</sub>, R<sup>/</sup>=Ph)</u>. A solution of methyl N-4-nitrobenzylidene phenylglycinate (1.192g, 4 mmol) and ADE (568mg, 4 mmol) in dry toluene(12 ml) was heated in a sealed tube under an atmosphere of dry argon for 36h. Evaporation of the solvent under reduced pressure afforded a brown gum which was triturated with ether to afford a yellow solid. Crystallisation of the yellow solid from ether afforded the *product* (1.16g, 66%) as yellow prisms, m.p. 134-136°C (Found: C, 60.25; H, 4.7; N, 6.1.  $C_{22}H_{20}N_2O_6$  requires C, 60.0; H, 4.6; N, 6.35%);  $v_{max}$  3400, 1720, 1690, 1200, 870, 820 and 750 cm<sup>-1</sup>;  $\delta$  8.26-7.21 (m, 9H, ArH), 5.51(s, 1H, ArCHN), and 3.85, 3.77 and 3.62(3 x s, 3 x 3H, 3 x OMe); m/z(%) 440(M<sup>+</sup>, 0.5) and 381(100).

<u>Trimethyl 2-phenyl-5-(4<sup>/</sup>-cyanophenyl)-3-pyrroline 2,3,4-tricarboxylate (7, R=CN, R<sup>/</sup>=Ph)</u>. Obtained as colourless prisms from ether, m.p. 154°C (Found: C, 65.9; H, 4.7; N, 6.55.  $C_{23}H_{20}N_2O_6$  requires C, 65.7; H, 4.8; N, 6.65%);  $v_{max}$  3340, 2940, 2220, 1735, 1720, 1665, 1430, 1200, 930, 860, 830, 805, 780 and 750 cm<sup>-1</sup>; δ 7.72-7.34(m, 9H, ArH), 5.46(s, 1H, 5-H), 3.85, 3.77, 3.62(3 x s, 3 x 3H, 3 x OMe), and 2.40(br s, 1H, NH); m/z(%) 420(M<sup>+</sup>, 1), 361(100), 317(16), 302(24), 285(21) and 258(11). Trimethyl 2-phenyl-5-(4<sup>/</sup>-trifluoromethylphenyl)-3-pyrroline 2,3,4-tricarboxylate (7,R=CF<sub>3</sub>, R<sup>/</sup>=Ph). Obtained as colourless prisms from ether, m.p. 64-67°C (Found: C, 59.75; H, 4.3; N, 3.0.  $C_{23}H_{20}F_3NO_6$  requires C, 59.6; H, 4.3; N, 3.0%);  $v_{max}$  3370, 1740, 1730, 1710, 1660, 1615 and 860 cm<sup>-1</sup>; δ 7.95-7.34(m, 9H, ArH), 5.11(s, 1H, ArCHN), and 3.90, 3.81 and 3.65(3 x s, 3 x 3H, 3 x Me); m/z(%) 464(M+H, 2), 404(100), 372(79), 360(16), 345(32), 328(27), 314(30) and 77(6).

<u>Trimethyl 2-phenyl-5-(pentamethylphenyl)-3-pyrroline-2,3,4-tricarboxylate (7, 5-pentamethylphenyl, R<sup>4</sup>=Ph)</u>. Obtained as colourless needles from methanol, m.p. 181°C (Found: C, 69.7; H, 6.75; N, 2.95.  $C_{27}H_{31}NO_6$  requires C, 69.65; H, 6.7; N, 3.0%);  $v_{max}$  3400, 2940, 1730, 1720, 1710, 1600, 1200 and 700 cm<sup>-1</sup>;  $\delta(C_6D_6)$  6.96-6.72(m, 5H, ArH), 4.31(d, 1H, 5-H, J 6.3Hz), 3.62(s, 3H, OMe), 3.55(d, 1H, NH, does not exchange with  $D_2O$ ), 3.30 and 2.86(2 x s, 2 x 3H, OMe), 2.59 and 2.02(2 x br s, 2 x 3H, Me), 1.86(s, 3H, Me) and 1.70(br s, 6H, 2 x Me); m/z(%) 465(M<sup>+</sup>, 9), 450(100), 406(3), 374(8) and 136(54).

<u>Trimethyl 2-phenyl-5-(4<sup>/</sup>-chlorophenyl)-3-pyrroline-2,3,4-tricarboxylate (7, R=Cl, R<sup>/</sup>=Ph)</u>. Colourless prisms from dichloromethane-petroleum ether, m.p. 173-175°C (Found: C, 61.2; H, 4.65; N, 3.15.  $C_{22}H_{20}CINO_6$  requires C, 61.45; H, 4.65; N, 3.25%);  $v_{max}$ (nujol) 3355, 1720 and 1700 cm<sup>-1</sup>;  $\delta$  7.6-7.0(m, 9H, ArH), 5.45(s, 1H, 5-H), 3.9, 3.85 and 3.6(3 x s, 3 x 3H, OMe) and 6.8(br s, 1H, NH); m/z(%) 429(M<sup>+</sup>, 3) and 370(100).

<u>Trimethyl 2-phenyl-5-(4<sup>/</sup>-methylphenyl)-3-pyrroline-2,3,4-tricarboxylate (7,R=Me, R<sup>/</sup>=Ph)</u>. Obtained as colourless needles from dichloromethane-petroleum ether, m.p. 158-161°C (Found: C, 67.6; H, 5.7; N, 3.2.  $C_{23}H_{23}NO_6$  requires C, 67.45; H, 5.65, N, 3.4%);  $v_{max}$  3340, 1725 and 1710 cm<sup>-1</sup>;  $\delta$ 7.5-7.0(m, 9H, ArH), 5.3(s, 1H, 5-H), 3.8, 3.7 and 3.55(3 x s, 3 x 3H, OMe), 3.25(br s, 1H, NH) and 2.3(s, 3H, Me).

<u>Trimethyl 2-phenyl-5-(4<sup>/</sup>-methoxyphenyl)-3-pyrroline-2,3,4-tricarboxylate (7, R=OMe, R<sup>/</sup>=Ph)</u>. Obtained as colourless needles from dichloromethane-petroleum ether, m.p. 141-143°C (Found: C, 64.9; H, 5.45; N, 3.4.  $C_{23}H_{23}NO_7$  requires C, 64.95; H, 5.5; N, 3.2%);  $v_{max}$  3370, 1740, 1715, and 1670 cm<sup>-1</sup>:  $\delta$  7.3(m, 7H, ArH), 7.8(d, 2H, ArH), 5.3(s, 1H, 5-H), 3.75-3.85(3 x s, 3 x 3H, OMe), 3.6(s, 3H, OMe) and 3.1(br s, 1H, NH); m/z(%) 425(M<sup>+</sup>, 24), 393(27), 366(26), 334(38) and 209(100).

<u>Trimethyl 2-(4<sup>/</sup>-chlorophenyl)-5-(4<sup>/</sup>-nitrophenyl)-3-pyrroline-2,3,4-tricarboxylate (7, R=NO<sub>2</sub>, R<sup>/</sup>=p-ClC<sub>6</sub>H<sub>4</sub>).</u> Obtained as colouriess plates from dichloromethane-petroleum ether, m.p. 166-168<sup>o</sup>C (Found: C, 55.85; H, 4.15; N, 6.1. C<sub>22</sub>H<sub>19</sub>ClN<sub>2</sub>O<sub>8</sub> requires C, 55.9; H, 4.0; N, 5.9%); v<sub>max</sub>(nujol) 3360 and 1710 cm<sup>-1</sup>; δ 8.3 and 7.65(2 x d, 2 x 2H, ArH), 7.45(s, 4H, ArH), 5.55(d, 1H, J 5Hz, 5-H), 3.9, 3.85 and 3.65(3 x s, 3 x 3H, OMe) and 3.15(d, 1N, NH); m/z(%) 474(M<sup>+</sup>, 0.5), 415(75) and 383(100). Trimethyl 2-(4<sup>/</sup>-chlorophenyl)-5-(4<sup>/</sup>-methoxyphenyl)-3-pyrroline-2,3,4-tricarboxylate (7, R=MeO, R<sup>/</sup>=p-ClC<sub>6</sub>H<sub>4</sub>). <u>CIC<sub>6</sub>H<sub>4</sub></u>). Colourless plates from ether-petroleum ether, m.p. 103-105<sup>o</sup>C (Found: C, 60.2; H, 4.95; N, 3.05. C<sub>23</sub>H<sub>22</sub>CINO<sub>7</sub> requires C, 60.05; H, 4.8; N, 3.05%);  $\nu_{max}$  3330, 1730 and 1715 cm<sup>-1</sup>;  $\delta$  7.5 and 7.15(2 x dd, 2 x 4H, ArH), 5.4(br s, 1H, 5-H), 3.90-3.8(3 x s, 3 x 3H, OMe), 3.7(s, 3H, OMe) and 3.2(br s, 1H, NH).

### **Pyrrole Forming Rearrangements**

Reaction times and yields are collected in Table 3.

<u>Trimethyl 5-phenylpyrrole-2,3,4-tricarboxylate (9a)</u>. A solution of trimethyl 2,5-diphenyl-3-pyrroline-2,3,4-tricarboxylate (79mg, 0.2 mmol) and ADE (31mg, 0.22 mmol) in toluene (0.5ml) was heated in a sealed tube under an argon atmosphere at 110°C for 24 h. The solvent was then removed and the residue triturated with ether to afford a colourless solid (58mg) whose p.m.r. spectrum showed it to comprise a ca. 1.6:1 mixture of (9a) (i.e. 44%) and (8b)(i.e. 28%). Fractional crystallisation from methanol-ether afforded the pure products.

(<u>9a</u>) Colourless prisms, m.p. 164-165°C (Found: C, 60.55; H, 4.75; N, 4.4.  $C_{16}H_{15}NO_6$  requires C, 60.55; H, 4.65; N, 4.4%);  $v_{max}$  3285, 1745, 1725, 1680 and 1600 cm<sup>-1</sup>;  $\delta$  9.44(br s, 1H, NH), 7.60-7.36(m, 5H, ArH), and 3.96, 3.83 and 3.72(3 x s, 3 x 3H, 3 x OMe); m/z(%) 317(M<sup>+</sup>, 18), 316(100), 284(81) and 254(67).

<u>Trimethyl 2,5-diphenyl N-(1<sup>7</sup>,2<sup>7</sup>-dimethoxycarbonylethenyl)-3-pyrroline-2,3,4-tricarboxylate (8b)</u>. Colourless prisms from methanol-ether, m.p. 166°C (Found: C, 62.25; H, 5.05; N, 2.75.  $C_{28}H_{27}NO_{10}$  requires C, 62.55; H, 5.05; N, 2.6%);  $v_{max}$  2950, 1745, 1730, 1705, 1435, 825, 760 and 700 cm<sup>-1</sup>; δ 7.56-7.28(m, 10H, ArH), 4.71(s, 1H, C=CH), 4.05(s, 1H, PhCHN), and 4.04, 3.66, 3.55, 3.44, and 3.21(5 x s, 5 x 3H, 5 x OMe); m/z(%) 537(M<sup>+</sup>, 0.5), 447(5), 317(100), 285(81), 254(78), 169(48) and 77(9). <u>Trimethyl 5-(4<sup>7</sup>-nitrophenyl)pyrrole-2,3,4-tricarboxylate (9b)</u>. Fine yellow needles from ether, m.p. 171°C (Found: C, 52.85; H, 3.9; N, 7.65.  $C_{16}H_{14}N_2O_8$  requires C, 53.05; H, 3.9; N, 7.75%);  $v_{max}$  3300, 2960, 1740, 1715, 1700, 1325, 1205, 860, 850, 795 and 750 cm<sup>-1</sup>; δ 9.62(br, 1H, NH), 8.34-7.74(dd, 4H, ArH), and 3.98, 3.88 and 3.76(3 x s, 3 x 3H, 3 x OMe); m/z(%) 362(M<sup>+</sup>, 100), 331(43), 330(81), 299(70), 220(7), and 214(48).

<u>Trimethyl 5-(4<sup>/</sup>-trifluoromethylphenyl)pyrrole-2,3,4-tricarboxylate (9c)</u>. Obtained as colourless rods from ether, m.p. 153-154°C (Found: C, 52.5; H, 3.55; N, 3.45.  $C_{17}H_{14}F_3NO_6$  requires C, 52.95; H, 3.65; N, 3.65%);  $v_{max}$  3245, 2945, 1745, 1725, 1690, 1450, 845, 790, and 700 cm<sup>-1</sup>;  $\delta$  9.86(br s, 1H, NH), 7.69(s, 4H, ArH), and 3.88, 3.79 and 3.74(3 x s, 3 x 3H, 3 x OMe); m/z(%) 385(M<sup>+</sup>, 100), 354(48), 353(86), 323(19), 322(96), 321(26) and 237(57). In addition (10b) was also isolated (below).

<u>Methyl 3-ethoxycarbonylcinnamate (10b)</u>. The mother liquor obtained from the experiment above was chromatographed on silica when (10b) was obtained as a pale yellow liquid (42%) ( $R_f$  0.30) eluted by

3:7 v/v ether-petroleum ether; accurate mass: 234.0893. C13H14O4 requires 234.0892; vmax(film) 3050, 2980, 2940, 1730, 1720, 1620, 1365, 1315, 1200, 770 and 690 cm<sup>-1</sup>; δ 7.53-7.38(m, 5H, ArH), 6.31(s, 1H, CH=C), 4.44(q, 2H, CH\_Me), 3.79(s, 3H, OMe), and 1.39(t, 3H, CH\_Me); m/z(%) 234(M<sup>+</sup>, 100), 206(14), 189(71), 175(45), 161(86), 147(28), 131(38), 115(30), 102(45), 91(17) and 77(17). Triethyl 5-(4/-trifluoromethylphenyl)pyrrole-2,3,4-tricarboxylate (9d). Obtained as colourless rods from ether-petroleum ether, m.p. 137-138°C (Found: C, 56.4; H, 4.9; N, 3.35. C20H20F3NO6 requires C, 56.25; H, 4.7; N, 3.3%); v<sub>max</sub> 3260, 2980, 1740, 1715, 1695, 1440, 1325, 1230, 840, 790 and 700 cm<sup>-1</sup>; δ 9.83(br s, 1H, NH), 7.71(s, 4H, ArH), 4.41(q, 2H, CH<sub>2</sub>Me), 4.21(q, 4H, 2 x CH<sub>2</sub>Me), and 1.41, 1.30 and 1.22(3 x t, 3 x 3H, CH2Me); m/z(%) 427(M<sup>+</sup>, 100), 382(44), 381(59), 354(12), 308(26), 281(10), 237(47), and 172(24). The residual mother liquor from the reaction of ethyl N-4trifluorobenzylidene phenylglycinate was chromatographed on silica (preparative t.l.c., eluting with 3:7 v/v ether-petroleum ether) and the band at Re=0.35 gave ethyl 3-methoxycarbonylcinnamate (10c) as a yellow oil; accurate mass: 234.0893. C13H14O4 requires 234.0892; vmax (film) 2980, 1735, 1710, 1620 and 770 cm<sup>-1</sup>; δ 7.51-7.39(m, 5H, ArH), 6.32(s, 1H, C=CH), 4.25(q, 2H, CH<sub>2</sub>Me), 3.95(s, 3H, OMe), 1.32(t, 3H, CH<sub>2</sub>Me); m/z(%) 234(M<sup>+</sup>, 100), 219(17), 189(60), 175(32), 161(78), 102(58), 91(19) and 77(18).

<u>Methyl 3-methoxycarbonylcinnamate (10d)</u>. Obtained as a pale yellow oil, admixed with a little ADE, by column chromatography(silica, 1:1 v/v ether-petroleum ether) of the mother liquors from the reaction of (3, R=CF<sub>3</sub>, R<sup>/</sup>=Ph) and ADE(2.2 mol).  $\delta$  7.57(m, 5H, ArH), 6.43(s, 1H, C=CH), and 3.9 and 3.85(2 x s, 2 x 3H, OMe); m/z(%) 220(M<sup>+</sup>, 100), 205(35), 189(67), 161(100) and 102(100).

<u>Trimethyl 5-(4<sup>7</sup>-cyanophenyl)pyrrole-2,3,4-tricarboxylate (9e)</u>. Colourless prisms from ether, m.p. 195-197°C (Found: C, 59.55; H, 3.95; N, 8.05.  $C_{17}H_{14}N_2O_6$  requires C, 59.65; H, 4.1; N, 8.2%);  $v_{max}$  3260, 2940, 2220, 1730, 1705, 1685, 1440, 1130, 1025, 970, 940 and 835 cm<sup>-1</sup>;  $\delta$  9.54(s, 1H, NH), 7.78-7.68(m, 4H, ArH) and 3.97, 3.87 and 3.74(3 x s, 3 x 3H, OMe); m/z(%) 342(M<sup>+</sup>, 97), 311(46), 310(100) and 279(77).

<u>Triethyl 5-(4<sup>/</sup>-cyanophenyl)-pyrrole-2,3,4-tricarboxylate (9f)</u>. Colourless prisms from ether, m.p. 118°C (Found: C, 62.5; H, 5.3; N, 7.05.  $C_{20}H_{20}N_2O_6$  requires C, 62.5; H, 5.3; N, 7.3%);  $v_{max}$  3310, 2980, 2225, 1725, 1700, 1690, 1435, 1235, 1030, 840 and 700 cm<sup>-1</sup>;  $\delta$  9.74(br s, 1H, NH), 7.76-6.31(m, 4H, ArH), 4.41(q, 2H, <u>CH<sub>2</sub>Me</u>), 4.21(q, 4H, 2 x <u>CH<sub>2</sub>Me</u>), and 1.42, 1.32 and 1.23(3 x t, 3 x 3H, CH<sub>2</sub><u>Me</u>); m/z(%) 384(M<sup>+</sup>, 22), 359(100), 338(20), 314(46), 313(77), 285(20), 268(13), 240(28), 197(26), and 169(57).

<u>Ethyl 2-(4<sup>'</sup>-cyanophenyl)-3,4-dimethoxycarbonylpyrrole-5-carboxylate (9g)</u>. Colourless needles from ether, m.p. 218-219°C (Found: C, 60.1; H, 4.4; N, 7.85.  $C_{18}H_{16}N_2O_6$  requires C, 60.65; H, 4.55; N, 7.85%);  $v_{max}$  3260, 2220, 1730, 1720, 1690, 1445, 1200, 1130, 850, 790, 780 and 760 cm<sup>-1</sup>;  $\delta$  9.56(br s, 1H, NH), 7.77-7.67(m, 4H, ArH), 4.29(q, 2H, <u>CH<sub>2</sub>Me</u>), 3.95 and 3.74(2 x s, 2 x 3H, OMe), and 1.34(t, 3H, CH<sub>2</sub><u>Me</u>); m/z(%) 356(M<sup>+</sup>, 100), 342(24), 324(56), 310(53), 279(80), 222(27), 194(79) and 165(9).

Michael Adducts from 3-Pyrrolines and Methyl Propiolate

Dimethyl 2,5-diphenyl-N-(2'-methoxycarbonylethenyl)-3-pyrroline 2,4-dicarboxylate (12a). A solution of

dimethyl 2,5-diphenyl-3-pyrroline-2,4-dicarboxylate (34 mg, 0.1 mmol) and methyl propiolate (9mg, 0.11 mmol) in toluene (0.5 ml) was heated at 110°C for 48 h under an argon atmosphere. Removal of the solvent and crystallisation of the residue from ether afforded the *product* (29 mg, 69%) as colourless prisms, m.p. 175-176°C (Found: C, 68.5; H, 5.6; N, 3.2.  $C_{24}H_{23}NO_6$  requires C, 68.4; H, 5.5; N, 3.35%);  $v_{max}$  3100, 2940, 1735, 1720, 1695, 1620, 1430, 1245, 825, 750 and 695 cm<sup>-1</sup>;  $\delta$  7.48-7.16(m, 11H, ArH and H<sub>A</sub>), 6.87(d, 1H, 3-H, J 1.84Hz), 5.67(d, 1H, 5-H, J 1.84Hz), 4.54(d, 1H, H<sub>B</sub>, J<sub>BC</sub> 13.6Hz), and 3.99, 3.67 and 3.50(3 x s, 3 x 3H, 3 x OMe); m/z(%) 421(M<sup>+</sup>, 46), 390(15), 363(25), 362(100), 330(42), 272(13), 244(21) and 77(6).

<u>Dimethyl 2-phenyl-5-(4<sup>/</sup>-methoxyphenyl)-N-(2<sup>/</sup>-methoxycarbonylethenyl)-3-pyrroline-2,4-dicarboxylate (12b)</u>. Prepared in an analogous manner to that described above from 3-pyrroline (4e). The *product* (67%) crystallised from ether as colourless prisms, m.p. 180-182°C. (Found: C, 66.65; H, 5.65; N, 2.9.  $C_{25}H_{25}NO_7$  requires C, 66.5; H, 5.6; N, 3.1%);  $v_{max}$  3150, 1730, 1720, 1695, 1630, 700 and 690 cm<sup>-1</sup>; δ 7.47-6.84(m, 11H, ArH, 3-H, H<sub>A</sub>), 5.63(s, 1H, 5-H), 4.56(d, 1H, H<sub>B</sub>, J<sub>AB</sub> 13.6Hz) and 3.98, 3.79, 3.67 and 3.51(4 x s, 4 x 3H, OMe); m/z(%) 451(M<sup>+</sup>, 75), 420(12), 392(100), 360(74), 333(14), 302(25) and 274(17).

Dimethyl2-phenyl-5-(4<sup>/</sup>-trifluoromethylphenyl)-N-(2<sup>/</sup>-methoxycarbonylethenyl)-3-pyrroline-2,4-dicarboxylate (<u>12c</u>). Prepared in an analogous manner to that described above from 3-pyrroline (4f). The *product* (71%) crystallised from ether as fine colourless needles, m.p. 128°C (Found: C, 61.4; H, 4.55; N, 2.8.  $C_{25}H_{22}F_3NO_6$  requires C, 61.35; H, 4.5; N, 2.85%);  $v_{max}$  2945, 1745, 1720, 1695, 1685, 1615, 1606, 1325, and 1010 cm<sup>-1</sup>; δ 7.63-7.16(m, 10H, ArH and H<sub>A</sub>), 6.91(d, 1H, 3-H, J 1.47Hz), 5.72(d, 1H, 5-H), 4.44(d, 1H, H<sub>B</sub>, J 13.6Hz) and 4.00, 3.69 and 3.51(3 x s, 3 x 3H, 3 x OMe); m/z(%) 489(M<sup>+</sup>, 42), 458(16), 431(51), 430(100), 398(40), 371(7), 340(10) and 312(22).

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