An Efficient Multicomponent Synthesis of Acridinedione Employed by Ammonium Molibdate and Study of Aantimicrobial Activity

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ABSTRACT:
An effective ammonium molibdate catalyst is used to promote a straight forward method of producing acridinedione using the one-pot, three-component condensation of an aromatic aldehyde, 5,5-dimethyl-1,3-cyclohexanedione (dimedone), and p-methoxy aniline in isopropanol in the presence of ammonium molibdate as active catalyst. This green procedure has desirable advantages, including fast work-up, catalyst recovery and reusability, and excellent yields. Melting points, elemental analysis, spectral data (^{1}HNMR, ^{13}CNMR, and LCMS), and the assessment of antibacterial activity were used to characterize each of the synthesized acridinedione. In addition to studied antimicrobial activity against bacterial as well as fungal strains.

KEYWORDS: Acridinedione; aromatic aldehyde, Ammonium molibdate; p-methoxy aniline, antimicrobial activity

1. INTRODUCTION:

The ability to synthesize complex compounds quickly and effectively without the need to isolate intermediates makes multicomponent reactions (MCRs) an exciting and important area of chemistry [1]. In MCR condensations, three or more compounds react in a single event but in a sequential manner to create a new product that has all of the necessary components of the initial materials. Because MCRs use less energy and produce less trash, they satisfy the criteria for an environmentally beneficial process. Additionally, MCRs are simpler and more efficient to synthesize than traditional chemical processes. Consequently, it is of great importance to find new MCRs and fully utilize existing ones. A novel class of laser dyes called acridinedione dyes has comparable laser efficiency to coumarin-102 [2, 3]. Because of their tricyclic structures, which shield the enamine moieties, these dyes have been demonstrated to more closely resemble NADHanalogues [4]. Both the concept and synthesis of an acridinedione-functionalized gold nanoparticle-based PET anion sensor [6] and 1,3-dithiol-linked acridinedione functionalized gold nanoparticles [5] were recently reported. The Hantzsch method, which entails the heat reaction of 5,5-dimethyl-1,3-cyclohexanedione (dimedone) with an aldehyde and ammonia, was used to create 1,8-(2H,5H)-Acridinedione.

A variety of techniques have been employed to create acridinedione, such as the use of microwaves [7, 8], ionic liquids [9, 10], LiBr [11], proline [12], silica-bonded S-sulfonic acid [13], ceric ammonium nitrate [14], and catalysts such as methane sulphonic acid [28]. Although many of the methods reported have limitations, including the use of toxic chemical solvents, long reaction times, low yields, the generation of side products, and multistep synthesis, acridinedione are also produced in aqueous media [15–18]. Consequently, there is a need and opportunity to create a quick, simple, and environmentally safe method of obtaining acridinedione.

The production of 9-Phenyl-3, 3, 6, 6-tetramethyl-10-p-tolyl-hexahydro acridine-1,8-dione comparable to the reaction of substituted aromatic aldehydes, dimedone, and p-Toluidine in isopropanol at 75°C was shown to be catalyzed by an effective ammonium molibdate. Ammonium molibdate was used as the catalyst in this study's synthesis of Acridinedione

2. METHODS AND MATERIALS:

2.1. EXPERIMENTAL:

The businesses Fluka, Aldrich, and Merck supplied the chemicals. Unless otherwise indicated, all yields are for isolated products. 1H On a Bruker DRX-400 Avance, at room temperature, nuclear magnetic resonance (NMR) (400 MHz) and 13C NMR (100 MHz) spectra were acquired using Deuterochloroform ($CDCl_3$) as the solvent and tetramethyl silanes as the internal standard. Using a Shimadzu spectrometer, Fourier transforms infrared (IR) spectra were acquired as KBr discs. A Varion Saturn 2000 gas chromatograph–mass spectrometer was used to determine the mass spectra. A Perkin Elmer 2400 CHN elemental analyzer flowchart was used to do elemental

2.2. General procedure for synthesis of 9-Phenyl-3, 3, 6, 6-tetramethyl-10-p-methoxyaniline-hexahydro acridine-1,8-dione (4a-4j):

As determined by thin-layer chromatography (hexane: ethyl acetate; 6:4), a mixture of substituted aldehyde 1 (10 mmol), dimedone 2 (20 mmol), p-methoxyaniline3 (10.5 mmol), ammonium molibdate (10 mmol%), and isopropanol (50 mL) was put in a 50 mL flask, heated to 70°C, and agitated for the proper amount of time. The mixture was cooled once the reaction was finished, and the pure product was obtained by filtering, drying, and recrystallizing it from methanol (Scheme-1). Based on their melting temperatures, elemental analysis, and spectral data (^{1}H NMR, ^{13}C NMR, and mass spectra (LCMS)), all of the products were crystalline and completely described.

2. Spectral data for compounds (4a-4j):

2.2.1.9-Phenyl-3,3,6,6-tetramethyl-10-p-methoxyphenyl-hexahydroacridine-1,8-di one(4a):

Paleredsolid:Yield-87%;M.P-174-176^{0}C;^{1}HNMR(400MHz,$CDCl_3$)δppm:1.094(s,6H,2× CH_3), 1.159(s,6H,2×CH_3),1.915–2.208(m,8H,4×CH_2), 2.413(s,3H,CH_3), 5.378(s,1H,CH), 7.025–7.356(m,5H,Ar-H),7.494(d,d,J=1.5,8.8Hz,2H,Ar-H),7.550(d,d,J=2.5,9.2Hz,2H,Ar-H)ppm;^{13}CNMR(100MHz,$CDCl_3$)δppm:21.94,28.08,29.88,31.08,34.58,40.59,51.42,112.57,115.26,128.12,128.55,129.02,131.65,132.28,134.51,138.51,141.09,148.27,152.67,192.08;LCMS(m/z):440.58(M+H)$^+$;Molecularformulae:$C_{30}H_{33}NO_2$:AnalysisofElements:Calculated:C-82.00;H-7.52;N-3.19;Obtained:C-81.92;H-7.50;N-3.29.

2.2.2.9-(4-Hydroxyphenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenyl-hexahydroacridine-1,8-dione(4b)

PaleRedsolid:Yield-93%;M.P-178-180^{0}C;^{1}HNMR (400MHz, $CDCl_3$) δppm: 0.987(s,6H, 2×CH_3),1.104(s,6H,2×CH_3),1.885–2.186(m,8H,4×CH_2), 2.354(s,3H,CH_3), 5.414(s,1H,CH), 7.021–7.240(m,4H,Ar-H), 7.612(d, J=7.0Hz, 2H,Ar-H), 7.784(d, J=8.0Hz, 2H, Ar-H), 9.231 (s,1H,OH);^{13}CNMR(100MHz,$CDCl_3$)δppm: 21.74, 27.84, 29.21, 32.98, 33.84, 42.45, 51.74, 114.04,116.59,128.75,128.88,129.35,130.54,132.89,134.66,138.04,141.54, 152.56, 154.09, 193.79;LCMS(m/z):456.57$(M+H)^+$;Molecularformulae:$C_{30}H_{33}NO_3$:AnalysisofElements:Calculated:C-79.12;H-7.25;N-3.08;Obtained:C-79.05;H-7.22;N-3.03

2.2.3.9-(4-Methoxyphenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenyl-hexahydro acridine-1,8-dione(4c):

PaleRedsolid:Yield-90%;M.P-204-206^{0}C;^{1}HNMR(400MHz,$CDCl_3$)δppm:0.954(s,6H,2× CH_3),1.154(s,6H,2×CH_3),2.102–2.274(m,8H,4×CH_2),2.275(s,3H,CH_3),3.714(s,3H,OCH_3), 5.185(s,1H,CH),7.115–7.384(m,4H,Ar-H),7.447(d,J=8.8Hz,2H,Ar-H),7.971(d,J=8.2Hz, 2H, Ar-H);^{13}CNMR (100MHz,$CDCl_3$) δppm: 21.51,26.04, 28.87, 31.25, 34.95, 42.54, 52.86, 108.07,114.56,126.97,128.14,129.55,130.74,131.95,133.04,139.82,142.04,149.87,152.87,196.57;LCMS (m/z):469.87$(M)^+$;Molecularformulae:$C_{31}H_{35}NO_3$:AnalysisofElements:Calculated:C-79.32;H-7.46;N-2.98;Obtained:C-79.25;H-7.45;N-3.09.

2.2.4.9-(4-Methylphenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenylhydroacridine-1,8-dione(4d):

PaleRedsolid:Yield-89%;M.P-210-212^{0}C:^{1}HNMR(400MHz,$CDCl_3$)δppm:0.917(s,6H,2× CH_3),1.024(s,6H,2×CH_3),2.114–2.241(m,8H,4×CH_2),2.450(s,3H,CH_3),5.257(s,1H,CH), 7.105–7.258(m,4H,Ar-H),7.369(d,J=7.6Hz,2H,Ar-H),7.487(d,J=8.0Hz,2H,Ar-H);^{13}CNMR (100MHz,$CDCl_3$)δppm:20.89,27.53,29.82,31.74,33.5,39.77,51.76,108.58,114.08,126.89,127.45,129.07, 130.45,132.14,132.86,136.50,140.47,150.04,151.73,195.44;LCMS(m/z):454.87$(M+H)^+$;Molecularformulae:$C_{31}H_{35}NO_2$:AnalysisofElements:Calculated:C-82.12;H-7.72;N-3.09;Obtained:C-82.05;H-7.70;N-3.17.

2.2.4.9-(4-N(CH3)2phenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenyl-hexahydroacridine-1,8-dione(4e):

PaleRedsolid:Yield-87%;M.P-218-220^{0}C:^{1}HNMR(400MHz,$CDCl_3$)δppm:0.917(s,6H, 2×CH_3),1.024(s,6H,2×CH_3),2.114–2.241(m,8H,4×CH_2),2.450(s,3H,CH_3),5.257(s,1H,CH), 7.105–7.258(m,4H,Ar-H),7.369(d,J=7.6Hz,2H,Ar-H),7.487(d,J=8.0Hz,2H,Ar-H);^{13}CNMR (100MHz,$CDCl_3$)δppm:20.89,27.53,29.82,31.74,33.5,39.77,51.76,108.58,114.08,126.89,127.45,129.07, 130.45,132.14,132.86,136.50,140.47,150.04,151.73,195.44;LCMS(m/z):454.87$(M+H)^+$;Molecularformulae:$C_{31}H_{35}NO_2$:AnalysisofElements:Calculated:C-82.12;H-7.72;N-3.09;Obtained:C-82.05;H-7.70;N-3.17.

2.2.5.9-(4-Chlorophenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenylhexahydroacridine-1,8-dione(4f):

PaleRedsolid:Yield-89%;M.P-232-234^{0}C;^{1}HNMR(400MHz,$CDCl_3$)δppm:0.887(s,6H,2× CH_3),1.074(s,6H,2×CH_3),2.078–2.292(m,8H,4×CH_2),2.348(s,3H,CH_3),5.224(s,1H,-CH-), 2.087–2.287(m,8H,4×CH_2),7.089–7.247(m,4H,Ar-H),7.478(d,J=8.0Hz,2H,Ar-H),7.547(d, J=9.2Hz,2H,Ar-H);^{13}CNMR(100MHz,$CDCl_3$)δppm:21.01,26.51,29.42,32.87,33.39,41.87, 50.64,108.79,113.44,128.24,128.98,129.56,130.64,132.49,132.88,136.56139.07,151.08,151.19,196.99;LCMS(m/z):474.45$(M+H)^+$;Molecularformulae:$C_{30}H_{32}ClNO_2$:AnalysisofElements:Calculated:C-76.04;H-6.76;N-2.96;Obtained:C-75.94;H-6.78;N-2.99.

2.2.6.9-(4-Bromophenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenylhexahydroacridine-1,8-dione(4g):

DarkRedsolid:Yield-88%;M.P-241-243^{0}C;1HNMR(400MHz,$CDCl_3$)δppm:0.874(s,6H,2× CH_3),1.099(s,6H,2×CH_3),2.022–2.124(m,8H,4×CH_2),2.230(s,3H,CH_3),5.320(s,1H,CH), 7.104–7.384(m,4H,Ar-H),7.484(d,J=8.8Hz,2H,Ar-H),7.778(d,J=6.8Hz,2H,Ar-H);^{13}CNMR

(100MHz,$CDCl_3$)δppm:20.89,27.20,29.09,32.44,33.59,40.79,51.07,109.05,113.55,127.65,128.45,129.02,130.54,131.88,132.12,136.81,141.54,150.55,151.55,195.84;LCMS(m/z):518.95$(M+H)^+$;Molecularformulae:$C_{30}H_{32}BrNO_2$:AnalysisofElements:Calculated:C-69.51;H-6.18;N-2.70;Obtained:C-69.44;H-6.16;N-2.78.

2.2.7.9-(4-Cyanophenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenylhexahydroacridine-1,8-dione(4h):

DarkRedsolid:Yield-85%;M.P-204-206^0C;^{1}HNMR(400MHz,$CDCl_3$)δppm:0.974(s,6H,2×CH_3),1.012(s,6H,2×CH_3),2.011–2.287(m,8H,4×CH_2),2.494(s,3H,CH_3),5.454(s,1H,CH),7.010–7.324(m,4H,Ar-H),7.749(d,J=7.6Hz,2H,Ar-H),7.887(d,J=9.0Hz,2H,Ar-H);^{13}CNMR (100MHz,$CDCl_3$)δppm:22.39,27.54,29.27,31.08,34.53,40.43,52.56,111.54,114.52,118.44,128.74,128.98,129.14,132.77,134.01,138.46,141.04,149.08,153.53,193.99;;LCMS(m/z):465.19$(M+H)^+$;Molecularformulae:$C_{31}H_{32}N_2O_2$:AnalysisofElements:Calculated:C-80.17;H-6.89;N-6.03;found:C-80.11;H-6.87;N-6.13.

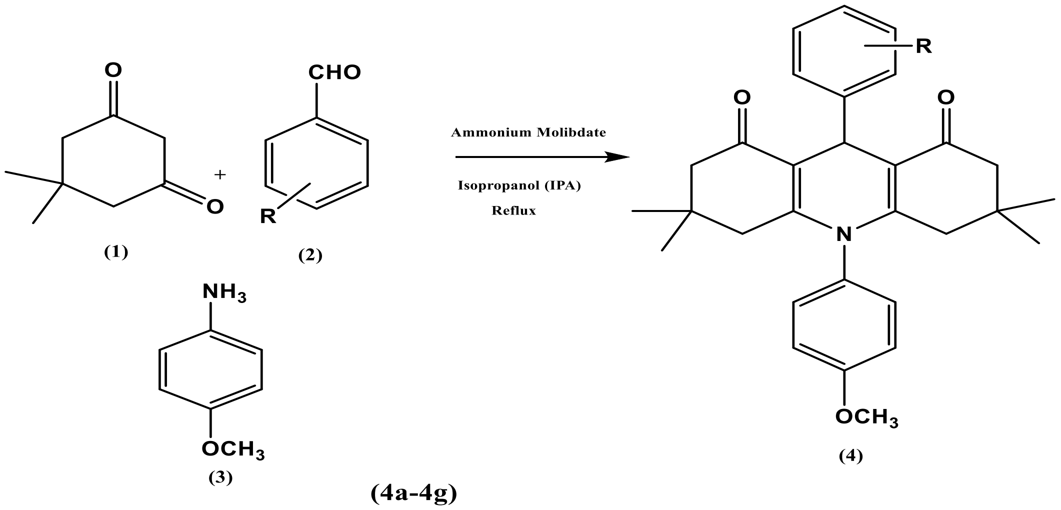
2.2.7.9-(3-Nitrophenyl)-3,3,6,6-tetramethyl-10 p-methoxyphenyl hexahydroacridine-1,8-dione(4i):

DarkRedsolid:Yield-84%;M.P-194-196^0C;^{1}HNMR(400MHz,$CDCl_3$)δppm:0.897(s,6H,2×CH_3),0.986(s,6H,2×CH_3),2.044–2.217(m,8H,4×CH_2),2.494(s,3H,CH_3),5.454(s,1H,CH), 7.187–7.354(m,4H,Ar-H),7.584(d,J=6.6Hz,2H,Ar-H),7.848(d,J=8.4Hz,2H,Ar-H);^{13}CNMR (100MHz,$CDCl_3$)δppm:20.37,27.58,29.54,32.45,34.53,42.43,51.56,112.54,114.55,120.87,128.14,128.87,129.46,131.07,132.69,137.74,140.88,152.08,152.74,196.99;LCMS(m/z):465.74$(M+H)^+$;Molecularformulae:$C_{31}H_{32}N_2O_2$:AnalysisofElements:Calculated:C-80.17;H-6.89;N-6.03;found:C-80.11;H-6.87;N-6.13.

2.2.7.9-(4-Nitrophenyl)-3,3,6,6-tetramethyl-10-p-methoxyphenyl hexahydroacridine-1,8-dione(4j):

DarkRedsolid:Yield-83%;M.P-196-198^0C;^{1}HNMR(400MHz,$CDCl_3$)δppm:0.947(s,6H,2×CH_3),1.014(s,6H,2×CH_3),1.968–2.289(m,8H, 4×CH_2),2.410 (s,3H,CH_3), 5.489(s,1H, CH), 7.159–7.387(m,4H,Ar-H),7.584(d,J=7.6Hz,2H,Ar-H),7.817(d,J=9.0Hz,2H,Ar-H);^{13}CNMR (100MHz,$CDCl_3$)δppm:21.47,26.87,29.09,31.08,32.53,42.43,51.56,113.54,115.52,119.55,128.26,128.87,129.11,132.28,134.57,137.46,142.74,153.08,155.53,198.07;LCMS(m/z):465.22$(M+H)^+$;Molecularformulae:$C_{31}H_{32}N_2O_2$:AnalysisofElements:Calculated:C-80.18;H-6.88;N-6.05;found:C-80.12;H-6.86;N-6.12.

3. 1. RESULTS AND DISCUSSION:



(4a-4g)

R = H, 4-OH, 4-OCH_3, 4-CH_3 , 4-N(CH3)2, 4-Cl, 4-Br, 4-CN, 4-NO2

(Scheme-1)

Under heat conditions, the process produced a versatile, ecologically safe, one-pot, three-component synthesis of 9-arylacridinediones by reacting substituted aromatic aldehydes, dimedone, p-methoxy aniline 3 (1.5 mmol), ammonium molibdate (5 mmol%), and isopropanol (Scheme 1).

Initially, p-methoxyanilnine (1.5 mmol), dimedone (2 mmol), and substituted aromatic aldehydes (1 mmol) were agitated in isopropanol at 75◦C during refluxing. Only 60% of the anticipated product 4c was produced after 5 hours. The same reaction was conducted under comparable conditions with varying concentrations of ammonium molibdate acid in order to develop the yield and optimize the reaction conditions. The circumstances were set up for 100% conversion in each reaction

These derivatives' reaction conditions were adjusted using a variety of catalysts, catalyst concentrations, and solvents. Whereas varying amounts of catalyst were used during the reaction, the highest yield of compounds was obtained in the presence of zinc oxide (ZnO) catalyst compared to oxidatively related catalysts like titanium dioxide (TiO2), copper oxide (CuO), and ammonium molibdate (Table I).

Table-I: The reaction of aryl aldehyde, dimedone, and Ammonium molibdate (4b):

Entry	Catalyst	Time (hrs)	Yield (%)
1	ZnO	8	59
2	TiO_2	7	70
3	CuO	10	68
4	Ammonium molibdate	5	93

The model reaction involved the use of many solvents, including DMF, ethanol, methanol, cyclohexane, isopropanol acetonitrile, and others. With a 92% product yield, it was determined to be the most effective medium for the reaction. As a result, it was utilized as the solvent for further reactions due to its quick work-up, greater yield, and environmentally friendly nature.

Table-II: The reaction of aryl aldehyde, dimedone, and Ammonium molibdate (4b):

Entry	Catalyst	Time (hrs)	Yield (%)
1	DMF	5	45
2	IPA	5	93
3	CH_3CN	5	62
4	EtOH	5	56
5	MeOH	5	67

The yield of 4c was raised to 92%, indicating a notable improvement. Use of only 1.5m mol% was sufficient to drive the reaction forwards within 2.0hrs. The results were not improved by using the catalyst in its maximum concentrations. The yield surprisingly dropped to 77%, as indicated in Table III, even though the reaction time could be shortened to 1 hour by using 2.0 mmol% ammonium molibdate.

Table-III: Different amounts of catalyst in Isopropanol at reflux (4b):

Entry	**Amount** catalyst**(mmol)**	Time (hrs)	Yield (%)
1	0.5	3	Traces
2	1.0	3	42

3	1.5	3	58
4	2.0	3	93

3.2. BIOLOGICAL ACTIVITIES:

Antibacterial and antifungal activities:

The micro broth dilution method was used to assess the named derivatives(4a-4j) *in-vitro* antibacterial and antifungal properties. Gram(-Ve) (*E. coli and P. aeruginosa*) and gram(+Ve) (*B. subtilis* and *S. aureus*) microorganisms were used to test the *invitro* antibacterial activity. The bacteria Aspergillus Niger and C. albicans were used to test the antifungal activity in vitro. Streptomycin was utilized as the conventional medication for this investigation in order to screen for microorganisms. Ketonozole was used to screen for antifungals and both of them is references drugs The Culture Collection and Geneank (MTCC), located in Chandigarh, India, provided the standard strains used to screen for antibacterial and antifungal activity. Bacteria were nourished with Mueller Hinton Broth, whereas fungi were grown with Sabouraud dextrose Broth. By analyzing the turbidity, the inoculum size for the test strain was optimized to 108 CFU/mL. Primary and secondary evaluations of the results were documented. The substances under investigation and conventional medications were diluted twice in succession to create a stock solution (2000 µg/mL).

Table-IV: Antimicrobial activity of compounds (4a-4j)

Entry	Antibacterial MIC (µg/mL)				Antifungal MIC (µg/mL)	
Strains	**B. subtilis**	**S. aureus**	**P. aeruginosa**	**E. coli**	**A. Niger**	**C. Albicans**
4a	06	05	08	07	05	05
4b	17	16	18	17	13	10
4c	18	16	18	14	13	10
4d	18	19	16	15	12	10
4e	14	13	16	14	10	11
4f	20	18	18	17	17	14
4g	22	20	21	21	13	14
4h	07	08	07	06	18	18
4i	08	07	10	07	18	19
4j	06	08	05	06	19	18
Streptomycin	25	25	25	25	-	-
Ketonozole	-	-	-	-	22	22
DMSO						

500, 250, and 100 µg/mL quantities of the substances were utilized in the initial analysis. The compounds identified as active in this initial screening were subjected to additional analysis. Concentrations of 200, 100, 50, and 25 µg/mL were employed in secondary screening. The inoculation wells were incubated in a humid environment at 37°C for the entire night. The minimum inhibitory concentration (MIC) was defined as the highest dilution that demonstrated complete inhibition. The produced compounds demonstrated moderate to good inhibition, according to the MIC values. Compounds 4d and 4e demonstrated high activity against strains of bacteria. Compounds 4h, 4i and 4j was displayed effiency against all fungal strains, according to the MIC values of antifungal activity and Table-IV lists the antimicrobial activity of substances (4a–4j)

4. CONCLUSIONS

We have developed a new, easy, and efficient technique for the synthesis of substituted acridinedione derivatives using ammonium molibdate as an efficient catalyst. It entails the condensation of substituted aromatic aldehyde, dimedone and P-methoxyanilnine in an isopropanol medium using a single pot and three components. This method's mild conversion, ease of experimentation, compatibility with various functional groups, high product yields, and straightforward work-up process make it attractive for producing a variety of such derivatives. The antimicrobial activity of the identified compounds was also examined. The compounds with electron-withdrawing groups showed excellent active potential.

5. ACKNOWLEDGEMENTS

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6. REFERENCES:

1. J. Zhu, H. Bienayme, Multicomponent Reactions, Wiley, Weinheim, 2005.
2. P. Shanmugasundaram, P. Murugan, V.T. Ramakrishnan, N. Srividya, P. Ramamurthy, Synthesis of acridinedione derivatives of laser dyes, Heteroatom. Chem. 7 (1996) 17–22.
3. N. Srividya, P. Ramamurthy, P. Shanmugasundaram, V.T. Ramakrishnan, Synthesis, characterization, and electrochemistry of some acridine-1,8-dione dye, J. Org. Chem. 61 (1996)5083–5089.
4. C. Selvaraju, P. Ramamurthy, Excited-state behavior and photoionization of 1,8-acridinrdione dyes in micelles – comparison with NADH oxidation, Chem. Eur. J. 10 (2004)2253–2262.
5. R. Velu, E.J.P. Malar, V.T. Ramakrishnan, P. Ramamurthy, Acridinedione-functionalized gold nanoparticles and model forthe binding of 1,3-dithiol linked acridinedione on gold clusters, Tetrahedron Lett. 51 (2010) 5680–5685.
6. R. Velu, V.T. Ramakrishnan, P. Ramamurthy, Selective fluorideion recognition by a thiourea based receptor linked acridinedionefunctionalized gold nanoparticles, J. Photochemical. Photobiol. A:Chem. 217 (2011) 313–320.
7. A.A. Abdelhamid, S.K. Mohamed, A.M. Maharramov, A.N.Khalilov, M.A. Allahverdiev, Facile and efficient synthesis of Acridinedione from primary amino alcohols via three-component condensation reactions assisted by microwave irradiation. Saudi Chem. Soc. (2011), http://dx.doi.org/10.1016/j.jscs.2011.10.005.
8. S.K. Singh, K.N. Singh, Eco-friendly and facile one-pot multicomponent synthesis of Acridinedione in water undermicrowave,J. Heterocyclic Chem. 48 (2011) 69–73.

9. M. Dabiri, M. Baghbanzadeh, E. Arzroomchilar, 1-Methylimidazolium trifluoroacetate ([Hmim]TFA): an efficient reusable acidic ionic liquid for the synthesis of 1,8-dioxooctahydroxanthenes and 1,8-dioxo-decahydroacridines,Catal. Commun. 9 (2008) 939–942.
10. D.Q. Shi, S.N. Ni, F. Yang, J.W. Shi, G.L. Dou, X.Y. Li, X.S.Wang, An efficient synthesis of polyhydroacridine derivatives bythe three-component reaction of aldehydes, amines and dimedonein ionic liquid, J Heterocyclic Chem. 45 (2008) 653–660.
11. D. Kumar, J.S. Sandhu, Efficient, solvent-free, microwave enhanced condensation of 5,5-dimethyl-1,3-cyclohexanedionewith aldehydes and imines using LiBr as inexpensive, mild catalyst, Synth. Commun. 40 (2010) 510–517.
12. K. Venkatesan, S.S. Pujari, K.V. Srinivasan, Proline-catalyzed simple and efficient synthesis of 1,8-dioxo-decahydroacridinesinaqueous ethanol medium, Synth. Commun. 39 (2009) 228–241.
13. K. Niknam, F. Panahi, D. Saberi, M. Mohagheghnejad, Silicabonded S-sulfonic acid as recyclable catalyst for the synthesis of 1,8-dioxo-decahydroacridines and 1,8-dioxooctahydroxanthenes, J. Heterocyclic Chem. 47 (2010) 292–300.
14. M. Kidwai, D. Bhatnagar, Ceric ammonium nitrate (CAN) catalyzed synthesis of n-substituted decahydroacridine-1,8-dionesin PEG, Tetrahedron Lett. 51 (2010) 2700–2703.
15. Y.-B. Shen, G.-W. Wang, Solvent-free synthesis of xanthematin's and acridinedione, Arkivoc xvi (2008) 1–8.
16. J.-J. Xia, K.-H. Zhang, Synthesis of N-substituted acridinedione and polyhydroxy-quinoline derivatives in refluxing water, Molecules 17 (2012) 5339–5345.
17. D.Q. Shi,J.W. Shi, H. Yao, Clean synthesis of 9,10-diarylacridinederivatives in aqueous media, Chin. J. Org. Chem. 29 (2009)239–244.
18. W. Shen, L.-M. Wang, H. Tian, J. Tang, J.-J. Yu, Brønstedacidic imidazolium salts containing perfluoroalkyl tails catalyze done-pot synthesis of 1,8-dioxo-decahydroacridines in water, J. Fluorine Chem. 130 (2009) 522–527.