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Studies on the reduction of the nitro group in 3-aryl-2-methylene-4-nitro-alkanoates afforded by the Baylis-Hillman adducts: Synthesis of 4-aryl-3-methylene-2-pyrrolidinones and 3-(1-alkoxycarbonyl-vinyl)-1*H*-indole-2-carboxylates

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Abstract— The formation of substituted 2-pyrrolidinones and indoles by the reduction of the secondary nitro group in appropriate 3-aryl-2-methylene-4-nitroalkanoates afforded by Baylis-Hillman chemistry via different reducing agents is described. The 3-aryl-2-methylene-4-nitroalkanoate obtained from S_N2 nucleophilic reaction between the acetate of Baylis-Hillman adducts and ethyl nitroacetate upon reduction with indium-HCl furnishes a mixture of *cis* and *trans* substituted phenyl-3-methylene-2-pyrrolidinones. In contrast, similar reductions of analogous substrates derived from nitroethane stereoselectively furnished only the *trans* substituted phenyl-3-methylene-2-pyrrolidinones. On the other hand the $SnCl_2.2H_2O$-promoted reductions of substrates derived from nitro ethylacetate give oxime derivatives while the ones obtained from nitroethane yield a mixture of *cis* and *trans* 4-aryl-3-methylene-2-pyrrolidinones. Alternatively, the $SnCl_2.2H_2O$-promoted reduction of substituted 2-nitrophenyl-2-methylene-alkanoate furnished from ethyl nitroacetate yields 3-(1-alkoxycarbonyl-vinyl)-1*H*-indole-2-carboxylate while indium-promoted reaction of this substrate leads to a complex mixture. Analogous reactions with $SnCl_2.2H_2O$ of substituted 2-nitrophenyl-2-methylene-alkanoate obtained from nitroethane yield 4-alkyl-3-methylene-2-quinolones in moderate yields.

1. Introduction

Nitrogen-heterocycles are structural units of several natural products and represent compounds of pharmacological significance. Their prevalence and medicinal utility perhaps are the major driving force for attracting organic and medicinal chemists to formulate their diverse syntheses via novel, convenient and efficient methods. The propensity of the Baylis-Hillman reaction to afford products with multifunctional backbone, which could be tailored further, has found profound application towards the construction of an array of useful synthons, heterocycles and natural products.[1] In order to expand the synthetic utility of this reaction, for the last couple of years our group has been involved in a program to carry out convenient and efficient syntheses of diverse heterocyclic systems utilizing the Baylis-Hillman chemistry.[2,3] Based on our previous work in this area and on the results reported by Janecki et al.[4] and Yus et al.[5] we reasoned that the 3-aryl-2-methylene-4-nitroalkanoates, obtained by S_N2 nucleophillic reaction of the acetate of the Baylis-Hillman products with nitroalkanes, should in principle offer opportunities for constructing highly substituted 3-methylene-2-pyrrolidinones provided the nitro group is chemoselectively reduced and the resulting amine could be made to undergo intramolecular cyclization. Recently, Kim and coworkers have reported the synthesis of 2-amino-2,3-dihydrobenzofuran derivatives via oxidation of similar nitro compounds afforded via S_N2' reaction of ethyl nitroacetate on the allyl bromides afforded by the Baylis-Hillman adducts.[6] In addition, several groups have accomplished the facile synthesis of different heterocyclic compounds employing nitro derivatives afforded via Baylis-Hillman adducts.[7,8] In order to investigate our envisaged strategy, we have carried out selective reduction of the nitro group in nitroalkanoates with In to afford the 4-aryl-3-methylene-2-pyrrolidinones in good yields. Interestingly, we have observed that reduction of the secondary nitro group via $SnCl_2.2H_2O$ in these compounds occurs only partially leading to the oxime derivatives. This unique observation has led to us to formulate a simple synthesis of substituted

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Keywords- Baylis-Hillman, nitroalkanoate, 2-pyrrolidinone, 1*H*-indole-2-carboxylate, Indium, $SnCl_2.2H_2O$.

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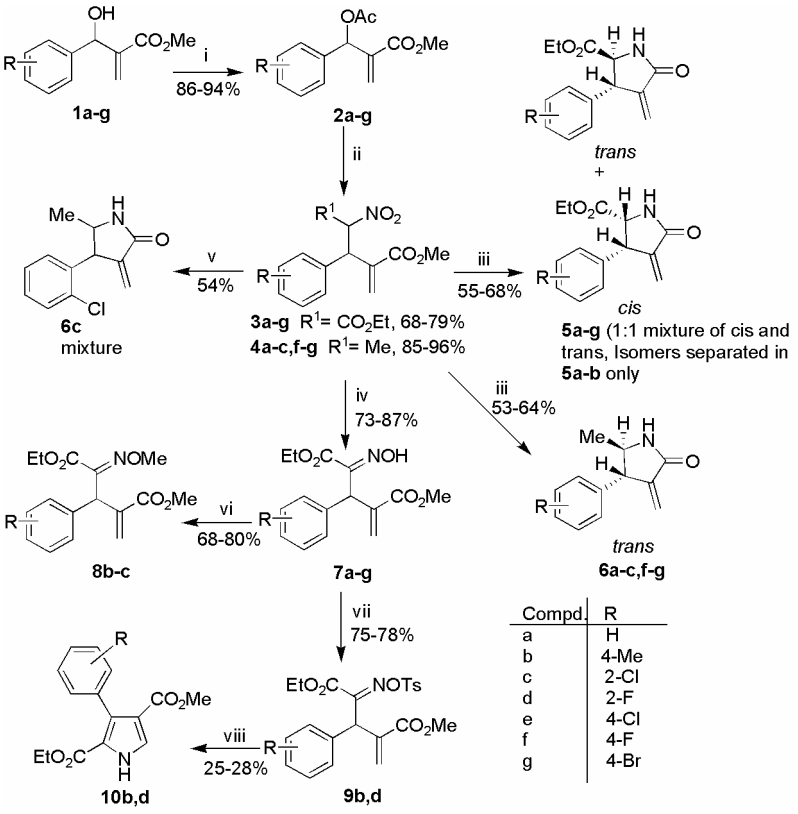
indoles from the nitroalkanoates obtained from the Baylis-Hillman adducts of 2-nitrobenzaldehyde. The details of the results of our studies are described herein.

2. Results and Discussion

The preparation of the starting materials in our synthetic sequence (Scheme 1), the acetates **2a-g**, was accomplished by acetylating Baylis-Hillman adducts **1a-g** which in turn were afforded from substituted benzaldehydes following the literature procedure.[9] The S_N2 nucleophilic substitution of the acetate **2a-g** with ethyl nitroacetate in the presence of DABCO in a THF-water system yielded the nitro alkanoates **3a-g** in 4-6 h in 68 to 79 % yields as diastereoisomeric mixtures. This observation is in contrast to the reactions carried out by Kim et al. who have reported the synthesis of similar derivatives after 2 days.[10] In the next step the products **3a-g** were subjected to chemoselective reduction of the nitro group without affecting the double bond. In a model reaction, the reduction of the nitro group of compound **3b** was examined with metallic In, Sn, Zn, Fe in the presence of HCl or AcOH and $SnCl_2.2H_2O$.[11] The selection of these reagents was based on the fact that they are inexpensive, readily available and do not require any elaborate reaction conditions. Results of our evaluation in this direction are illustrated in Table 1. The highest yield of the expected substituted 3-methylene-2- pyrrolidinone **4b** was achieved when the reaction was carried out in the presence of In using HCl in a THF: H_2O system at room temperature. Consequently all the substituted 3-methylene-2-pyrrolidinones **5a-g** were prepared by reducing the required nitro compound with In in the presence of aq. HCl. In all cases these compounds were obtained as a mixture of *cis* and *trans* products. Our attempts to separate these diastereoisomers via silica gel column chromatography were successful with compounds **5a** and **5b**, whereas for compounds **5c-g** these could not be separated. The NOESY experiment of the polar isomer of compound **5b** indicated it to be the *trans* isomer.



Scheme 1. *Reagents and conditions*: i) AcCl, Pyridine, CH_2Cl_2, rt, 3 h; ii) DABCO, $R^1CH_2NO_2$, THF:H_2O, rt, 4-7 h; iii) In, HCl, THF: H_2O, rt, 2 h; iv) $SnCl_2.2H_2O$, MeOH, reflux, 1.5 h; v) $SnCl_2.2H_2O$, MeOH, reflux, 24 h; vi) MeI, Ag_2O, neat, reflux, 1 h; vii) TsCl, Et_3N, CH_2Cl_2, rt, 3 h; viii) DBU, CH_2Cl_2, rt, 330 min.

However the reduction of compound **3b** with $SnCl_2.2H_2O$, instead of yielding the expected pyrrolidinone **5b** gave the oxime **7b** (entry 5, Table 1). This was found to be the general course of reaction as substrates **3a-g** also furnished

Table 1. Results of optimization study for the synthesis of 4-aryl-3-methylene-2-pyrrolidinones

Entry	Metal/metal salt	Condition	Product	Yield (%)
1	In	In/HCl in THF:H_2O for 2h at rt	**5b**	64
2	Sn	Sn/HCl for 2h at reflux	**5b**	42
3	Zn	Zn/HCl in EtOH for 24h at rt	**5b**	39
4	Fe	Fe/AcOH for 2h at rt	**5b**	45
5	$SnCl_2.2H_2O$	$SnCl_2.2H_2O$ in MeOH for 2h at reflux	**7b**	78

the corresponding oximes **7a-g** when subjected to the $SnCl_2$ reductive conditions. The spectroscopic data supported the structure assignments. Further support for the assigned structures of the oximes was made on the basis of an alternate synthesis. It is reported in the literature that the tin complexes generated from $SnCl_2.2H_2O$ in the presence of thiophenol and triethylamine reduces secondary aliphatic nitro compound to the corresponding oxime.[12] On the basis of this report, the compound **3a** was treated with $SnCl_2.2H_2O$, thiophenol and triethylamine to yield a product which was similar in all respect to the oxime **7a**. As would be expected, the methylation of the oximes **7b-c** using methyl iodide in the presence of silver oxide furnished the methyl derivatives **8b-c**.[13] Although, the $SnCl_2.2H_2O$-promoted reduction of nitroalkenes to the corresponding oximes is documented,[14] the ability of $SnCl_2.2H_2O$ alone to transform the secondary aliphatic nitro compound to the oxime derivative is unreported.

The next phase of the study was aimed at determining the driving force responsible for the formation of the oximes. One possibility was the presence of the carboethoxy group on the α-carbon of the nitroalkane derivative as illustrated in Fig. 1. In order to validate this concept experimentally, the S_N2 reaction of acetates **2a-c,f-g** with nitroethane in the presence of DABCO in a THF:H_2O system to afford products **4a-c,f-g** was accomplished. The nitro group in compound **4c** in the presence of $SnCl_2.2H_2O$ underwent reduction followed by cyclization to give 3-methylene-2-pyrrolidinones **6c** as a diastereoisomeric mixture, although the reaction took more than 24 h for completion. This supported our assumption that the presence of carboethoxy group was responsible for the formation of the oxime probably by the formation of an oximino intermediate. In order to establish that oxime were not the intermediate for the pyrrolidinone, in a model reaction the oxime **7c** was treated with $SnCl_2.2H_2O$ for more than 24 h. But this reaction failed indicating that the presence of the ester moiety stabilises the oximes. Nevertheless, the reduction of the nitro group in compounds **4a-c**,**f-g** in the presence of In was complete in 2h in a highly diastereoselective fashion to furnish the *trans* isomer of 4-aryl-5-methyl-3-methylene-2-pyrrolidinones **6a-c**,**f-g** exclusively in 53-64% yields.

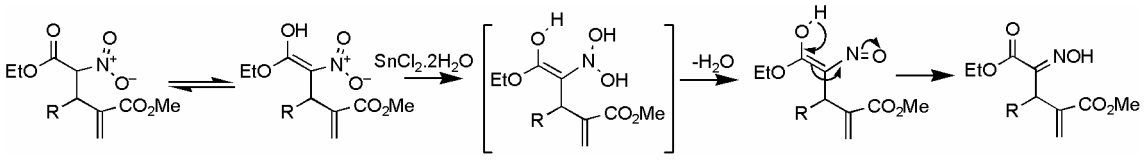


Figure 1. Mechanism for the formation of oximes.

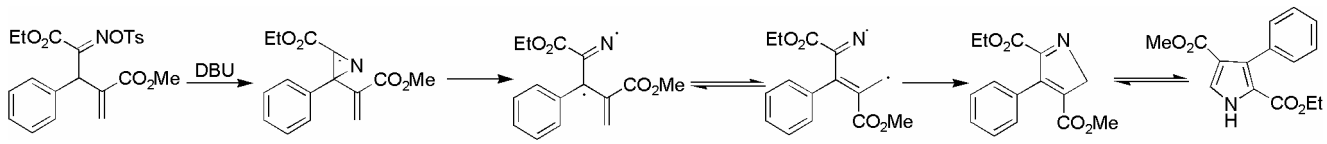
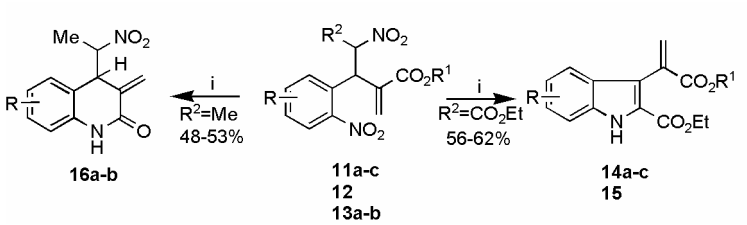


Figure 2. Mechanism for the formation of pyrroles.

Of particular relevance to **7**, it has been very recently reported that oximes obtained from α-aryl ketones can be transformed to indoles by an intermediate azirine in two steps.[15] In order to investigate such possibility with the oxime **7** generated during the present study, compounds **7b,d** were treated with tosyl chloride in the presence of triethylamine in dichloromethane at room temperature to yield the corresponding tosyl derivatives **9b,d**. Reaction of compounds **9b,d** with DBU in dichloromethane gave a complex mixture of products. The column chromatogrphy of this mixture led to isolation of a pure product in low yield, the structure of which was established as substituted pyrroles **10a,d**. The formation of the pyrroles can be explained on the basis of the mechanism shown in Fig. 2.

Having demonstrated the utility of substrates such as **3a-g** and **4a-c,f-g** for the generation of the 3-methylene-2-pyrrolidinone system and oximes via selective reduction, we decided to explore the synthetic utility of similar substrates derived from 2-nitrophenyl benzaldehyde, such as **11a-c** (Scheme 2) for the following reasons. It is well established that the Baylis-Hillman derivatives obtained from 2-nitrobenzaldehyde and acrylates, upon reduction of the nitro moiety to amine invariably results in the formation of quinoline derivatives through an in situ intramolecular cyclization between the amino group on the phenyl ring and the ester group of the side chain.[16] However, in view of the findings of the present study, if compounds **11a-c,12** are reduced in the presence of $SnCl_2.2H_2O$, the aromatic

nitro group will be chemoselectively reduced to an amino group which will then compete for the two ester moieties for the intramolecular cyclization. Consequently compound **11a** was synthesized and reacted with $SnCl_2.2H_2O$ in methanol under reflux conditions. This reaction proceeded smoothly to be completed in 1.5 h to give a product, the structure of which was established as substituted 3-(1-methoxycarbonyl-vinyl)-1*H*-indole-2- carboxylic acid ethyl ester **14a** (Scheme 2). Subsequently other analogs **11b-c** and **12** were prepared and subjected to reaction with $SnCl_2.2H_2O$. All these substrates afforded the respective indole derivatives **14b-c, 15** indicating the general nature of this reaction and implying that this transformation invariably eliminates the aliphatic nitro group, presumably after reduction to the oxime. The expected mechanism for the formation of the indole derivative is shown in Fig. 3. Unlike compounds **11** and **12**, compounds**13a-b** upon reduction in the presence of $SnCl_2.2H_2O$ yielded the corresponding substituted 2-quinolones **16a-b** in 2 h in moderate yields. The formation of **16** was understandable since it has been previously observed that the aliphatic nitro group is reduced to an amino group only when the reaction is prolonged beyond 24 h. These results provoked us to evaluate the reactions of compounds **11,13a-b** with In in the presence of HCl in aqueous medium. However, this reaction led to a complex mixture which could not be purified in all cases.



Compd.	R	R^1
11a	H	Me
11b	3,4-OCH_2O	Me
11c	5-Cl	Me
12	H	Et
13a	H	Me
13b	5-Cl	Me

Scheme 2. *Reagents and Conditions*: i) $SnCl_2.2H_2O$, MeOH, reflux, 1.5 h-2 h.

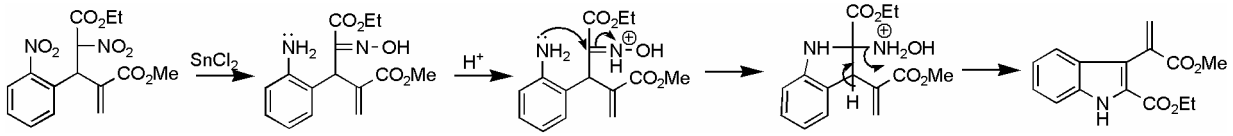


Figure 3. Mechanism for the formation of indole derivatives

3. Conclusions

In summary, we demonstrated the scope of 3-aryl-2-methylene-4-nitroalkanoates obtained from the Baylis-Hillman chemistry for the generation of 4-aryl-3-methylene-2-pyrrolidinones and 3-(1-alkoxycarbonyl-vinyl)-1*H*-indole-2-carboxylates by the reduction of the secondary nitro group using different reducing conditions. The mechanistic details to account for the formation of different heterocyclic systems have also been proposed. All the synthetic achievements described herein were operationally simple and diversity oriented. We believe that the lactam and the indole derivatives described in this paper will serve as useful building blocks for the synthesis of compounds belonging to these classes.

4. Experimental

4.1. General

Melting points were recorded on a hot stage melting point apparatus and are uncorrected. The IR spectra were recorded on a FTIR spectrophotometer. The ^1H- and ^{13}C-NMR spectra were recorded on 200MHz or 300MHz spectrometer using TMS as internal standard. The mass spectra were recorded as FAB or LCMS having ES probe. The HRMS spectra were recorded as EI-HRMS. All the solvents and chemicals were used as procured from the suppliers. The compounds **3a-g, 4a-c,f-g, 5c-g, 11a-c, 12, 13a-b** and **16a-b** were obtained as diastereoisomeric mixtures. All yields indicated herein are the isolated yields after column chromatography.

4.2. General Procedure for the preparation of compounds 3a-g, 4a-c,f-g.

To the stirred solution of appropriate compound from **2a-g** (1.0 equiv.) in THF: H_2O (10 mL for approx. 1.5 g of compound, 50:50, v/v) was added DABCO (1.5 equiv.) at room temperature and the reaction was allowed to continue for 20 min. Thereafter ethyl nitroacetate or nitroethane (1.2 equiv.) was added to the reaction mixture and the reaction was allowed to proceed at room temperature for 4 h. The THF was removed from the reaction mixture via rotary evaporation and the residue was diluted with water (100 mL) and extracted with EtOAc (3x40 mL). The organic layers were pooled, washed with brine (50 mL), dried (anhyd. Na_2SO_4) and evaporated to yield a residue which was purified via silica gel chromatography employing hexane: EtOAc (80:20, v/v) to afford products as oils or solids.

4.2.1. 2-Methylene-4-nitro-3-phenylpentanedioic acid 5-ethyl ester 1-methyl ester (3a)- 77% (1.0 g) as a colorless

oil; ν_{max} (Neat) 1723 (CO_2Et), 1751 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 0.97 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.27 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.71 (s, 3H, CO_2CH_3), 3.73 (s, 3H, CO_2CH_3), 3.99 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.26 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.89 (d, 1H, *J*= 12.0 Hz, CHAr), 4.95 (d, 1H, *J*= 12.0 Hz, CHAr), 5.80 (s, 1H, =CH), 5.86 (s, 1H, =CH), 5.87 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.05 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.34 (s, 1H, =CH), 6.38 (s, 1H, =CH), 7.28-7.30 (m, 10H, 2 x 5ArH); mass (ES+) *m/z* 330.0 (M^++Na); Anal. Calcd. for $C_{15}H_{17}NO_6$: C, 58.63; H, 5.58; N, 4.56. Found: C, 58.38; H, 5.76; N, 4.64.

4.2.2. 2-Methylene-4-nitro-3-p-tolylpentanedioic acid 5-ethyl ester 1-methyl ester (3b)- 68% (1.4 g) as a colorless oil: ν_{max} (Neat) 1724 (CO_2Et), 1751 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.00 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.27 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 2.30 (s, 6H, 2 x ArCH_3), 3.70 (s, 3H, CO_2CH_3), 3.72 (s, 3H, CO_2CH_3), 4.01 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.25 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.85 (d, 1H, *J*= 12.0 Hz, CHAr), 4.91 (d, 1H, *J*= 12.0 Hz, CHAr), 5.79 (s, 1H, =CH), 5.83 (s, 1H, =CH), 5.82 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.02 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.32 (s, 1H, =CH), 6.35 (s, 1H, =CH), 7.08-7.22 (m, 8H, 2 x 4ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 13.9, 14.2, 21.4, 48.2, 48.6, 52.6, 63.3, 63.6, 90.1, 90.7, 125.6, 127.5, 128.2, 129.0, 129.9, 130.0, 132.2, 133.5, 138.3, 138.4, 139.0, 163.5, 163.7, 166.1; mass (ES+) *m/z* 344.0 (M^++Na); Anal. Calcd. for $C_{16}H_{19}NO_6$: C, 59.81; H, 5.96; N, 4.36. Found: C, 59.48; H, 5.82; N, 4.26.

4.2.3. 3-(2-Chlorophenyl)-2-methylene-4-nitro-pentanedioic acid 5-ethyl ester 1-methyl ester (3c)- 79% (2.5 g) as a colorless oil; ν_{max} (Neat) 1724 (CO_2Et), 1751 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.03 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.27 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.71 (s, 3H, CO_2CH_3), 3.73 (s, 3H, CO_2CH_3), 4.05 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.24 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.34 (d, 1H, *J*= 12.1 Hz, CHAr), 5.40 (d, 1H, *J*= 12.1 Hz, CHAr), 5.98 (s, 1H, =CH), 5.99 (s, 1H, =CH), 6.14 (d, 1H, *J*= 12.1 Hz, $CHCO_2Et$), 6.31 (d, 1H, *J*= 12.1 Hz, $CHCO_2Et$), 6.39 (s, 1H, =CH), 6.42 (s, 1H, =CH), 7.20-7.25 (m, 4H, ArH), 7.36-7.41 (m, 3H, ArH), 7.48-7.52 (m, 1H, ArH); mass (FAB+) *m/z* 342 (M^++1); Anal. Calcd. for $C_{15}H_{16}ClNO_6$: C, 52.72; H, 4.72; N, 4.14. Found: C, 53.08; H, 4.93; N, 4.24.

4.2.4. 3-(2-Fluorophenyl)-2-methylene-4-nitro-pentanedioic acid 5-ethyl ester 1-methyl ester (3d)- 73% (1.4 g from 1.5 g) as a colorless oil; ν_{max} (Neat) 1724 (CO_2Et), 1753 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.02 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.28 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.72 (s, 3H, CO_2CH_3), 3.74 (s, 3H, CO_2CH_3), 4.04 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.28 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.10-5.19 (m, 2H, CHAr), 5.92 (d, 1H, *J*= 1.0 Hz, =CH), 5.95 (s, 1H, =CH), 6.08 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.23 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.38 (s, 1H, =CH), 6.41 (s, 1H, =CH), 7.03-7.39 (m, 8H, 2 x 4ArH); mass (ES+) *m/z* 326.4 (M^++1); Anal. Calcd. for $C_{15}H_{16}FNO_6$: C, 55.38; H, 4.96; N, 4.31. Found: C, 55.89; H, 5.21; N, 4.52.

4.2.5. 3-(4-Chlorophenyl)-2-methylene-4-nitro-pentanedioic acid 5-ethyl ester 1-methyl ester (3e)- 78% (1.23 g) as a pale yellow solid, mp 96-98^{o}C; ν_{max} (KBr) 1724 (CO_2Et), 1751 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.04 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.26 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.71 (s, 3H, CO_2CH_3), 3.73 (s, 3H, CO_2CH_3), 4.04 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.26 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.86 (d, 1H, *J*= 12.1 Hz, CHAr), 4.91 (d, 1H, *J*= 12.1 Hz, CHAr), 5.81 (s, 1H, =CH), 5.86 (s, 1H, =CH), 5.87 (d, 1H, *J*= 12.1 Hz, $CHCO_2Et$), 6.02 (d, 1H, *J*= 12.1 Hz, $CHCO_2Et$), 6.35 (s, 1H, =CH), 6.38 (s, 1H, =CH), 7.24-7.38 (m, 8H, 2 x 4ArH); mass (FAB+) *m/z* 342 (M^++1); Anal. Calcd. for $C_{15}H_{16}ClNO_6$: C, 52.72; H, 4.72; N, 4.14. Found: C, 53.28; H, 4.54; N, 4.35.

4.2.6. 3-(4-Fluorophenyl)-2-methylene-4-nitro-pentanedioic acid 5-ethyl ester 1-methyl ester (3f)- 72% (1.56 g 1) as a pale yellow solid, mp 82-84^{o}C; ν_{max} (KBr) 1723 (CO_2Et), 1750 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.00 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.27 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.72 (s, 3H, CO_2CH_3), 3.73 (s, 3H, CO_2CH_3), 4.03 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.26 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.85 (d, 1H, *J*= 12.0 Hz, CHAr), 4.98 (d, 1H, *J*= 12.0 Hz, CHAr), 5.80 (s, 1H, =CH), 5.86 (s, 1H, =CH), 5.87 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.01 (d, 1H, *J*= 12.0 Hz, $CHCO_3Et$), 6.35 (s, 1H, =CH), 6.38 (s, 1H, =CH), 6.96-7.04 (m, 4H, 2 x 2ArH), 7.21-7.30 (m, 4H, 2 x 2ArH); mass (FAB+) *m/z* 326 (M^++1); Anal. Calcd. for $C_{15}H_{16}FNO_6$: C, 55.38; H, 4.96; N, 4.31. Found: C, 55.98; H, 5.11; N, 4.52.

4.2.7. 3-(4-Bromophenyl)-2-methylene-4-nitro-pentanedioic acid 5-ethyl ester 1-methyl ester (3g)- 72% (1.5 g) as a colorless oil; ν_{max} (Neat) 1721 (CO_2Et), 1750 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.04 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.26 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.71 (s, 3H, CO_2CH_3), 3.73 (s, 3H, CO_2CH_3), 4.05 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.26 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 4.85 (d, 1H, *J*= 12.0 Hz, CHAr), 4.89 (d, 1H, *J*= 12.0 Hz, CHAr), 5.81 (s, 1H, =CH), 5.86 (s, 1H, =CH), 5.87 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.02 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.34 (s, 1H, =CH), 6.38 (s, 1H, =CH), 7.14-7.22 (m, 4H, 2x 2ArH), 7.42-7.57 (m, 4H, 2 x 2ArH); mass (ES+) *m/z* 386.2 (M^++1); Anal. Calcd. for $C_{15}H_{16}BrNO_6$: C, 46.65; H, 4.18; N, 3.63. Found: C, 46.98; H, 4.25; N, 3.71.

4.2.8. 2-Methylene-4-nitro-3-phenylpentanoic acid methyl ester (4a)- 96% (2.35 g) as a colorless oil; ν_{max} (Neat) 1721 (CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.40 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 1.61 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 3.73 (s, 6H, CO_2CH_3), 4.37 (d, 1H, *J*= 12.0 Hz, CHAr), 4.44 (d, 1H, *J*= 12.0 Hz, CHAr), 5.19-5.28 (m, 1H, C*H*CH$_3$), 5.42-5.60 (m, 1H, C*H*CH$_3$), 5.81 (s, 1H, =CH), 5.91 (d, 1H, *J*= 1.8 Hz, =CH), 6.34 (s, 1H, =CH), 6.36 (s, 1H, =CH), 7.28-7.35 (m, 10H, 2 x 5ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 19.3, 19.5, 51.5, 52.5, 52.7, 85.5, 86.0, 125.2, 128.0, 128.2, 129.1, 129.4, 131.1, 137.8, 139.6, 139.9, 166.3, 166.6; mass (ES+) *m/z* 272.1 (M^++Na); Anal. Calcd. for $C_{13}H_{15}F_3NO_5$: C, 62.64; H, 6.07; N, 5.62. Found: C, 62.97; H, 5.99; N, 5.53.

4.2.9. 2-(2-Nitro-1-p-tolylpropyl)-acrylic acid methyl ester (4b)- 88% (0.73 g) as a colorless oil; ν_{max} (Neat) 1721 (CO_2Me) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ= 1.42 (d, 3H, *J*= 6.0 Hz, C*H*$_3$CH), 1.62 (d, 3H, *J*= 6.0 Hz, C*H*$_3$CH), 2.30 (s, 3H, ArCH_3), 2.34 (s, 3H, ArCH_3), 3.70 (s, 3H, CO_2CH_3), 3.75 (s, 3H, CO_2CH_3) 4.36 (d, 1H, *J*= 12.0 Hz, CHAr), 4.43 (d, 1H, *J*= 12.0 Hz, CHAr), 5.19-5.25 (m, 1H, C*H*CH$_3$), 5.44-5.50 (m, 1H, C*H*CH$_3$), 5.81 (s, 1H, =CH),

5.91 (d, 1H, *J*= 3.0 Hz, =CH), 6.34 (s, 1H, =CH), 6.36 (s, 1H, =CH), 7.09-7.20 (m, 8H, 2 x 2ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 19.3, 19.5, 21.4, 51.2, 52.4, 52.5, 52.6, 85.6, 86.1, 125.0, 127.7, 128.3, 129.0, 130.1, 134.0, 134.8, 137.9, 138.1, 139.8, 140.0, 166.4, 166.7; mass (ES+) *m/z* 286.1 (M^++Na); Anal. Calcd. for $C_{14}H_{17}NO_4$: C, 63.87; H, 6.51; N, 5.32. Found: C, 64.23; H, 6.89; N, 5.21.

4.2.10. 3-(2-Chlorophenyl)-2-methylene-4-nitro-pentanoic acid methyl ester (4c)- 85% (1.8 g) as a pale yellow oil; ν_{max} (Neat) 1726 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.45 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 1.63 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 3.68 (s, 3H, CO_2CH_3), 3.74 (s, 3H, CO_2CH_3), 4.93 (d, 1H, *J*= 11.0 Hz, CHAr), 5.08 (d, 1H, *J*= 11.0 Hz, CHAr), 5.21-5.28 (m, 1H, C*H*CH$_3$), 5.64-5.73 (m, 1H, C*H*CH$_3$), 5.95 (s, 1H, =CH), 5.97 (s, 1H, =CH), 6.39 (s, 1H, =CH), 6.41 (s, 1H, =CH), 7.17-7.25 (m, 4H, 2 x 2ArH), 7.33-7.37 (m, 2H, 2 x 1ArH), 7.53-7.58 (m, 2H, 2 x 1ArH); mass (ES+) *m/z* 284.6 (M^++1); Anal. Calcd. for $C_{13}H_{14}ClNO_4$: C, 55.04; H, 4.97; N, 4.94. Found: C, 54.78; H, 5.08; N, 4.86.

4.2.11. 3-(4-Fluorophenyl)-2-methylene-4-nitro-pentanoic acid methyl ester (4f)- 85% (1.5 g) as a pale yellow oil; ν_{max} (Neat) 1721 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.40 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 1.61 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 3.70 (s, 3H, CO_2CH_3), 3.74 (s, 3H, CO_2CH_3), 4.35 (d, 1H, *J*= 11.2 Hz, CHAr), 4.43 (d, 1H, *J*= 11.2 Hz, CHAr), 5.18-5.25 (m, 1H, C*H*CH$_3$), 5.40-5.49 (m, 1H, C*H*CH$_3$), 5.83 (s, 1H, =CH), 5.90 (s, 1H, =CH), 6.34 (s, 1H, =CH), 6.37 (s, 1H, =CH), 6.92-7.06 (m, 4H, 2 x 2ArH), 7.21-7.30 (m, 4H, 2 x 2ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 19.3, 19.5, 51.5, 52.5, 52.7, 85.5, 86.0, 125.2, 128.0, 128.2, 129.1, 129.4, 131.1, 137.8, 139.6, 139.9, 166.3, 166.6; mass (FAB+) *m/z* 268. (M^++1); Anal. Calcd. for $C_{13}H_{14}FNO_4$: C, 58.42; H, 5.28; N, 5.24;. Found: C, 58.01; H, 5.52; N, 5.20.

4.2.12. 3-(4-Bromophenyl)-2-methylene-4-nitro-pentanoic acid methyl ester (4g)- 92% (2.4 g) as a colorless oil; ν_{max} (Neat) 1725 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.41 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 1.61 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 3.68 (s, 3H, CO_2CH_3), 3.73 (s, 3H, CO_2CH_3), 4.32 (d, 1H, *J*= 11.5 Hz, CHAr), 4.41 (d, 1H, *J*= 11.5 Hz, CHAr), 5.14-5.22 (m, 1H, C*H*CH$_3$), 5.41-5.47 (m, 1H, C*H*CH$_3$), 5.81 (s, 1H, =CH), 5.90 (s, 1H, =CH), 6.35 (s, 1H, =CH), 6.37 (s, 1H, =CH), 7.13-7.19 (m, 4H, 2 x 2ArH), 7.39-7.48 (m, 4H, 2 x 2ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 19.3, 19.4, 51.1, 52.4, 52.6, 52.8, 85.0, 85.7, 122.3, 125.6, 128.3, 130.1, 130.8, 132.3, 132.5, 136.1, 136.9, 139.1, 139.4, 166.1, 166.4; mass (FAB+) *m/z* 328 (M^++1); Anal. Calcd. for $C_{13}H_{14}BrNO_4$: C, 47.58; H, 4.30; N, 4.27. Found: C, 46.71; H, 4.53; N, 4.41.

4.3. General Procedure for the reduction of 3a-g, 4a-c,f-g with indium.

To the stirred solution of appropriate compound from **3a-g, 4a-c,f-g** (1.0 equiv.) in THF: H_2O (5 mL for approx. 0.5 g of compound, 1:3, v/v) was added In powder (4.0 equiv.) followed by 6N HCl (6.0 equiv.). The reaction was allowed to proceed at room temperature and was monitored via TLC. On completion, approximately 2h, THF was evaporated and the pH of the residue was made alkaline with saturated $NaHCO_3$ solution. The solution was diluted with EtOAc and filtered through a bed of Celite. The filtrate was then extracted with EtOAc (3x25 mL) and the combined organic layer was dried (Na_2SO_4) and concentrated. The residue was purified by column chromatography over silica gel using hexane: EtOAc (30:70, v/v) to yield products **5a-g, 6a-c,f-g**.

4.3.1. 4-Methylene-5-oxo-3-phenylpyrrolidine-2-carboxylic acid ethyl ester (5a)- (*cis*) total yield 68% **(**0.54 g) as a white solid, mp 122-124^{o}C; ν_{max} (KBr) 1692 (CONH), 1746 (CO_2Et), 3400 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.27 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 4.18-4.27 (m, 4H, C*H*$_2$CH$_3$, CHAr and CHCO$_2$Et), 5.26 (s, 1H, =CH), 6.22 (s, 1H, =CH), 6.56 (s, 1H, NH), 7.29-7.38 (m, 5H, ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.5, 48.9, 61.9, 62.3, 119.8, 128.0, 128.4, 129.4, 141.7, 142.9, 170.1, 171.3; mass (ES+) *m/z* 246.1 (M^++1); HR-EIMS calculated for $C_{14}H_{15}NO_3$ 245.1052, found, 245.1052.

4.3.2. 4-Methylene-5-oxo-3-phenylpyrrolidine-2-carboxylic acid ethyl ester (5a)- (*trans*) total yield 68% (0.54 g) as a white solid, mp 160-162^{o}C; ν_{max} (KBr) 1692 (CONH), 1738 (CO_2Et), 3445 (NH) cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ= 0.83 (t, 3H, *J*= 6.0 Hz, C*H*$_3$CH$_2$), 3.57-3.63 (m, 1H, CHAr), 3.75-3.81 (m, 1H, CHCO$_2$Et), 4.52-4.61 (m, 2H, C*H*$_2$CH$_3$), 5.33 (s, 1H, =CH), 6.26 (s, 1H, =CH), 6.76 (s, 1H, NH), 7.18-7.29 (m, 5H); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 13.9, 48.2, 59.7, 61.6, 119.6, 128.2, 128.9, 129.4, 138.6, 142.3, 170.4, 171.4; mass (ES+) *m/z* 246.1 (M^++1); HR-EIMS calculated for $C_{14}H_{15}NO_3$ 245.1052, found, 245.1052.

4.3.3. 4-Methylene-5-oxo-3-p-tolylpyrrolidine-2-carboxylic acid ethyl ester (5b)- (*cis*) total yield 64% (0.268 g) as a white solid, mp 123-125^{o}C; ν_{max} (KBr) 1695 (CONH), 1738 (CO_2Et), 3445 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.28 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 2.35 (s, 3H, ArCH$_3$), 4.15-4.27 (m, 4H, C*H*$_2$CH$_3$, CHAr and CHCO$_2$Et), 5.25 (d, 1H, *J*= 1.8 Hz, =CH), 6.20 (d, 1H, *J*= 2.6 Hz, =CH), 6.62 (s, 1H, NH), 7.17 (s, 4H, ArH); mass (FAB+) *m/z* 260 (M^++1); HR-EIMS calculated for $C_{15}H_{17}NO_3$ 259.1208, found, 259.1208.

4.3.4. 4-Methylene-5-oxo-3-p-tolylpyrrolidine-2-carboxylic acid ethyl ester (5b)- (*trans*) total yield 64% (0.268 g**)** as a white solid, mp 162-164^{o}C; ν_{max} (KBr) 1695 (CONH), 1738 (CO_2Et), 3442 (NH) cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ= 0.85 (t, 3H, *J*= 7.3 Hz, C*H*$_3$CH$_2$), 2.30 (s, 3H, ArCH$_3$), 3.57-3.64 (m, 1H, CHAr), 3.74-3.77 (m, 1H, CHAr), 4.46-4.54 (m, 2H, C*H*$_2$CH$_3$), 5.29 (d, 1H, *J*= 3.0 Hz, =CH), 6.22 (d, 1H, *J*= 3.0 Hz, =CH), 6.57 (s, 1H, NH), 7.04-7.10 (m, 4H, ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 13.9, 21.4, 48.0, 59.8, 61.6, 119.4, 129.3, 129.5, 135.5, 137.9, 142.4, 170.4, 171.4; mass (FAB+) m/z 260 (M++1); HR-EIMS calculated for $C_{15}H_{17}NO_3$ 259.1208, found, 259.1208.

4.3.5. 3-(2-Chlorophenyl)-4-methylene-5-oxo-pyrrolidine-2-carboxylic acid ethyl ester (5c)- 56% (0.37 g) as white solid, mp 110-112^{o}C; ν_{max} (KBr) 1710 (CONH), 1728 (CO_2Et), 3412 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 0.82 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.27 (t, 3H,

J= 7.1 Hz, C*H*$_3$CH$_2$), 3.49-3.62 (m, 1H, CH*H*CH$_3$), 3.67-3.79 (m, 1H, C*H*HCH$_3$), 4.17-4.31 (m, 2H, C*H*$_2$CH$_3$), 4.68 (d, 2H, *J*= 9.0 Hz, 2 x CHAr), 5.13 (d, 2H, *J*= 9.0 Hz, 2 x CHCO$_2$Et), 5.23 (s, 1H, =CH), 5.35 (s, 1H, =CH), 6.16 (d, 1H, *J*= 2.4 Hz, =CH), 6.31 (d, 1H, *J*= 2.6 Hz, =CH), 6.69 (brs, 2H, 2 x 1NH), 7.20-7.27 (m, 6H, 2 x 3ArH), 7.40-7.41 (m, 2H, 2 x 1ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 13.9, 14.4, 44.2, 46.1, 58.2, 60.5, 61.1, 62.4, 119.1, 119.7, 127.4, 127.9, 129.4, 129.7, 130.0, 130.3, 130.4, 134.2, 135.9, 138.8, 140.9, 142.1, 170.0, 170.4, 171.2; mass (ES+) *m/z* 280.1 (M$^+$+1), 282.1 (M$^+$+3); HR-EIMS calculated for $C_{14}H_{14}ClNO_3$ 279.0662, found, 279.0664.

4.3.6. 3-(2-Fluorophenyl)-4-methylene-5-oxo-pyrrolidine-2-carboxylic acid ethyl ester (5d)- 57% (0.12 g) as white solid, mp 105-107^{o}C; ν_{max} (KBr) 1704 (CONH), 1743 (CO$_2$Et), 3332 (NH) cm^{-1}; ^{1}H NMR (200 MHz, CDCl$_3$) δ= 0.85 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 1.29 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.48-3.61 (m, 2H, C*H*$_2$CH$_3$), 4.23-4.39 (m, 5H, C*H*$_2$CH$_3$, 2 x CHAr and CHCO$_2$Et), 4.71-4.84 (m, 1H, CHCO$_2$Et), 5.28 (d, 1H, *J*= 1.3 Hz, =CH), 5.36 (d, 1H, *J*=0.6 Hz, =CH), 6.20 (d, 1H, *J*= 1.1 Hz, =CH), 6.38 (d, 1H, *J*= 1.0 Hz, =CH), 7.04-7.30 (m, 8H, 2 x 4ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 13.9, 14.4, 40.0, 43.0, 58.8, 60.8, 61.7, 61.9, 115.3, 115.7, 116.1, 116.5, 119.7, 119.8, 124.7, 125.0, 125.1, 125.7, 129.8, 130.0, 130.2, 130.3, 138.9, 140.8, 142.0, 169.9, 170.2, 171.0, 171.5; mass (ES+) *m/z* 264.3 (M$^+$+1); HR-EIMS calculated for $C_{14}H_{14}FNO_3$ 263.0958, found, 263.0954.

4.3.7. 3-(4-Chlorophenyl)-4-methylene-5-oxo-pyrrolidine-2-carboxylic acid ethyl ester (5e)- 61% (0.174 g) as white solid, mp 106-108^{o}C; ν_{max} (KBr) 1713 (CONH), 1748 (CO$_2$Et), 3445 (NH) cm^{-1}; ^{1}H NMR (200 MHz, CDCl$_3$) δ= 0.88 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 1.29 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.51-3.92 (m, 2H, 2 x CHAr), 4.14-4.27 (m, 4H, 2 x C*H*$_2$CH$_3$), 4.40-4.68 (m, 2H, 2 x CHCO$_2$Et), 5.25 (d, 1H, *J*= 1.9 Hz, =CH), 5.31 (d, 1H, *J*= 1.6 Hz, =CH), 6.22 (d, 1H, *J*= 2.9 Hz, =CH), 6.26 (d, 1H, *J*= 2.6 Hz, =CH), 6.98 (s, 2H, 2 x NH), 7.11-7.37 (m, 8H, 2 x 4ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 14.0, 14.5, 47.5, 48.2, 59.6, 61.8, 61.9, 62.6, 119.5, 120.1, 129.0, 129.6, 129.7, 129.8, 130.8, 133.9, 134.2, 137.1, 138.9, 140.0, 141.9, 142.6, 169.9, 170.1, 171.0, 171.3; mass (ES+) *m/z* 280.1 (M$^+$+1); HR-EIMS calculated for $C_{14}H_{14}ClNO_3$ 279.0662, found, 279.0658.

4.3.8. 3-(4-Fluorophenyl)-4-methylene-5-oxo-pyrrolidine-2-carboxylic acid ethyl ester (5f)- 63% (0.315 g) as a white solid, mp 114-116^{o}C; ν_{max} (KBr) 1705 (CONH), 1743 (CO$_2$Et), 3214 (NH) cm^{-1}; ^{1}H NMR (200 MHz, CDCl$_3$) δ= 1.21-1.39 (m, 6H, 2 x C*H*$_3$CH$_2$), 3.70-3.98 (m, 2H, 2 x CHAr), 4.05-4.38 (m, 6H, 2 x C*H*$_2$CH$_3$ and 2 x CHCO$_2$Et), 5.27-5.32 (m, 2H, 2 x =CH), 6.23-6.28 (m, 2H, 2 x =CH), 7.01-7.43 (m, 8H, 2 x 4ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 14.0, 14.5, 44.3, 45.8, 62.0, 62.6, 66.2, 67.9, 115.7, 116.1, 116.2, 116.7, 120.0, 120.3, 129.8, 130.0, 131.5, 131.7, 136.1, 139.2, 139.7, 142.0, 160.3, 164.7, 165.2, 168.2, 169.8; mass (FAB+) *m/z* 264 (M$^+$+1); HR-EIMS calculated for $C_{14}H_{14}FNO_3$ 263.0958, found, 263.0958.

4.3.9. 3-(4-Bromophenyl)-4-methylene-5-oxo-pyrrolidine-2-carboxylic acid ethyl ester (5g)- 55% (0.21 g) as a white solid, mp 159-161^{o}C; ν_{max} (KBr) 1712 (CONH), 1750 (CO$_2$Et), 3430 (NH) cm^{-1}; ^{1}H NMR (200 MHz, CDCl$_3$) δ= 0.88 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 1.29 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.60-3.91 (m, 2H, 2 x CHAr), 4.21-4.27 (m, 4H, 2 x C*H*$_2$CH$_3$), 4.38-4.60 (m, 2H, 2 x CHCO$_2$Et), 5.25 (d, 1H, *J*= 2.0 Hz, =CH), 5.30 (d, 1H, *J*= 1.7 Hz, =CH), 6.22 (d, 1H, *J*= 2.9 Hz, =CH), 6.25 (d, 1H, *J*= 2.5 Hz, =CH), 6.66 (brs, 2H, 2 x NH), 7.06-7.57 (m, 8H, 2 x 4ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 14.0, 14.5, 47.5, 48.3, 59.4, 61.8, 62.4, 120.0, 122.0, 122.3, 130.2, 131.1, 131.5, 132.0, 132.5, 134.4, 137.7, 140.6, 141.9, 142.6, 170.2, 171.1, 171.9; mass (ES+) *m/z* 324.1 (M$^+$+1), 326.1 (M$^+$+3); HR-EIMS calculated for $C_{14}H_{14}BrNO_3$ 323.0157, found, 323.0155.

4.3.10. 5-Methyl-3-methylene-4-phenylpyrrolidin-2-one (6a)- 62% (0.144 g) as an off white solid, mp 118-120^{o}C; ν_{max} (KBr) 1674 (CONH), 3413 (NH) cm^{-1}; ^{1}H NMR (200MHz, CDCl$_3$) δ= 1.45 (d, 3H, *J*= 6.2 Hz, C*H*$_3$CH), 3.55-3.58 (m, 1H, CHAr), 3.82-3.88 (m, 1H, C*H*CH$_3$), 5.13 (d, 1H, *J*= 2.4 Hz, =CH), 6.09 (d, 1H, *J*= 3.0 Hz, =CH), 7.19 (m, 5H, ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 18.4, 51.2, 63.0, 117.8, 128.0, 128.8, 129.3, 140.4, 163.6; mass (ES+) 188.2 (M$^+$+1); HR-EIMS calculated for $C_{12}H_{13}NO$ 187.0997, found, 187.0991.

4.3.11. 5-Methyl-3-methylene-4-p-tolylpyrrolidin-2-one (6b)- 60% (0.107 g) as brown solid, mp 155-157^{o}C; ν_{max} (KBr) 1686 (CONH), 3431 (NH) cm^{-1}; ^{1}H NMR (200MHz, CDCl$_3$) δ= 1.32 (d, 3H, *J*= 6.0 Hz, C*H*$_3$CH), 2.35 (s, 3H, ArCH$_3$), 3.54 (d, 1H, *J*= 2.7 Hz, CHAr), 3.68 (t, 1H, *J*= 6.1 Hz, CHCH$_3$), 5.12 (s, 1H, =CH), 6.08 (d, 1H, *J*= 2.7 Hz, =CH), 6.92 (s, 1H, NH), 7.11 (d, 2H, *J*= 8.0 Hz, ArH), 7.17 (d, 2H, *J*= 8.0 Hz, ArH); ^{13}C NMR (50.32 MHz, CDCl$_3$) δ= 18.3, 21.4, 50.9, 62.9, 117.9, 128.7, 130.0, 137.3, 137.7, 163.8; mass (ES+) 188.2 (M$^+$+1); HR-EIMS calculated for $C_{13}H_{15}NO$ 201.1155, found, 201.1148.

4.3.12. 4-(2-Chlorophenyl)-5-methyl-3-methylenepyrrolidin-2-one (6c)- 58% (0.09 g) as brown solid, mp 117-119^{o}C; ν_{max} (KBr) 1684 (CONH), 3433 (NH) cm$^{-1.}$ ^{1}H NMR (300MHz, CDCl$_3$) δ= 0.76 (d, 3H, *J*= 6.0 Hz, C*H*$_3$CH), 4.20-4.25 (m, 1H, CHAr), 4.85-4.90 (m, 1H, C*H*CH$_3$), 5.33 (d, 1H, *J*= 3.0 Hz, =CH), 6.30 (d, 1H, *J*= 3.0 Hz, =CH), 7.18-7.25 (m, 2H, ArH), 7.38-7.44 (m, 2H, ArH); mass (ES+) 222.1 (M$^+$+1); HR-EIMS calculated for $C_{12}H_{12}ClNO$ 221.0607, found, 221.0606.

4.3.13. 4-(2-Chlorophenyl)-5-methyl-3-methylenepyrrolidin-2-one (6c) *(diastereoisomeric mixture as obtained from reaction of $SnCl_2.2H_2O$)*- 54% (0.13 g) as brown solid, mp 96-98^{o}C; ν_{max} (KBr) 1670 (CONH), 3415 (NH) cm^{-1}; ^{1}H NMR (200 MHz, CDCl$_3$) δ= 0.77 (d, 3H, *J*= 6.5 Hz, C*H*$_3$CH), 0.89 (d, 3H, *J*= 6.5 Hz, C*H*$_3$CH), 3.60-3.65 (m, 1H, CHAr), 4.22-3.29 (m, 1H, CHAr), 4.35-4.39 (m, 1H, C*H*CH$_3$), 4.87-4.92 (m, 1H, C*H*CH$_3$), 5.26 (s, 1H, =CH), 5.37 (d, 1H, *J*= 2.5 Hz, =CH), 6.14 (s, 1H, =CH), 6.34 (d, 1H, *J*= 2.5 Hz, =CH), 6.96 (brs, 2H, 2 x NH), 7.17-7.27 (m, 6H, 2 x 3ArH), 7.33-7.45 (m, 2H, 2 x 1ArH); mass (FAB+) 222 (M$^+$+1); HR-EIMS calculated for $C_{12}H_{12}ClNO$ 221.0607, found, 221.0608.

4.3.14. 4-(4-Fluoro-phenyl)-5-methyl-3-methylenepyrrolidin-2-one (6f)- 53% (0.13 g) as white solid, mp 162-164^{o}C; ν_{max} (KBr) 1667 (CONH), 3413 (NH) cm^{-1}; ^{1}H NMR (200MHz, CDCl$_3$) δ= 1.45 (d, 3H, *J*= 6.2 Hz, C*H*$_3$CH), 3.54-3.57 (m, 1H, CHAr), 3.75-3.84 (m, 1H,

C*H*CH_3), 5.12 (d, 1H, *J*= 2.3 Hz, =CH), 6.08 (d, 1H, *J*= 2.8 Hz, =CH), 6.99-7.08 (m, 2H, ArH), 7.14-7.21 (m, 2H, ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 18.3, 50.5, 63.1, 116.1, 116.5, 118.0, 130.2, 130.4, 131.4, 136.1, 141.8, 165.0; mass (ES+) *m/z* 206.1 (M^++1); HR-EIMS calculated for $C_{12}H_{12}FNO$ 205.0903, found, 205.0905.

4.3.15. 4-(4-Bromophenyl)-5-methyl-3-methylenepyrrolidin-2-one (6g)- 64% (0.23 g) as yellow oil; ν_{max} (Neat) 1688 (CONH), 3427 (NH) cm^{-1}; ^{1}H NMR (200MHz, $CDCl_3$) δ= 1.44 (d, 3H, *J*= 6.2 Hz, C*H*$_3$CH), 3.53-3.58 (m, 1H, CHAr), 3.76-3.86 (m, 1H, C*H*CH_3), 5.13 (d, 1H, *J*= 2.4 Hz, =CH), 6.07 (d, 1H, *J*= 2.9 Hz, =CH), 7.08 (d, 2H, *J*= 8.4 Hz, ArH), 7.48 (d, 2H, *J*= 8.4 Hz, ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 18.5, 51.2, 62.8, 117.9, 128.9, 130.2, 137.3, 137.9, 164.5; mass (ES+) *m/z* 266.0 (M^++1); HR-EIMS calculated for $C_{12}H_{12}BrNO$ 265.0102, found, 265.0108.

4.4. General Procedure for reduction of compounds 3a-g with $SnCl_2.2H_2O$.

To the solution of compounds from **3a-g** (1.0 equiv.) in methanol (10 mL) was added $SnCl_2.2H_2O$ (5.0 equiv.) and the reaction mixture was heated at reflux with stirring at 80^{o}C for 1.5 h in a nitrogen atmosphere. On completion, methanol was evaporated and the residue was made alkaline with saturated $NaHCO_3$ and then EtOAc (100 mL) was added. The suspension was passed through a bed of celite and the filtrate was partitioned in a separating funnel. The organic layer was separated, dried (Na_2SO_4) and concentrated to afford a residue, which was purified by silica gel chromatography using hexane: EtOAc (90:10, v/v) or (20:80, v/v) as eluent to yield products **7a-g** as oils.

4.4.1. 2-Hydroxyimino-4-methylene-3-phenylpentanedioic acid 1-ethyl ester 5-methyl ester (7a)- 73% (0.83 g) as pale yellow oil; ν_{max} (Neat) 1630 (C=N), 1735 (CO_2Me and CO_2Et), 3425 (OH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.26 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.21 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 5.32 (d, 1H, *J*= 2.1 Hz, =CH), 5.48 (s, 1H, CHAr), 6.35 (s, 1H, =CH), 7.31 (s, 5H, ArH), 9.20 (brs, 1H, OH); mass (ES+) *m/z* 291.9 (M^++1); HR-EIMS calculated for $C_{15}H_{17}NO_5$ 291.1107, found, 291.1110.

4.4.2. 2-Hydroxyimino-4-methylene-3-p-tolylpentanedioic acid 1-ethyl ester 5-methyl ester (7b)- 78% (1.48 g), ν_{max} (Neat) 1631 (C=N), 1731 (CO_2Me and CO_2Et), 3425 (OH) cm^{-1}; ^{1}H NMR ($CDCl_3$, 200 MHz) δ= 1.19-1.30 (m, 3H, C*H*$_3$CH$_2$), 2.33 (s, 3H, ArC*H*$_3$), 3.75 (s, 3H, CO_2CH_3), 4.07-4.28 (m, 2H, C*H*$_2$CH$_3$), 5.32 (d, 1H, *J*= 1.2 Hz, =CH), 5.42 (s, 1H, CHAr), 6.33 (d, 1H, *J*= 1.2 Hz, =CH), 7.13 (d, 2H, *J*= 8.2 Hz, ArH), 7.20 (d, 2H, *J*= 8.2 Hz, ArH), 9.20 (brs, 1H, OH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.2, 21.5, 45.1, 52.5, 62.2, 126.9, 129.8, 134.2, 137.4, 137.4, 140.4, 151.5, 163.6, 167.5; mass (FAB+) *m/z* 306 (M^++1); HR-EIMS calculated for $C_{16}H_{19}NO_5$ 305.1263, found, 305.1249.

4.4.3. 3-(2-Chlorophenyl)-2-hydroxyimino-4-methylenepentanedioic acid 1-ethyl ester 5-methyl ester (7c)- 79% (0.45 g**)** as colorless oil, ν_{max} (Neat) 1627 (C=N), 1726 (CO_2Et and CO_2Me), 3497(OH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.27-1.29 (m, 3H, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.11-4.28 (m, 2H, C*H*$_2$CH$_3$), 5.29 (s, 1H, =CH), 5.86 (s, 1H, CHAr), 6.40 (s, 1H, =CH), 7.20-7.34 (m, 3H, ArH), 7.38-7.41 (m, 1H, ArH), 9.21 (brs, 1H, OH); mass (FAB+) *m/z* 326 (M^++1); HR-EIMS calculated for $C_{15}H_{16}ClNO_5$ 325.0717, found, 325.0717.

4.4.4. 3-(2-Fluorophenyl)-2-hydroxyimino-4-methylenepentanedioic acid 1-ethyl ester 5-methyl ester (7d)- 77% (0.73 g) as colorless oil, ν_{max} (Neat) 1630 (C=N), 1724 (CO_2Et and CO_2Me), 3452 (OH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.26 (t, 3H, *J*= 7.0 Hz, C*H*$_3$CH$_2$), 3.76 (s, 3H, CO_2CH_3), 4.24 (q, 2H, *J*= 7.0 Hz, C*H*$_2$CH$_3$), 5.31 (s, 1H, =CH), 5.77 (s, 1H, CHAr), 6.38 (s, 1H, =CH), 7.01-7.10 (m, 2H, ArH), 7.14-7.32 (m, 2H, ArH), 9.26 (brs, 1H, OH); mass (ES+) *m/z* 310.1 (M^++1); HR-EIMS calculated for $C_{15}H_{16}FNO_5$ 309.1013, found, 309.1015.

4.4.5. 3-(4-Chlorophenyl)-2-hydroxyimino-4-methylenepentanedioic acid 1-ethyl ester 5-methyl ester (7e)- 75% (0.47 g) as colorless oil; ν_{max} (Neat) 1627 (C=N), 1722 (CO_2Et and CO_2Me), 3341 (OH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.26 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.07-4.29 (m, 2H, C*H*$_2$CH$_3$), 5.33 (d, 1H, *J*= 1.8 Hz, =CH), 5.45 (s, 1H, CHAr), 6.36 (d, 1H, *J*= 1.6 Hz, =CH), 7.22-7.33 (m, 4H, ArH), 9.28 (brs, 1H, OH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.2, 44.8, 52.6, 62.4, 127.2, 129.2, 131.3, 133.7, 135.8, 139.7, 151.3, 163.3, 167.3; mass (FAB+) m/z 326; HR-EIMS calculated for $C_{15}H_{16}ClNO_5$ 325.0717, found, 325.0718.

4.4.6. 3-(4-Fluorophenyl)-2-hydroxyimino-4-methylenepentanedioic acid 1-ethyl ester 5-methyl ester (7f)- 87% (0.24 g) as colorless oil; ν_{max} (Neat) 1628 (C=N), 1722 (CO_2Et and CO_2Me), 3367 (OH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.27 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.23 (q, 2H, *J* =7.1 Hz, C*H*$_2$CH$_3$), 5.32 (d, 1H, *J*= 1.6 Hz, =CH), 5.45 (s, 1H, CHAr), 6.35 (d, 1H, *J*= 1.6 Hz, =CH), 6.97-7.09 (m, 2H, ArH), 7.29-7.33 (m, 2H, ArH), 9.35 (brs, 1H, OH); mass (ES+) m/z 310.0; HR-EIMS calculated for $C_{15}H_{16}FNO_5$ 309.1013, found, 309.1016.

4.4.7. 3-(4-Bromophenyl)-2-hydroxyimino-4-methylenepentanedioic acid 1-ethyl ester 5-methyl ester (7g)- 73% (0.7 g from 1.0 g) as pale yellow oil; ν_{max} (Neat) 1633 (C=N), 1722 (CO_2Et and CO_2Me), 3450 (OH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.27 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.23 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 5.34 (d, 1H, *J*= 1.9 Hz, =CH), 5.43 (s, 1H, CHAr), 6.37 (d, 1H, *J*= 1.6 Hz, =CH), 7.19 (d, 2H, *J*= 8.4 Hz, ArH), 7.45 (d, 2H, *J*= 8.4 Hz, ArH), 9.26 (brs, 1H, OH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.3, 44.8, 52.7, 62.4, 127.3, 131.7, 132.2, 141.8, 144.6, 152.2, 164.3, 166.7, mass (ES+) *m/z* 370.2 (M^++1); HR-EIMS calculated for $C_{15}H_{16}BrNO_5$ 369.0212, found, 369.0210.

4.5. Reaction of 3a with $Sn(SPh)_2$ complex

To a stirred solution of $SnCl_2.2H_2O$ (0.81 g, 3.61 mmol) in MeCN (5 mL), PhSH (1.12 mL, 12.1 mmol) and Et_3N (1.67 mL, 12.1 mmol) were added at room temperature. Subsequently a solution of compound **3a** (0.74 g, 2.25

mmol) in MeCN (2 mL) was added and the reaction was allowed to continue for 30 min. Thereafter, the reaction mixture was concentrated and the residue was purified by column chromatography over silica gel using Hexane: EtOAc (90:10, v/v) as eluent to give compound 0.42 g (60%) of **7a** as a pale yellow oil.

4.6. General Procedure for the preparation of methyl derivatives 8b-c

To the flask charged with oxime **7b** or **7c** (1.0 equiv.) and Ag_2O (1.0 equiv.) was added MeI (5 mL for approx. 0.3 g substrate) with stirring at room temperature. After the initial exothermic reaction has subsided, the reaction mixture was heated at reflux for 1h. The reaction mixture was cooled to room temperature and filtered through a bed of Celite bed with the help of $CHCl_3$. The combined filtrate was evaporated and the residue was purified via silica gel column chromatography. Elution with hexane: EtOAc (90:10, v/v) gave pure **8b** or **8c**.

4.6.1. 2-Methoxyimino-4-methylene-3-p-tolylpentanedioic acid 1-ethyl ester 5-methyl ester (8b)- 80% (0.25 g) as a pale yellow oil; ν_{max} (Neat) 1625 (C=N), 1735 (CO_2Me and CO_2Et) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.25 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 2.32 (s, 3H, ArC*H*$_3$), 3.74 (s, 3H, CO_2CH_3), 3.98 (s, 3H, NCH_3), 4.23 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.32 (d, 1H, *J*= 1.5 Hz, =CH), 5.39 (s, 1H, CHAr), 6.30 (s, 1H, =CH), 7.12 (s, 4H, ArH); mass (FAB+) *m/z* 320 (M^++1); EI-HRMS calculated for $C_{17}H_{21}NO_5$ 319.1420, found, 319.1421.

4.6.2. 3-(2-Chlorophenyl)-2-methoxyimino-4-methylene-pentanedioic acid 1-ethyl ester 5-methyl ester (8c)- 68% (0.05 g) as a colorless oil; ν_{max} (Neat) 1627 (C=N), 1728 (CO_2Et and CO_2Me), cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.24 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.74 (s, 3H, CO_2CH_3), 3.97 (s, 3H, NCH_3), 4.23 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.29 (d, 1H, *J*= 1.5 Hz, =CH), 5.80 (s, 1H, CHAr), 6.37 (s, 1H, =CH), 7.18-7.25 (m, 3H, ArH), 7.37-7.40 (m, 1H, ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.4, 43.4, 52.6, 62.3, 63.8, 127.3, 129.0, 130.0, 130.6, 134.7, 135.8, 138.2, 151.1, 163.4, 167.0; mass (FAB+) *m/z* 340 (M^++1); HR-EIMS calculated for $C_{16}H_{18}ClNO_5$ 339.0871, found,: 339.0868.

4.7. General Procedure for the preparation of tosyl derivatives 9b,d

To the stirred solution of appropriate oxime from **7b,d** (1.0 equiv.) in dry dichloromethane (10 mL) was added Et_3N (1.5 mmol). The reaction mixture was brought to 0°C via ice-bath and to it was added tosyl chloride (1.1 equiv.) and the reaction was continued for 2 h at rt. Thereafter, the mixture extracted with water and dichloromethane. The organic layer was separated, dried (Na_2SO_4) and evaporated to dryness to yield the crude product which was purified by silica gel coloum chromatography using Hexane: EtOAc (80: 20, v/v) to yield pure products.

4.7.1. 2-Tosyloxyimino-4-methylene-3-p-tolylpentanedioic acid 1-ethyl ester 5-methyl ester (9b)- 75% (0.61 g) as yellow oil, ν_{max} (Neat) 1628 (C=N), 1732 (CO_2Et and CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.25 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 2.34 (s, 3H, ArC*H*$_3$), 2.44 (s, 3H, ArC*H*$_3$), 3.69 (s, 3H, CO_2CH_3), 4.17 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 5.35 (two s merged, 2H, CHAr and =CH), 6.37 (s, 1H, =CH), 7.09 (s, 4H, ArH), 7.27 (d, 2H, *J*= 8.0 Hz, ArH), 7.69 (d, 2H, *J*= 8.0 Hz, ArH), mass (ES+) *m/z* 460.2 (M^++1); HR-EIMS calculated for $C_{23}H_{25}NO_7S$ 459.1352, found, 459.1364.

4.7.2. 3-(4-Fluorophenyl)-2-hydroxyimino-4-methylene pentanedioic acid 1-ethyl ester 5-methyl ester (9d)- 78% (0.20 g) as yellow oil; ν_{max} (Neat) 1630 (C=N), 1729 (CO_2Et and CO_2Me) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.23 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 2.45 (s, 3H, ArC*H*$_3$), 3.70 (s, 3H, CO_2CH_3), 4.20 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.33 (two s merged, 2H, CHAr and =CH), 6.39 (d, 1H, *J*= 1.3 Hz, =CH), 7.11-7.15 (m, 2H, ArH), 7.23-7.34 (m, 4H, ArH), 7.64-7.68 (m, 2H, ArH); mass (ES+) *m/z* 464.1 (M^++1); HR-EIMS calculated for $C_{22}H_{22}FNO_7S$ 463.1101, found, 463.1124.

4.8. General Procedure for the reaction of 9b,d with DBU

To the stirred solution of appropriate tosyl derivatives from **9b,d** (1.0 mmol) in dry dichloromethane (5mL), a solution of DBU (1.2 mmol) in dichloromethane (4.0 mL) was added dropwise at rt. After 30 min, organic layer was washed with water, dried (anhyd. Na_2SO_4) and evaporated to furnish a residue which was purified via silica gel coloum chromatography using Hexane: EtOAc (85: 15, v/v) to give the pyrroles in low yields.

4.8.1. 3-p-Tolyl-1*H*-pyrrole-2,4-dicarboxylic acid 2-ethyl ester 4-methyl ester (10b)- 28% (0.11 g) as white solid, mp 150-152°C; ν_{max} (KBr) 1730 (CO_2Et and CO_2Me), 3429 (NH) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.37 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 2.40 ((s, 3H, ArC*H*$_3$), 3.77 (s, 3H, CO_2CH_3), 4.33 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 7.25 (d, 2H, *J*= 7.8 Hz, ArH), 7.38 (d, 1H, *J*= 2.8 Hz, =CH), 7.52 (d, 2H, *J*= 7.8 Hz, ArH), 9.36 (s, 1H, NH); mass (FAB+) *m/z* 288 (M^++1); HR-EIMS calculated for $C_{16}H_{17}NO_4$ 287.1158, found, 287.1146.

4.8.2. 3-(4-Fluorophenyl)-1H-pyrrole-2,4-dicarboxylic acid 2-ethyl ester 4-methyl ester (10d)- 25% (0.023 g) as white solid mp 156-158°C, ν_{max} (KBr) 1728 (CO_2Et and CO_2Me), 3441 (NH) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ= 1.38 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.77 (s, 3H, CO_2CH_3), 4.32 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 7.10-7.18 (m, 2H, ArH), 7.38 (d, 1H, *J*= 2.8 Hz, =CH), 7.59-7.65 (m, 2H, ArH), 9.38 (s, 1H, NH), mass (ES+) *m/z* 292.0 (M^++1); HR-EIMS calculated for $C_{15}H_{14}FNO_4$ 291.0907, found, 291.0919.

4.9. General Procedure for the preparation of compounds 11a-c, 12, 13a-b.

The compounds **11a-c, 12, 13a-b** were prepared following the procedure as described for compound **3a-g** and the reactions were worked up after 1 h.

4.9.1. 2-Methylene-4-nitro-3-(2-nitrophenyl)-pentanedioic acid 5-ethyl ester 1-methyl ester (11a)- 72% (1.36 g) as an off white solid, mp 116-118^{o}C; ν_{max} (KBr) 1721 (CO_2Et), 1755 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.07 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.68 (s, 3H, CO_2CH_3), 4.09 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.53 (d, 1H, *J*= 11.5 Hz, CHAr), 5.99 (s, 1H, =CH), 6.08 (d, 1H, *J*= 11.5 Hz, $CHCO_2Et$), 6.46 (s, 1H, =CH), 7.42-7.49 (m, 1H, ArH), 7.52-7.58 (m, 2H, ArH), 7.82-7.84 (d, 1H, *J*= 7.6, Hz, ArH); ^{13}C NMR (50.632 MHz, $CDCl_3$) δ= 13.8, 42.9, 52.8, 63.8, 89.3, 125.4, 128.5, 129.5, 130.1, 130.8, 133.2, 137.0, 150.5, 163.0, 165.7; mass (ES+) *m/z* 375.0 (M$^+$+Na); HR-EIMS calculated for $C_{15}H_{16}N_2O_6$ 352.0907, found, 352.0909.

5. 2-Methylene-4-nitro-3-(6-nitrobenzo[1,3]dioxol-5-yl)-pentanedioic acid 5-ethyl ester 1-methyl ester (11b)- 68% (0.42 g) as a yellow solid, mp 148-150^{o}C; ν_{max} (KBr) 1722 (CO_2Et), 1749 (CO_2Me) cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ= 1.17 (t, 3H, *J*= 7.2 Hz, C*H*$_3$CH$_2$), 3.71 (s, 3H, CO_2CH_3), 4.15 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 5.63 (d, 1H, *J*= 12.0 Hz, CHAr), 5.99 (d, 1H, *J*= 12.0 Hz, $CHCO_2Et$), 6.02 (s, 1H, =CH), 6.12 (s, 2H, CH_2), 6.47 (s, 1H, =CH), 6.93 (s, 1H, ArH), 7.38 (s, 1H, ArH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.2, 42.8, 52.9, 63.9, 89.3, 103.7, 106.4, 109.3, 126.3, 128.4, 137.2, 144.7, 148.0, 151.8, 163.0, 165.8; mass (ES+) *m/z* 419.0 (M$^+$+Na); HR-EIMS calculated for $C_{16}H_{16}N_2O_{10}$ 396.0805, found, 396.0806.

5.1.1. 3-(5-Chloro-2-nitro phenyl)-2-methylene-4-nitro-pentanedioic acid 5-ethyl ester 1-methyl ester (11c)- 75% (0.80 g) as a brown solid, mp 130-132^{o}C; ν_{max} (KBr) 1725 (CO_2Et), 1750 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.12 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.70 (s, 3H, CO_2CH_3), 4.12 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.56 (d, 1H, *J*= 11.6 Hz, CHAr), 6.00-6.06 (m, 2H, $CHCO_2Et$ and =CH), 6.49 (s, 1H, =CH), 7.39-7.44 (m, 1H, ArH), 7.52 (d, 1H, *J*= 2.1 Hz, ArH), 7.83 (d, 1H, *J*= 8.7 Hz, ArH), mass (ES+) *m/z* 409.0 (M$^+$+Na); HR-EIMS calculated for $C_{15}H_{15}ClN_2O_8$ 386.0517, found, 386.0515.

5.1.2. 2-Methylene-4-nitro-3-(2-nitrophenyl)-pentanedioic acid diethyl ester (12)- 71% (0.44 g from) as a yellow solid, mp 90-92^{o}C; ν_{max} (KBr) 1728 (CO_2Et), cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.03-1.30 (m, 6H, 2 x C*H*$_3$CH$_2$), 4.03-4.28 (m, 4H, 2 x C*H*$_2$CH$_3$), 5.52-5.59 (m, 2H, 2 x CHAr), 5.96 (two s merged, 2H, =CH), 5.08 (d, 1H, *J*= 11.5 Hz, $CHCO_2Et$), 6.29 (d, 1H, *J*= 11.5 Hz, $CHCO_2Et$), 6.41 (s, 1H, =CH), 6.47 (s, 1H, =CH), 7.44-7.49 (m, 2H, 2 x 1ArH), 7.55-7.58 (m, 4H, 2 x 2ArH), 7.68-7.71 (m, 1H, ArH), 7.85 (d, 2H, *J*= 7.8 Hz, ArH), mass (ES+) *m/z* 389.0 (M$^+$+Na); HR-EIMS calculated for $C_{15}H_{16}N_2O_8$ 366.1063, found, 366.1059**.**

5.1.3. 2-Methylene-4-nitro-3-(2-nitrophenyl)-pentanoic acid methyl ester (13a)- 65% (0.58 g) as a brown solid, mp 110-112^{o}C; ν_{max} (KBr) 1722 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.56 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 1.63 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 3.63 (s, 3H, CO_2CH_3), 3.75 (s, 3H, CO_2CH_3), 5.08 (d, 1H, *J*= 11.0 Hz, CHAr), 5.21-5.35 (m, 2H, CHAr and $CHCO_2Et$), 5.64-5.68 (m, 1H, $CHCO_2Et$), 5.96 (s, 1H, =CH), 6.00 (s, 1H, =CH), 6.41 (two s merged, 2H, 2 x =CH), 7.34-7.47 (m, 4H, 2 x 2ArH), 7.57 (t, 2H, *J*= 7.2 Hz, 2 x 1ArH), 7.79 (t, 2H, *J*= 7.2 Hz, 2 x 1ArH); mass (ES+) *m/z* 395.1 (M$^+$+1); HR-EIMS calculated for $C_{15}H_{15}ClN_2O_8$ 294.0852, found, 294.0853.

5.1.4. 3-(5-Chloro-2-nitrophenyl)-2-methylene-4-nitro-pentanoic acid methyl ester (13b)- 66% (0.50 g) as brown solid, mp 104-106^{o}C; ν_{max} (KBr) 1724 (CO_2Me) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.57 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 1.63 (d, 3H, *J*= 6.6 Hz, C*H*$_3$CH), 3.65 (s, 3H, CO_2CH_3), 3.77 (s, 3H, CO_2CH_3), 5.06 (d, 1H, *J*= 11.1 Hz, CHAr), 5.24-5.34 (m, 2H, CHAr and $CHCO_2Et$), 5.63-5.68 (m, 1H, $CHCO_2Et$), 5.99 (s, 1H, =CH), 6.04 (s, 1H, =CH), 6.45 (two s merged, 2H, 2 x =CH), 7.30-7.31 (m, 2H, 2 x 1ArH), 7.38-7.44 (m, 2H, 2 x 1ArH), 7.76-7.83 (m, 2H, 2 x 1ArH); mass (ES+) *m/z* 329.1 (M$^+$+1); HR-EIMS calculated for $C_{15}H_{15}ClN_2O_8$ 328.0462, found, 328.0458.

5.2. General Procedure for the preparation of compounds 14a-c, 15, 16a-b.

To the solution of appropriate compound from **11a-c, 12, 13a-b** (1.0 equiv.) in methanol (10 mL) was added $SnCl_2.2H_2O$ (10 equiv.) and the reaction mixture was heated at reflux with stirring at 80^{o}C for 1 h in a nitrogen atmosphere. After completion, methanol was evaporated and the residue was made basic with saturated $NaHCO_3$ and taken up in EtOAc (100 mL). The suspension formed was filtered through a bed of Celite and the filtrate was partitioned in a separating funnel. The organic layer was separated, dried (Na_2SO_4) and concentrated to give a residue, which was purified by silica gel chromatography using hexane: EtOAc (80:20, v/v) as eluent to yield the final products.

5.2.1. 3-(1-Methoxycarbonyl-vinyl)-1H-indole-2-carboxylic acid ethyl ester (14a)- 56% (0.183 g) as a yellow oil; ν_{max} (Neat) 1723 (CO_2Et and CO_2Me), 3315 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.36 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.40 (q, 2H, *J* =7.1 Hz, C*H*$_2$CH$_3$), 5.93 (s, 1H, =CH), 6.66 (s, 1H, =CH), 7.16-7.19 (m, 1H, ArH), 7.34-7.41 (m, 1H, ArH), 7.54-7.61 (m, 2H, ArH), 10.64 (s, 1H, NH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.4, 52.5, 61.7, 110.1, 114.2, 119.6, 120.9, 121.8, 126.4, 129.4, 133.3, 133.9, 164.3, 167.9; mass (ES+) *m/z* 274.0 (M$^+$+1); HR-EIMS calculated for $C_{15}H_{15}NO_4$ 273.1001, found, 273.1004.

5.2.2. 3-(1-Methoxycarbonyl-vinyl)-5H-[1,3]dioxolo[4,5-f]indole-6-carboxylic acid ethyl ester (14b)- 58% (0.093 g) as a pale yellow solid, mp 116-118^{o}C; ν_{max} (KBr) 1732 (CO_2Et and CO_2Me), 3308 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.23-1.36 (m, 3H, C*H*$_3$CH$_2$), 3.73 (s, 3H, CO_2CH_3), 4.31 (q, 2H, *J*= 7.2 Hz, C*H*$_2$CH$_3$), 5.85 (t, 1H, *J*= 2.8 Hz, =CH), 5.97 (s, 2H, CH_2), 6.60 (t, 1H, *J*= 4.1 Hz,

=CH), 6.85 (two s merged, 2H, ArH), 8.92 (s, 1H, NH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.6, 52.5, 62.5, 100.3, 102.7, 106.2, 115.3, 115.8, 120.4, 128.9, 136.9, 148.1, 151.6, 165.2, 168.3; mass (ES+) *m/z* 318.0 (M^++1), 340.1 (M^++Na); HR-EIMS calculated for $C_{16}H_{15}NO_6$ 317.0899, found, 317.0899

5.2.3. 5-Chloro-3-(1-methoxycarbonyl-vinyl)-1H-indole-2-carboxylic acid ethyl ester (14c)- 62% (0.103 g) as a yellow oil; ν_{max} (Neat) 1723 (CO_2Et and CO_2Me), 3372 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.36 (t, 3H, *J*= 7.1 Hz, C*H*$_3$CH$_2$), 3.75 (s, 3H, CO_2CH_3), 4.40 (q, 2H, *J*= 7.1 Hz, C*H*$_2$CH$_3$), 5.91 (s, 1H, = CH), 6.67 (s, 1H, =CH), 7.36 (s, 1H, ArH), 7.48-7.65 (m, 2H, ArH), 10.72 (s, 1H, NH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 13.8, 52.5, 61.8, 124.4, 125.6, 1127.2.7, 130.6, 131.1, 131.4, 136.2, 141.7, 145.9, 165.2, 167.3; mass (ES+) *m/z* 308.0 (M^++1); HR-EIMS calculated for $C_{15}H_{14}ClNO_4$ 307.0611, found, 307.0612.

5.2.4. 3-(1-Ethoxycarbonyl-vinyl)-1H-indole-2-carboxylic acid ethyl ester (15)- 59% (0.10 g) as brown solid, mp 104-106^{o}C; ν_{max} (KBr) 1713 (CO_2Et), 3331 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.14-1.47 (m, 6H, 2 x C*H*$_3$CH$_2$), 4.10-4.44 (m, 4H, 2 x C*H*$_2$CH$_3$), 5.92 (s, 1H, =CH), 6.66 (s, 1H, =CH), 7.12-7.23 (m, 1H, ArH), 7.34-7.41 (m, 1H, ArH), 7.54-7.62 (m, 2H, ArH), 10.60 (s, 1H, NH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 14.4,, 14.6, 61.4, 62.3, 110.1, 112.3, 114.2, 121.0, 121.7, 126.4, 129.1, 133.2, 134.2, 164.5, 167.7; mass (ES+) *m/z* 288.0 (M^++1); HR-EIMS calculated for $C_{16}H_{17}NO_4$ 287.1158, found, 287.1156.

5.2.5. 3-Methylene-4-(1-nitro-ethyl)-3,4-dihydro-1H-quinolin-2-one (16a)- 53% (0.062 g) as a white solid, mp 166-168^{o}C; ν_{max} (KBr) 1664 (CONH), 3218 (NH) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.47 (d, 3H, *J*= 4.7 Hz, C*H*$_3$CH), 1.50 (d, 3H, *J*= 4.7 Hz, C*H*$_3$CH), 4.15 (d, 1H, *J*= 7.6 Hz, CHAr), 4.23 (d, 1H, *J*= 7.6 Hz, CHAr), 4.61-4.72 (m, 2H, 2 x C*H*CH$_3$), 5.68 (two s merged, 2H, 2 x =CH), 6.41 (s, 1H, =CH), 6.49 (s, 1H, =CH), 6.89-6.94 (m, 2H, 2 x 1ArH), 7.01-7.08 (m, 2H, 2 x 1ArH), 7.14-7.17 (m, 2H, 2 x 1ArH), 7.23-7.33 (m, 2H, 2 x 1ArH), 8.95 (s, 1H, NH), 9.10 (s, 1H, NH); ^{13}C NMR (50.32 MHz, $CDCl_3$) δ= 19.3, 19.4, 51.2, 52.4, 85.6, 86.1, 124.9, 127.7, 128.3, 129.0, 129.8, 130.1, 134.0, 134.8, 137.9, 138.1, 139.8, 140.0, 166.4, 166.7; mass (FAB+) *m/z* 233 (M^++1); HR-EIMS calculated for $C_{12}H_{12}N_2O_3$ 232.0848, found, 232.0848.

5.2.6. 6-Chloro-3-methylene-4-(1-nitro-ethyl)-3, 4-dihydro-1H-quinolin-2-one (16b)- 48% (0.116 g) as pale yellow solid mp >250^{o}C, ν_{max} (KBr) 1672 (CONH), 3391 (NH) cm$^{-1.}$ ^{1}H NMR (200 MHz, $CDCl_3$) δ= 1.46 (d, 3H, *J*= 4.6 Hz, C*H*$_3$CH), 1.52 (d, 3H, *J*= 4.6 Hz, C*H*$_3$CH), 4.14 (d, 1H, *J*= 7.8 Hz, CHAr), 4.22 (d, 1H, *J*= 7.8 Hz, CHAr), 4.60-4.74 (m, 2H, 2 x C*H*CH$_3$), 5.69 (two s merged, 2H, 2 x =CH), 6.42 (s, 1H, =CH), 6.47 (s, 1H, =CH), 6.90-6.95 (m, 2H, 2 x 1ArH), 7.06-7.09 (m, 2H, 2 x 1ArH), 7.16-7.17 (m, 2H, 2 x 1ArH), 8.93 (s, 1H, NH), 9.08 (s, 1H, NH); mass (ES+) 266.9 (M^++1), 289.0 (M^++Na). HR-EIMS calculated for $C_{13}H_{14}N_2O_3$ 266.0458, found, 266.0455.

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