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AN EFFICIENT ONE-POT SYNTHESIS OF 1-AMINO-3-CYANO-4-ARYL-10-ETHOXYCARBONYLAZULENO[2,1-*b*]]PYRANS

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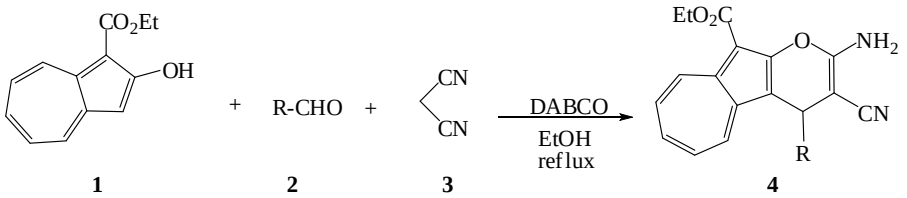
Abstract — An efficient and easy method for the one-pot three-component synthesis of 2-amino-3-cyano-4-aryl-10-ethoxycarbonylazuleno[2,1-*b*]pyran derivatives by the three-componenet condensation of ethyl 2-hydroxyazulene-1-carboxylate, aldehydes, and malononitrile in the presence of diazabicyclo[2.2.2]octane (DABCO) has been described.

It is well known that pyrans are important core units in a number of natural products[1] and photochromic materials.[2] Compounds with pyran ring system have many pharmacological properties and play important roles in biochemical process. Moreover, 4*H*-pyrans are useful intermediates for the synthesis of various compounds.[3,4] Therefore, preparation of this heterocyclic nucleus has gained great importance in organic synthesis.

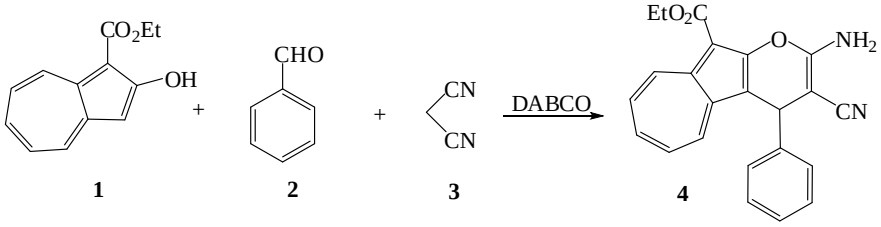
The azulene constitute was the best known of polycyclic nonbenenoid aromatic compounds and have long fascinated chemists with their beautiful colors and unusual electronic properties.[5] Azulenes have attracted interest in medicine as antiulcer drugs[6] anticancer agents,[7] and as antioxidant therapeutics for neurode-generative conditions.[8] A variety of heteroarylazulenes have so far been obtained on the viewpoints of chemical properties and physiological activities by several methods.[9] Recently, our group has developed several synthesis method s of heteroarylazulenes.[10] In this work, we report one-pot synthesis of 2-amino-3-cyano-4-aryl-10-ethoxycarbonylazuleno[2,1-*b*]pyrans by condensation of ethyl 2-hydroxyazulene-1-carboxylate (**1**), aldehydes (**2a**), and malononitrile using inexpensive and convenient available diazabicyclo[2.2.2]octane (DABCO) as catalyst (Scheme 1).



Scheme 1

In this three-component reaction, we found that catalysts had significant effects on the reaction time and yields (Table 1). The results indicated that this reaction could not take place in the presence of proton acids and classical Lewis acids as catalysts in EtOH under reflux conditions for 120 min, such as TsOH, NH_2SO_3H, CF_3CO_2H, $ZnCl_2$, and $MgCl_2$ (Table 1, entries 1-5). Then, we carried out the reaction using bases as the catalysts under the same reaction conditions, such as Et_3N, DBU, piperidine and DABCO (Table 1, entries 6-11). To our delight, the desired condensation product **4a** was obtained in moderate to excellent yields (45-92%), which meant that this three-component condensation reaction of ethyl 2-hydroxyazulene-1-carboxylate (**1**), benzaldehyde (**2a**), and malononitrile (**3**) could proceed smoothly catalyzed by bases. Furthermore, we found that the yields of **4a** were improved as the amount of DABCO increased from 10 to 20%, and the yields plateaued when the amount of DABCO was further increased to 30% (Table 1, entry 11). Therefore, 20 mol% of DABCO was considered to be the most suitable.

Table 1. Condensation of ethyl 2-hydroxyazulene-1-carboxylate (**1**), benzaldehyde (**2a**), and malononitrile (**3**) using various catalystsa [a]



Entry	Catalyst	Amount of Catalyst (mol%)	Time (min)	Yield[b] (%)	
1	TsOH	20	120	0	(84%) [c]
2	NH_2SO_3H	20	120	0	(92%)
3	CF_3CO_2H	20	120	0	(66%)
4	$ZnCl_2$	20	120	0	(98%)
5	$MgCl_2$	20	120	0	(90%)
6	Et_3N	20	90	45	
7	DBU	20	60	57	
8	piperidine	20	60	72	
9	DABCO	10	60	78	
10	DABCO	20	60	92	
11	DABCO	30	60	90	

[a] Reaction conditions: 1-cyanoacetylguaiazulene **1** (1 mmol), benzaldehyde **2a** (1.1 mmol), malononitrile **3** (1.1 mmol), EtOH (15 mL).
[b] Isolated yields.
[c] Recovery.

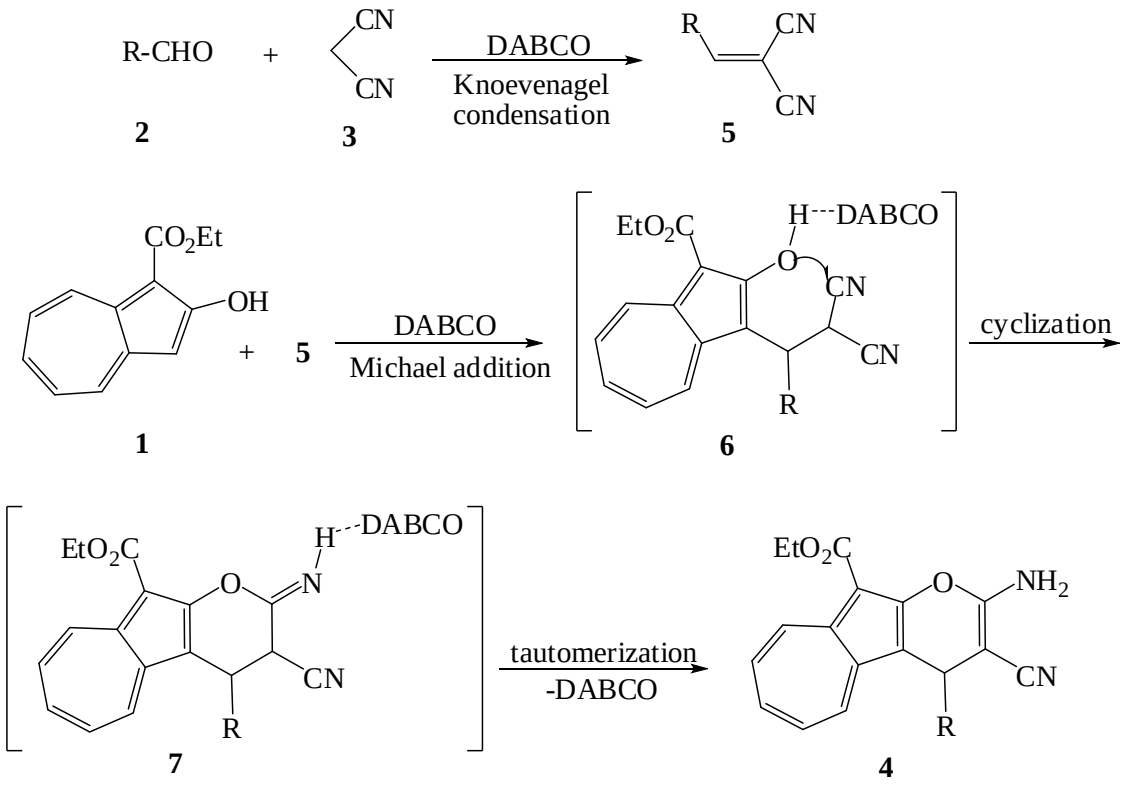
Furthermore, the reaction was optimized by screening the solvent such as CH_2Cl_2, CH_2ClCH_2Cl, THF, MeCN, AcOH, EtOH, toluene and DMF. The reaction using DMF and EtOH as the solvents gave the corresponding product **4a** in high yields and in short reaction time. From the economical and environmental point of view, EtOH was chosen as the reaction medium for all further reactions. Therefore, the best reaction conditions were obtained by using 20 mol % of ammonium acetate as the catalyst in EtOH at reflux temperature.

A series of aromatic and heterocyclic aldehydes were selected to undergo the condensation in the presence of DABCO. As shown in Table 2, aromatic aldehydes (**2**) carrying either electron-donating or electron-withdrawing substituents reacted efficiently giving excellent yields (Table 2, entries 1-12). Hence, the effect of the nature of the substituents on the aromatic ring showed no obvious effect on this conversion. Furthermore, heterocyclic aldehydes could react smoothly to give the corresponding products **4** in good yields (Table 2, entries 13, 14).

Table 2. Synthesis of compounds **4** catalyzed by DABCO

Entry	**2** /R		Time /min	Product	Yield /%
1	**2a**	C_6H_5	60	**4a**	92
2	**2b**	4-MeC_6H_4	60	**4b**	87
3	**2c**	4-$MeOC_6H_4$	40	**4c**	94
4	**2d**	4-ClC_6H_4	40	**4d**	90
5	**2e**	4-FC_6H_4	60	**4e**	86
6	**2f**	4-HOC_6H_4	90	**4f**	88
7	**2g**	2-$MeOC_6H_4$	50	**4g**	89
8	**2h**	2-HOC_6H_3	50	**4h**	93
9	**2i**	2,4-$(MeO)_2C_6H_3$	40	**4i**	90
10	**2j**	3,4-$(MeO)_2C_6H_3$	40	**4j**	90
11	**2k**	3-MeO,4-HOC_6H_3	40	**4k**	94
12	**2l**	3-$NO_2C_6H_4$	60	**4l**	80
13	**2m**	2-Furyl	50	**4m**	82
14	**2n**	2-Thienyl	50	**4n**	86

We propose a mechanism of the DABCO-catalyzed condensation as shown in Scheme 2. The condensation of ethyl 2-hydroxyazulene-1-carboxylate **1**, aldehyde **2**, malononitrile **3** may occur by a mechanism of Knoevenagel condensation, Michael addition, intramolecular cyclization, and tautomerization. Initially, intermediate **5** is formed by Knoevenagel condensation of aldehyde **2** and malononitrile **3** by the action of



Scheme 2

DABCO. In the presence DABCO, Michael addition of ethyl 2-hydroxy azulene-1-carboxylate **1** on **5** leads to form intermediate **6**, followed by intramolecular cyclization and tautomerization, affords the correspondding products **4** (Scheme 2). We think that DABCO serves as a base as well as a proton shuttle to promote this reaction.

In conclusion, the present method discloses a new and simple modification of the condensation of ethyl 2-hydroxyazulene-1-carboxylate **1**, aldehyde **2**, malononitrile **3** to the synthesis of 2-amino-3-cyano-4-aryl-10-ethylcarbonyl azuleno[2,1-*b*]pyran derivatives **4** by using DABCO as a catalyst in EtOH. The operational simplicity, mild reaction conditions, short reaction time, and little environmental impact are notable features of this procedure.

EXPERIMENTAL

All melting points were determined on a Yanako MP-3 apparatus and are uncorrected. ^{1}HNMR spectra were recorded on a Bruker spectrometer (400 MHz). IR spectra were measured on Shimadzu IR-740 spectrophotometer. Elemental analyses were performed on EA 2400 Ⅱ elemental analyzer (Perkin-Elmer).

Preparation of 2-amino-3-cyano-4-aryl-10-ethoxycarbonyl azuleno[2,1-*b*]pyran derivatives.

General procedure: A mixture of ethyl 2-hydroxyazulene-1-carboxylate[11] (**1**, 1.0 mmol), aldehyde (**2**, 1.1 mmol), malononitrile (**3**, 1.1 mmol), and DABCO (0.3 mmol) in EtOH (15 mL) was heated to reflux under stirring for the given time (Table **2**). After completion (by TLC), the reaction mixture was cooled to room temperature, then water (10 mL) was added to the mixture and stirred for 5 min. The solid was filtered and recrystallized to afford the corresponding products. The physical and spectra data of the compounds **4a-n** are as follows:

2-Amino-3-cyano-4-phenyl-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**4a**)**:** Deep red prism (from EtOH). mp 198-200 ºC; IR (KBr, cm^{-1}): ν 3280 (NH_2), 2216 (CN), 1628 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.26 (3H, t, J = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.59 (2H, q, J = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.94 (2H, s, NH_2), 5.28 (1H, s, CH), 7.30-7.33 (2H, m), 7.37-7.43 (4H, m), 7.57 (1H, dd, J = 9.6, 10.0 Hz), 7.69 (1H, dd, J = 9.6, 9.6 Hz), 7.99 (1H, d, J = 9.6 Hz), 9.64 (1H, d, J = 10.0 Hz). *Anal*. Calcd for $C_{23}H_{18}N_2O_3$: C 74.58, H 4.90, N 7.56. Found: C 74.67, H 5.13, N 7.68.

2-Amino-3-cyano-4-(4-methylphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3b**)**:** Deep red prism (from EtOH). mp 192-194 ºC; IR (KBr, cm^{-1}): ν 3312 (NH_2), 2209 (CN), 1631 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.25 (3H, t, J = 7.2 Hz, $OCH_2\underline{CH_3}$), 2.28 (3H, s, CH_3), 4.47 (2H, q, J = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.75 (2H, s, NH_2), 5.29 (1H, s, CH), 7.08 (4H, m), 7.30 (1H, dd, J = 9.6, 10.2 Hz), 7.56 (1H, dd, J = 9.6, 9.6 Hz), 7.66 (1H, dd, J = 9.6, 9.6 Hz), 7.90 (1H, d, J = 10.0 Hz), 9.53 (1H, d, J = 10.0 Hz). *Anal*. Calcd for $C_{24}H_{20}N_2O_3$: C 74.98, H 5.24, N 7.29. Found: C 74.74, H 5.37, N 7.31.

2-Amino-3-cyano-4-(4-methoxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3c**)**:** Deep red prism (from EtOH). mp 185-187 ºC; IR (KBr, cm^{-1}): ν 3322 (NH_2), 2215 (CN), 1642 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.25 (3H, t, J = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.85 (3H, s, OCH_3), 4.59 (2H, q, J = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.88 (2H, s, NH_2), 5.25 (1H, s, CH), 6.91 (2H, d, J = 8.2 Hz), 7.24 (2H, d, J = 8.2 Hz), 7.37 (1H, dd, J = 9.6, 10.2 Hz), 7.59 (1H, dd, J = 9.6, 9.6 Hz), 7.67 (1H, dd, J = 9.6, 10.0 Hz), 8.01 (1H, d, J = 10.0 Hz), 9.64 (1H, d, J = 10.0 Hz). *Anal*. Calcd for $C_{24}H_{20}N_2O_4$: C 71.99, H 5.03, N 7.00. Found: C 71.86, H 5.26, N 7.14.

2-Amino-3-cyano-4-(4-chlorophenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3d**)**:** Deep red prism (from EtOH). mp 206-208 ºC; IR (KBr, cm^{-1}): ν 332 1 (NH_2), 2219 (CN), 1642 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.25 (3H, t, J = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.59 (2H, q, J = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.96 (2H, s, NH_2), 5.26 (1H, s, CH), 7.24 (2H, d, J = 8.2 Hz), 7.35 (2H, d, J = 8.2 Hz), 7.43 (1H, dd, J = 9.6, 10.2 Hz), 7.63 (1H, dd, J = 9.6, 10.0 Hz), 7.78 (1H, dd, J = 9.6, 9.6 Hz), 7.94 (1H, d, J = 10.0 Hz), 9.65 (1H, d, J = 10.0 Hz). *Anal*. Calcd for $C_{23}H_{17}ClN_2O_3$: C 68.23, H 4.23, N 6.92. Found: C 68.36, H 4.41, N 7.14.

2-Amino-3-cyano-4-(4-fulorophenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3e**)**:** Deep red prism (from EtOH). mp 212-214 ºC; IR (KBr, cm^{-1}): *v* 3325 (NH_2), 2206 (CN), 1648 (C=O). ^{1}H-NMR ($CDCl_3$: *δ* 1.27 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.59 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.91 (2H, s, NH_2), 5.27 (1H, s, CH), 7.26 (2H, d, *J* = 8.8 Hz), 7.39 (2H, d, *J* = 8.8 Hz), 7.45 (1H, dd, *J* = 9.6, 10.2 Hz), 7.52 (1H, dd, *J* = 9.6, 9.6 Hz), 7.69 (1H, dd, *J* = 9.6, 10.0 Hz), 8.12 (1H, d, *J* = 10.0 Hz), 9.66 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{23}H_{17}FN_2O_3$: C 71.13, H 4.41, N 7.21. Found: C 71.26, H 4.58, N 7.39.

2-Amino-3-cyano-4-(4-hydroxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3f**)**:** Deep red prism (from EtOH). mp 221-222 ºC; IR (KBr, cm^{-1}): *v* 3334 (NH_2), 3225 (OH), 2208 (CN), 1640 (C=O). ^{1}H-NMR (DMSO): *δ* 1.40 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.35 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.10 (1H, s, CH), 6.62 (2H, d, *J* = 8.4 Hz), 6.95 (2H, s, NH_2), 6.96 (2H, d, *J* = 8.4 Hz), 7.44 (1H, dd, *J* = 9.6, 10.0 Hz), 7.64 (1H, dd, *J* = 10.0, 10.0 Hz), 7.77 (1H, dd, *J* = 9.6, 9.6 Hz), 8.03 (1H, d, *J* = 9.6 Hz), 9.25 (1H, s, OH), 9.38 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{23}H_{18}N_2O_4$: C 71.49, H 4.70, N 7.25. Found: C 71.63, H 4.84, N 7.36.

2-Amino-3-cyano-4-(4-methoxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3g**)**:** Deep red prism (from EtOH). mp 214-216 ºC; IR (KBr, cm^{-1}): *v* 3342 (NH_2), 2209 (CN), 1642 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.27 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.94 (3H, s, OCH_3), 4.50 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.84 (2H, s, NH_2), 5.31 (1H, s, CH), 6.84-6.86 (2H, m), 7.07-7.09 (1H, m), 7.16 (1H, dd, *J* = 8.0, 8.0 Hz), 7.30 (1H, dd, *J* = 9.6, 9.6 Hz), 7.52 (1H, dd, *J* = 9.6, 10.0 Hz), 7.62 (1H, d, *J* = 9.6, 10.0 Hz), 8.01 (1H, d, *J* = 10.0 Hz), 9.48 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{24}H_{20}N_2O_4$: C 71.99, H 5.03, N 7.00. Found: C 72.13, H 5.15, N 7.21.

2-Amino-3-cyano-4-(4-hydroxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3h**)**:** Deep red prism (from EtOH). mp 206-207 ºC; IR (KBr, cm^{-1}): *v* 3334 (NH_2), 3241 (OH), 2218 (CN), 1645 (C=O). ^{1}H-NMR (DMSO): *δ* 1.36 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.40 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.54 (1H, s, CH), 6.78 (1H, d, *J* = 8.0 Hz), 6.81 (2H, s, NH_2), 6.92 (1H, dd, *J* = 7.2, 7.2 Hz), 7.01 (1H, d, *J* = 8.0 Hz), 7.18 (1H, dd, *J* = 7.2, 7.2 Hz), 7.48 (1H, dd, *J* = 9.6, 9.6 Hz), 7.51~7.63 (2H, m), 8.63 (1H, d, *J* = 10.0 Hz), 9.01 (1H, d, *J* = 9.6 Hz), 10.51 (1H, s, OH). *Anal*. Calcd for $C_{23}H_{18}N_2O_4$: C 71.49, H 4.70, N 7.25. Found: C 71.72, H 4.86, N 7.42.

2-Amino-3-cyano-4-(2,4-dimethoxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3i**)**:** Deep red prism (from EtOH). mp 189-190 ºC; IR (KBr, cm^{-1}): *v* 3334 (NH_2), 2208 (CN), 1649 (C=O). ^{1}H-NMR ($CDCl_3$, 400MHz) δ (ppm): 1.26 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.76 (3H, s, OCH_3), 3.91 (3H, s, OCH_3), 4.50 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.71 (2H, s, NH_2), 5.63 (1H, s, CH), 6.32 (1H, d, *J* = 8.4 Hz), 6.50 (1H, s), 6.82 (1H, d, *J* = 8.4 Hz), 7.32 (1H, dd, *J* = 9.6, 9.6 Hz), 7.54 (1H, dd, *J* = 9.6, 10.0 Hz), 7.66 (1H,

dd, *J* = 9.6, 9.6 Hz), 7.98 (1H, d, *J* = 10.0 Hz), 9.52 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{25}H_{22}N_2O_5$: C 69.76, H 5.15, N 6.51. Found: C 69.84, H 5.28, N 6.71.

2-Amino-3-cyano-4-(3,4-dimethoxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3j**)**:** Deep red prism (from EtOH). mp 209-210 ºC; IR (KBr, cm^{-1}): *v* 3334 (NH_2), 2208 (CN), 1649 (C=O). ^{1}H-NMR (DMSO): *δ* 1.40 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.66 (6H, s, 2xOCH_3), 4.35 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.17 (1H, s, CH), 6.63 (1H, d, *J* = 8.0 Hz), 6.80~6.85 (2H, m), 6.98 (2H, s, NH_2), 7.46 (1H, dd, *J* = 9.6, 9.6 Hz), 7.65 (1H, dd, *J* = 9.6, 10.0 Hz), 7.77 (1H, dd, *J* = 10.0, 10.0 Hz), 8.08 (1H, d, *J* = 10.0 Hz), 9.39 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{25}H_{22}N_2O_5$: C 69.76, H 5.15, N 6.51. Found: C 69.87, H 5.23, N 6.63.

2-Amino-3-cyano-4-(4-hydroxy-3-methoxyphenyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3k**)**:** Deep red prism (from EtOH). mp 213-215 ºC; IR (KBr, cm^{-1}): *v* 3334 (NH_2), 3261 (OH), 2208 (CN), 1649 (C=O). ^{1}H-NMR (DMSO): *δ* 1.40 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.67 (3H, s, OCH_3), 4.36 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.11 (1H, s, CH), 6.49 (1H, d, *J* = 8.0 Hz), 6.64 (1H, d, *J* = 8.0 Hz), 6.82 (1H, s), 6.96 (2H, s, NH_2), 7.44 (1H, dd, *J* = 9.6, 10.0 Hz), 7.63 (1H, dd, *J* = 10.0, 10.0 Hz), 7.74 (1H, dd, *J* = 10.0, 10.0 Hz), 8.07 (1H, d, *J* = 10.0 Hz), 8.84 (1H, s, OH), 9.37 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{24}H_{20}N_2O_5$: C 69.22, H 4.84, N 6.73. Found: C 69.37, H 4.96 N 6.79.

2-Amino-3-cyano-4-(3-nitrophenyl)-10-ethoxycarbonoxyazuleno[2,1-*b*]pyran (**3l**)**:** Deep red prism (from MeOH). mp 209-210 ºC; IR (KBr, cm^{-1}): *v* 3339 (NH_2), 2212 (CN), 1656 (C=O). ^{1}H-NMR (DMSO): *δ* 1.41 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.36 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.51 (1H, s, CH), 7.20 (2H, s, NH_2), 6.50 (1H, dd, *J* = 9.6, 9.6 Hz), 7.56 (1H, dd, *J* = 8.0, 8.2 Hz), 7.64 (1H, d, *J* = 8.4 Hz), 7.68 (1H, d, *J* = 9.6 Hz), 7.77 (1H, dd, *J* = 9.6, 9.6 Hz), 8.04~8.07 (2H, m), 8.09 (1H, d, *J* = 9.6 Hz), 9.42 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{23}H_{17}N_3O_5$: C 66.50, H 4.12, N 10.12. Found: C 66.64, H 4.33, N 10.26.

2-Amino-3-cyano-4-(2-thienyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3m**)**:** Deep red prism (from MeOH). mp 208-210 ºC; IR (KBr, cm^{-1}): *v* 3328 (NH_2), 2217 (CN), 1657 (C=O). ^{1}H-NMR (DMSO): *δ* 1.40 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.35 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.63 (1H, s, CH), 6.90 (1H, d, *J* = 3.2 Hz), 7.12 (2H, s, NH_2), 7.13~7.15 (2H, m), 7.28 (1H, d, *J* = 4.4 Hz), 7.51 (1H, dd, *J* = 9.6, 9.6 Hz), 7.66 (1H, dd, *J* = 9.6, 10.0 Hz), 7.81 (1H, dd, *J* = 9.6, 9.6 Hz), 8.22 (1H, d, *J* = 9.6 Hz), 9.39 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{21}H_{16}N_2O_3S$: C 67.00, H 4.28, N 7.44. Found: C 67.24, H 4.36, N 7.61.

2-Amino-3-cyano-4-(2-furyl)-10-ethoxycarbonylazuleno[2,1-*b*]pyran (**3n**): Deep red prism (from MeOH). mp 187-189 ºC; IR (KBr, cm^{-1}): *v* 3341 (NH_2), 2213 (CN), 1652 (C=O). ^{1}H-NMR (DMSO): *δ* 1.40 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.39 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.90 (2H, s, NH_2), 5.38 (1H, s,

CH), 6.19 (1H, d, *J* = 2.8 Hz), 6.30 (1H, dd, *J* = 1.8, 2.6 Hz), 7.30 (1H, d, *J* = 1.0 Hz), 7.47 (1H, dd, *J* = 9.6, 9.6 Hz), 7.62 (1H, dd, *J* = 9.6, 10.0 Hz), 7.76 (1H, dd, *J* = 9.6, 9.6 Hz), 8.24 (1H, d, *J* = 9.6 Hz), 9.39 (1H, d, *J* = 9.6 Hz). *Anal*. Calcd for $C_{21}H_{16}N_2O_4$: C 69.99, H 4.48, N 7.77. Found: C 69.87, H 4.61, N 7.65.

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