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Novel Acid Anthraquinone Dyes and Their Application on Various Fibres and Microbial Studies

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Various anthraquinone acid dyes have been synthesized by condensation of bromamine acid with N-methylpiprazine. This condensed product was diazotized and coupled with various naphthalene based acid coupling components to get novel series of acid anthraquinone dyes. The dyeing performance on wool, silk and nylon fibres has been assessed. These dyes have been found to give a wide range of orange to violet shades on each fibre. All the dyes give good to very good light fastness on each fibre. The percentage dye-bath exhaustion on different fibres was good and acceptable. The dyed fibres showed moderate to very good fastness to light, washing and rubbing. All the synthesized dyes have been screened for their antimicrobial activity.

Key Words: Anthraquinone dyes, Application.

INTRODUCTION

Acid anthraquinone dyes were probably originally so named because of the presence in their molecules of one or more sulphonic acid or other acidic group. The term applies to an application class rather than a chemical class. Since acidic groups are also presents in many moderent, direct and reactive dyes, their presence is not a distinguishing feature. Acid dyes have found wide application in dyeing wool, polyamide fibres and blends of both fibres[1,2] but they meet high requirements as regards their application and fastness. The characteristics chromophore of the anthraquinone series consists of one or more carbonyl groups in association with a conjugated system. Anthraquinone dyes and colorants make important contributions to a number of widely different usage groups. The more important are acid, direct, disperse, moderant, vat, solvent and reactive dyes even as pigments[3-8] as a class anthraquinone acid dyes are known for their specific colour and high light fastness characteristics. Acid anthraquinone dyes provide a number of bright fast to light blue and green neither available among the azo dyes nor in fact equaled by any other class. The colour of anthraquinone dyes depends upon substitution among definite lines[9,10].

EXPERIMENTAL

The purity of all the dyes has been check by TLC[11], IR spectra were recorded in KBr on a Perkin-Elmer Model 881 spectrophotometer and ^{1}H NMR spectra on

Brucker Avance II 400 NMR spectrometer (SAIF, Panjab University, Chandigarh) using TMS as internal standard and DMSO as solvent. Absorption spectra were recorded on a Shimadzu UV-1700 spectrophotometer. Elemental analysis of C, H and N was carried out on Carlo Erba 1108 instruments. The light fastness was assessed in accordance with BS: 1006-1978[12], the rubbing fastness test was carried out with corkmeter (atlas) in accordance with AATCC-1961[13] and the wash fastness test in accordance with IS: 765-1979[14].

1-Amino-4-(N-methylpiperazinyl)anthraquinone-2-sulfonic acid B: Bromamine acid A (0.1 mol) was dissolved in 400 mL hot water (70-80 °C), N-methylpeperazine (0.1 mol), acid binding agent sodium bicarbonate (0.2 mol), copper sulfate (0.5 g) and ferrous sulfate (0.5 g) catalysts were then added to it. The reaction mixture was stirred and heated to 90 °C. Maintained temperature 90 °C for 6 h under stirring. Charcoal (1 g) was added and stirred for 15 min and the solution was filtered by slowly adding dilute hydrochloric acid (1:1) under stirring. The product was salted out by adding sodium chloride, cooled to room temperature, stirred for 0.5 h at room temperature, filtered and washed with 10 % (w/v) brine solution. Dried it (85 % yield). IR (KBr, ν_{max}, cm^{-1}): 3546, 3430 (-NH_2), 2925, 2837 (-CH_2- of N-methyl-piprazine), 1272 (C-N) 1668 (C=O), 1218, 1047 (-SO_3H)

Diazotization of 1-amino-4-(N-methylpiperazinyl)anthraquinone-2-sulfonic acid C: The solution of 1-amino-4-(N-methylpiperazinyl)anthraquinone-2-sulfonic acid B (0.01 mol) in water. Hydrochloric acid (0.015 mol) was added to this and well stirred. The solution was cooled to 0-5 °C in an ice bath. A solution of sodium nitrite ($NaNO_2$ 0.015 mol) in water (8 mL) previously cooled to 0-5 °C, was then added over a period of 5 min with stirring. The stirring was continued for 1 h, maintained the same temperature with positive test for nitrous acid on starch iodide paper. After stirring 1 h, just destroyed excess of nitrous acid with require amount of a solution of sulfamic acid. The resulting diazo solution was obtained at 0-5 °C was used for subsequent coupling reaction.

Coupling of diazo solution with J-acid D: J-acid (2.39 g, 0.01 mol) was suspended in water (20 mL) and dissolved at neutral pH with sodium carbonate (10 % w/v) to obtain a clear solution. The solution was cooled to below 0-5 °C in an ice bath. To this well stirred solution, diazo chloride solution C was added drop wise over a period of 10-15 min maintained the pH 7.5-8.0 by simultaneous addition of sodium carbonate solution (10 % w/v). The stirring was continued for 3 h keeping the temperature at 0-5 °C. The temperature of reaction mixture was then raised to 60 °C and sodium chloride added to precipitate the colouring material. The stirring was continued for 1 h. Filter and washed with a small amount of sodium chloride solution (5 % w/v). The solid was dried at 80-90 °C and extracted with DMF. Coupling the DMF extract with excess of chloroform. The dye thus obtained was filtered, washed with chloroform and dried at 60 °C (83 % yield).

Following same procedure $\mathbf{D_2}$ to $\mathbf{D_{20}}$ were synthesized using various naphthalene base acid coupling components such as γ-acid, *m*-amino benzoyl k-acid, N-methyl

J-acid, sulfo γ-acid, chromotropic acid, violet acid, N-phenyl J-acid, G-acid, R-acid, N-benzoyl J-acid, Epsilon acid, Schaeffer acid, acetyl H-acid, N-(3-sulfophenyl)-γ-acid, acetyl γ-acid, *m*-aminobenzoyl H-acid, acetyl J-acid, H-acid and N-benzoyl H-acid. Characterization data, IR spectral data and ^{1}H NMR data of all the dyes are given in Tables 1-3 respectively.

TABLE-1
CHARACTERIZATION DATA OF **D_1-D_{20}**

Dye No.	Coupling component	m.f.	Yield (%)	Found (Calcd.) %			R_f value
				C	H	N	
D_1	J-acid	$C_{29}H_{23}N_5O_9S_2Na_2$	81	50.01 (50.07)	3.24 (3.31)	10.20 (10.07)	0.42
D_2	γ-Acid	$C_{29}H_{23}N_5O_9S_2Na_2$	85	50.01 (50.07)	3.24 (3.31)	10.03 (10.07)	0.45
D_3	*m*-Amino benzoyl K-acid	$C_{36}H_{27}N_6O_{13}S_3Na_3$	81	47.12 (47.16)	2.87 (2.95)	9.11 (9.17)	0.37
D_4	N-methyl J-acid	$C_{30}H_{25}N_5O_9S_2Na_2$	78	50.75 (50.63)	3.44 (3.52)	9.85 (9.87)	0.46
D_5	Sulfo γ-acid	$C_{29}H_{22}N_5O_{12}S_3Na_3$	81	43.60 (43.66)	2.70 (2.76)	8.72 (8.78)	0.41
D_6	Chromotropic acid	$C_{29}H_{21}N_4O_{13}S_3Na_3$	85	43.55 (43.50)	2.57 (2.63)	6.96 (7.02)	0.43
D_7	Violet acid	$C_{29}H_{21}N_4O_{13}S_3Na_3$	81	44.44 (44.50)	2.62 (2.68)	7.13 (7.18)	0.38
D_8	N-phenyl J-acid	$C_{35}H_{27}N_5O_9S_2Na_2$	77	54.40 (54.47)	3.43 (3.50)	9.01 (9.08)	0.47
D_9	G-acid	$C_{29}H_{21}N_4O_{12}S_3Na_3$	80	44.45 (44.50)	2.61 (2.68)	7.14 (7.16)	0.40
D_{10}	R-acid	$C_{29}H_{21}N_4O_{12}S_3Na_3$	78	44.43 (44.50)	2.60 (2.68)	7.11 (7.16)	0.44
D_{11}	N-benzoyl J-acid	$C_{29}H_{23}N_5O_9S_2Na_2$	81	50.01 (50.07)	3.24 (3.31)	10.20 (10.07)	0.42
D_{12}	Epsilon acid	$C_{29}H_{23}N_5O_9S_2Na_2$	85	50.01 (50.07)	3.24 (3.31)	10.03 (10.07)	0.45
D_{13}	Schaffer’s acid	$C_{36}H_{27}N_6O_{13}S_3Na_3$	81	47.12 (47.16)	2.87 (2.95)	9.11 (9.17)	0.37
D_{14}	Acetyl H-acid	$C_{30}H_{25}N_5O_9S_2Na_2$	78	50.75 (50.63)	3.44 (3.52)	9.85 (9.87)	0.46
D_{15}	N-(3-sulfophenyl)-γ-acid	$C_{29}H_{22}N_5O_{12}S_3Na_3$	81	43.60 (43.66)	2.70 (2.76)	8.72 (8.78)	0.41
D_{16}	Acetyl gamma acid	$C_{29}H_{21}N_4O_{13}S_3Na_3$	85	43.55 (43.50)	2.57 (2.63)	6.96 (7.02)	0.43
D_{17}	*m*-Amino benzoyl H-acid	$C_{29}H_{21}N_4O_{13}S_3Na_3$	81	44.44 (44.50)	2.62 (2.68)	7.13 (7.18)	0.38
D_{18}	Acetyl J-acid	$C_{35}H_{27}N_5O_9S_2Na_2$	77	54.40 (54.47)	3.43 (3.50)	9.01 (9.08)	0.47
D_{19}	H-acid	$C_{29}H_{21}N_4O_{12}S_3Na_3$	80	44.45 (44.50)	2.61 (2.68)	7.14 (7.16)	0.40
D_{20}	N-benzoyl H-acid	$C_{29}H_{21}N_4O_{12}S_3Na_3$	78	44.43 (44.50)	2.60 (2.68)	7.11 (7.16)	0.44

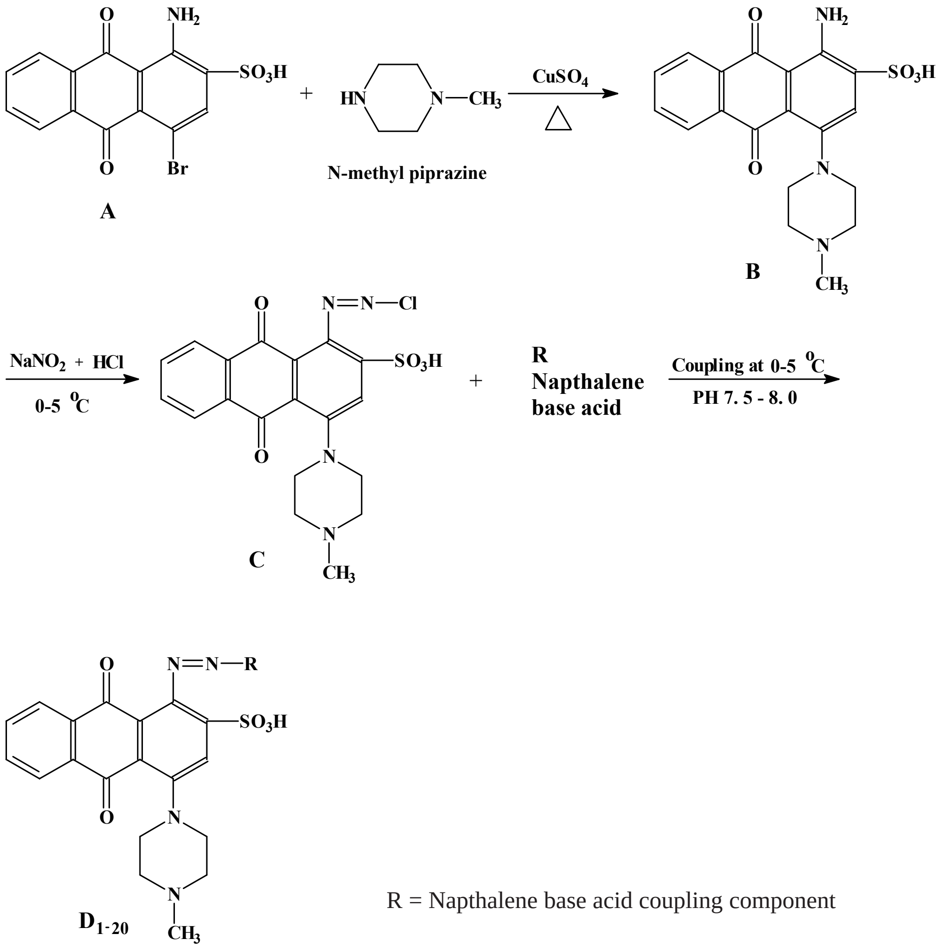
TABLE-2
IR SPECTRAL (cm^{-1}, ν_{max}) DATA OF **D$_1$** TO **D$_{20}$**

Comp.	IR Spectra
D$_1$	-NH$_2$ (3543, 3420), -OH (3390), -CH$_2$- (2925, 2837), -C=O str. (1672), -N=N- (1452), -C-N (1276), -S=O (1198, 1055)
D$_2$	-NH$_2$ (3548, 3428), -OH (3384), -CH$_2$- (2922, 2830), -C=O str. (1678), -N=N- (1462), -C-N (1269), -S=O (1200, 1049)
D$_3$	-NH$_2$ (3546, 3426), -OH (3400), -CH$_2$- (2918, 2832), -C=O str. (1682), -CONH- (1668), -N=N- (1455), -C-N (1272), -S=O (1194, 1047)
D$_4$	-NH- (3392), -OH (3376), -CH$_2$- (2926, 2835), -C=O str. (1675), -N=N- (1467), -C-N (1283), -S=O (1190, 1057)
D$_5$	-NH$_2$ (3532, 3424), -OH (3381), -CH$_2$- (2923, 2834), -C=O str. (1686), -N=N- (1466), -C-N (1264), -S=O (1198, 1043)
D$_6$	-OH (3388), -CH$_2$- (2928, 2841), -C=O str. (1670), -N=N- (1456), -S=O (1200, 1053)
D$_7$	-OH (3384), -CH$_2$- (2931, 2840), -C=O str. (1679), -N=N- (1435), -S=O (1205, 1055)
D$_8$	-NH- (3498), -OH (3376), -CH$_2$- (2922, 2838), -C=O str. (1682), -N=N- (1467), -S=O (1180, 1050)
D$_9$	-OH (3393), -CH$_2$- (2927, 2836), -C=O str. (1690), -N=N- (1454), -C-N (1284), -S=O (1182, 1062)
D$_{10}$	-OH (3410), -CH$_2$- (2932, 2845), -C=O str. (1665), -N=N- (1454), -S=O (1186, 1060)
D$_{11}$	-OH (3390), -CH$_2$- (2929, 2841), -C=O str. (1672), -CONH- (1668), -N=N- (1472), -S=O (1194, 1058)
D$_{12}$	-OH (3372), -CH$_2$- (2925, 2837), -C=O str. (1689), -N=N- (1453), -S=O (1197, 1056)
D$_{13}$	-OH (3377), -CH$_2$- (2923, 2834), -C=O str. (1670), -N=N- (1459), -S=O (1200, 1050)
D$_{14}$	-OH (3375), -CH$_2$- (2928, 2836), -C=O str. (1673), -CONH- (1656), -N=N- (1459), -S=O (1200, 1038)
D$_{15}$	-NH- (3399), -OH (3383), -CH$_2$- (2922, 2840), -C=O str. (1670), -N=N- (1458), -S=O (1196, 1047)
D$_{16}$	-OH (3368), -CH$_2$- (2924, 2839), -C=O str. (1671), -N=N- (1474), -S=O (1203, 1048)
D$_{17}$	-NH$_2$ (3548, 3440), -OH (3354), -CH$_2$- (2926, 2840), -C=O str. (1673), -CONH- (1646), -N=N- (1450), -C-N (1290), -S= (1189, 1051)
D$_{18}$	-OH (3367), -CH$_2$- (2922, 2837), -C=O str. (1686), -CONH- (1658), -N=N- (1463), -S=O (1208, 1051)
D$_{19}$	-NH$_2$ (3539, 3427), -OH (3378), -CH$_2$- (2925, 2838),-C=O str. (1672), -N=N- (1450), -C-N (1285), -S=O (1215, 1061)
D$_{20}$	-OH (3374), -CH$_2$- (2927, 2836), -C=O str. (1685), -CONH- (1652), -N=N- (1460), -S=O (1210, 1067)

Dyeing of fibres: All the dyes **D$_1$** to **D$_{20}$** were applied on wool, silk and nylon by using different procedure having dye bath material as given below:

DYE-BATH MATERIALS

Materials	For wool	For silk	For nylon
Fibre (g)	2.0	2.0	2.0
Amount of dye (mg)	40.0	40.0	40.0
Glauber salt (20 %) (mL)	1.5	1.0	1.0
Formic acid solution (10 %) (mL)	1.5	1.0	1.5
pH	3.0	3.0	3.0
MLR	1.40	1.40	1.40
Dyeing time (min)	60	40	90
Dyeing temperature (ºC)	100	85	100
Total volume (mL)	80	80	80



R = Napthalene base acid coupling component

Scheme

RESULTS AND DISCUSSION

The new series of acid anthraquinone dyes contain N-methylpiprazine were synthesized by condensation of bromamine acid with N-methylpiprazine. This condense product is diazotized and couple with various naphthalene based acid coupling components to produce the novel series of acid anthraquinone dyes. This series of dyes have found wide application in dyeing wool, polyamide fibre and blend. In this series chromophoric group such as carbonyl group is condence with conjugated system like anthraquinone to produce orange to violet shades and high light fast ness characteristics.

Exhaustion and fixation study: The percentage exhaustion of 2 % dyeing on wool fabric shows exhaustion 68.08 to 81.30 %, on silk fabric shows exhaustion 65.10 to 77.15 % and on nylon fabric shows exhaustion 68.17 to 76.45 %. The

TABLE-3
^{1}H-NMR SPECTRAL DATA OF $\mathbf{D_1}$ TO $\mathbf{D_{20}}$

Comp.	^{1}H-NMR
$\mathbf{D_1}$	-CH_3 (3H, s, 2.15), -CH_2- (2H, t, 2.40), -NH_2 (2H, s, 3.82) -OH (1H, s, 5.33), Ar-H (9H, m, 7.22-8.45)
$\mathbf{D_2}$	-CH_3 (3H, s, 2.10), -CH_2- (2H, t, 2.53), -NH_2 (2H, s, 3.74) -OH (1H, s, 5.22), Ar-H (9H, m, 7.26-8.35)
$\mathbf{D_3}$	-CH_3 (3H, s, 2.12), -CH_2- (2H, t, 2.50), -NH_2 (2H, s, 3.77) -OH (1H, s, 5.20), Ar-H (12H, m, 7.19-8.33), -NHCO- (1H, s, 9.61),
$\mathbf{D_4}$	-NH- (1H, s, 1.71), -CH_3 (3H, s, 2.14), -CH_2- (2H, t, 2.48), -OH (1H, s, 5.10), Ar-H (9H, m, 7.30-8.49)
$\mathbf{D_5}$	-CH_3 (3H, s, 2.16), -CH_2- (2H, t, 2.42), -NH_2 (2H, s, 3.74) -OH (1H, s, 5.15), Ar-H (8H, m, 7.40-8.62)
$\mathbf{D_6}$	-CH_3 (3H, s, 2.11), -CH_2- (2H, t, 2.33), -OH (1H, s, 5.17), Ar-H (8H, m, 7.45 -8.60)
$\mathbf{D_7}$	-CH_3 (3H, s, 2.18), -CH_2- (2H, t, 2.32), -OH (1H, s, 5.15), Ar-H (9H, m, 7.32 -8.52)
$\mathbf{D_8}$	-NH- (1H, t, 1.74), -CH_3 (3H, s, 2.19), -CH_2- (2H, t, 2.44), -OH (1H, s, 5.25), Ar-H (13H, m, 7.28-8.48)
$\mathbf{D_9}$	-CH_3 (3H, s, 2.10), -CH_2- (2H, t, 2.43), -OH (1H, s, 5.10), Ar-H (9H, m, 7.24-8.52)
$\mathbf{D_{10}}$	-CH_3 (3H, s, 2.13), -CH_2- (2H, t, 2.46), -OH (1H, s, 5.18), Ar-H (9H, m, 7.26-8.47)
$\mathbf{D_{11}}$	-CH_3 (3H, s, 2.17), -CH_2- (2H, t, 2.44), -OH (1H, s, 5.12), Ar-H (13H, m, 7.32-8.50), -NHCO- (1H, s, 9.55)
$\mathbf{D_{12}}$	-CH_3 (3H, s, 2.18), -CH_2- (2H, t, 2.46), -OH (1H, s, 5.14), Ar-H (9H, m, 7.35-8.54)
$\mathbf{D_{13}}$	-CH_3 (3H, s, 2.20), -CH_2- (2H, t, 2.42), -OH (1H, s, 5.17), Ar-H (10H, m, 7.29-8.56)
$\mathbf{D_{14}}$	-CH_3 (3H, s, 2.11), -CH_2- (2H, t, 2.49), -OH (1H, s, 5.10), Ar-H (8H, m, 7.30-8.55)
$\mathbf{D_{15}}$	-NH- (1H, t, 1.76), -CH_3 (3H, s, 2.21), -CH_2- (2H, t, 2.40), -OH (1H, s, 5.13), Ar-H (13H, m, 7.22-8.45)
$\mathbf{D_{16}}$	-CH_3 (3H, s, 2.16), -CH_2- (2H, t, 2.50), -OH (1H, s, 5.13), Ar-H (7.26-8.58), -NHCO- (1H, s, 9.70)
$\mathbf{D_{17}}$	-CH_3 (3H, s, 2.10), -CH_2- (2H, t, 2.46), -OH (1H, s, 5.14), Ar-H (12H, m, 7.31-8.52), -NHCO- (1H, s, 9.60)
$\mathbf{D_{18}}$	-CH_3 (3H, s, 2.19), -CH_2- (2H, t, 2.38), -OH (1H, s, 5.17), Ar-H (9H, m, 7.29-8.38), -NHCO- (1H, s, 9.73)
$\mathbf{D_{19}}$	-CH_3 (3H, s, 2.13), -CH_2- (2H, t, 2.45), -NH_2 (2H, s, 3.62) -OH (1H, s, 5.10), Ar-H (8H, m, 7.16-8.40),b-NHCO- (1H, s, 9.65)
$\mathbf{D_{20}}$	-CH_3 (3H, s, 2.19), -CH_2- (2H, t, 2.47), -OH (1H, s, 5.12), Ar-H (13H, m, 7.34-8.50), -NHCO- (1H, s, 9.72)

percentage fixation of 2 % dyeing on wool fabric shows fixation 79.32 to 92.90 %, for silk fabric shows fixation 80.88 to 91.25 % and for nylon fabric shows fixation 80.05 to 88.70 %. Exhaustion and fixation data of $\mathbf{D_1}$-$\mathbf{D_{20}}$ on wool, silk and nylon are given in Table-4.

Fastness properties: All the dyes give good to very good light fastness on wool, silk and nylon. All the dyes give moderate to very good fastness to washing and rubbing on each fiber. Fastness properties data of $\mathbf{D_1}$-$\mathbf{D_{20}}$ are given in Table-5.

TABLE-4
RESULTS OF EXHAUSTION AND FIXATION STUDY OF
$\mathbf{D}_1$-$\mathbf{D}_{20}$ ON WOOL, SILK AND NYLON

Dye No.	Wool		Silk		Nylon	
	Exhaustion (%)	Fixation (%)	Exhaustion (%)	Fixation (%)	Exhaustion (%)	Fixation (%)
$\mathbf{D}_1$	69.80	85.96	69.95	82.20	68.85	82.06
$\mathbf{D}_2$	79.43	86.08	69.85	80.88	76.25	86.56
$\mathbf{D}_3$	76.40	84.42	73.98	91.25	68.20	88.70
$\mathbf{D}_4$	76.25	90.10	73.15	84.76	70.20	84.76
$\mathbf{D}_5$	75.44	87.50	70.80	81.21	70.85	81.66
$\mathbf{D}_6$	74.10	82.09	74.28	86.17	74.93	86.08
$\mathbf{D}_7$	74.55	89.87	67.70	90.84	77.10	86.25
$\mathbf{D}_8$	68.08	79.32	67.70	84.93	73.15	83.39
$\mathbf{D}_9$	81.30	91.02	67.12	85.66	76.40	84.42
$\mathbf{D}_{10}$	74.93	83.41	68.20	87.98	75.50	86.10
$\mathbf{D}_{11}$	75.55	84.71	73.22	83.98	69.00	81.16
$\mathbf{D}_{12}$	68.08	79.32	67.65	89.43	68.17	83.61
$\mathbf{D}_{13}$	77.15	86.84	69.70	86.80	74.20	83.55
$\mathbf{D}_{14}$	75.98	80.94	71.37	82.66	76.45	86.98
$\mathbf{D}_{15}$	76.27	87.18	73.93	87.92	74.40	81.89
$\mathbf{D}_{16}$	71.70	81.58	66.90	91.18	71.82	84.23
$\mathbf{D}_{17}$	75.85	85.04	77.15	87.44	75.42	86.84
$\mathbf{D}_{18}$	69.40	85.73	75.80	89.05	76.32	87.78
$\mathbf{D}_{19}$	79.13	92.90	65.10	90.62	75.60	82.69
$\mathbf{D}_{20}$	72.60	87.47	72.00	88.88	76.20	80.05

TABLE-5
FASTNESS PROPERTIES OF $\mathbf{D}_1$-$\mathbf{D}_{20}$ ON WOOL, SILK AND NYLON

Dye No.	Wool				Silk				Nylon			
	Light	Wash	Rubbing		Light	Wash	Rubbing		Light	Wash	Rubbing	
			Dry	Wet			Dry	Wet			Dry	Wet
$\mathbf{D}_1$	3-4	4	3	3	5	3	4	3-4	5	4	3	3
$\mathbf{D}_2$	4	4	3-4	3-4	3-4	4	3	3	4	3-4	4-5	4
$\mathbf{D}_3$	4-5	3-4	3	3-4	3	3	3	2-3	3	5	3-4	3
$\mathbf{D}_4$	5	3-4	3	4	4-5	4	3-4	3	4	3	3	3-4
$\mathbf{D}_5$	4	4	3	4	4	4-5	3	2-3	3-4	3	4-5	3
$\mathbf{D}_6$	3-4	3	3-4	3-4	3	3	4	4	3	3-4	3	4-5
$\mathbf{D}_7$	4	3	3-4	3-4	3-4	3	4	2-3	4-5	3	3-4	3
$\mathbf{D}_8$	4-5	3-4	3	4	4-5	4	4	3	3	5	3	3-4
$\mathbf{D}_9$	3	3-4	4	4	4-5	3	3	4-5	3-4	4-5	3-4	3
$\mathbf{D}_{10}$	4	4-5	4	3-4	3	3-4	3	3	4	4	3	3
$\mathbf{D}_{11}$	3	3	3-4	3	4	3	3-4	2-3	4-5	3	4	3
$\mathbf{D}_{12}$	5	4	3-4	4-5	4-5	4	3-4	3	5	3-4	3	4-5
$\mathbf{D}_{13}$	4-5	4	4	3	3-4	3	3	3	3	3	3	3-4
$\mathbf{D}_{14}$	3-4	3-4	3	3-4	4	4-5	4-5	3	4	3	4-5	3
$\mathbf{D}_{15}$	3-4	3-4	4-5	4	4	3-4	3	3-4	4-5	4-5	3	3
$\mathbf{D}_{16}$	5	3	3	3	4-5	3-4	3-4	4	4	4	3-4	3-4
$\mathbf{D}_{17}$	4-5	3	3	3-4	3	3	4-5	3	3-4	3-4	4	3
$\mathbf{D}_{18}$	4	3	3-4	3-4	4-5	3	3	2-3	4	3	4	3
$\mathbf{D}_{19}$	4	4-5	4-5	3	5	4	4	3-4	5-6	3	4	3-4
$\mathbf{D}_{20}$	4	3	3	4	4	3	4-5	3	3-4	4	3-4	3

Light = Poor-1, Slight-2, Moderate-3, Fair-4, Good-5, Very good-6, Excellent-7
Wash & Rubbing = Poor-1, Slight-2, Moderate-3, Fair-4, Good-5, Very good-6, Excellent-7

Microbial studies: All the acid anthraquinone dyes are inactive against both Gram-positive (*Pseudomonas* sp. and *B. subtilis*) and Gram-negative (*Ceretium* and *E. coli*) bacteria at 100 and 200 μg/mL concentration compared to penicillin, ampicillin and amoxicillin.

All the acid anthraquinone dyes are inactive against *C. albicans* at 100 and 200 μg/mL concentration compared to amphotericine-B.

TABLE-6
CALIBRATION DATA FOR EXHAUSTION STUDY OF ACID DYES
Substrate for dyeing: Wool (2.0 g), Silk (2.0 g) & Nylon (2.0 g)
Medium of spectral study: Aqueous

Dye No.	Wavelength (nm)	Absorbance of dye solution at specified wavelength				Slop of linear plot K*
		Concentration × 10^{-3} mg mL^{-1}				
		4.0	8.0	12.0	16.0	
D$_{1}$	510	0.090	0.181	0.270	0.361	22.56
D$_{10}$	485	0.046	0.092	0.138	0.184	11.50
D$_{19}$	506	0.085	0.170	0.255	0.340	21.25

Absorbance = K* (Concentration × 10^{-3} mg mL^{-1})

TABLE-7
CALIBRATION DATA FOR FIXATION STUDY OF ACID DYES
Substrate for dyeing: Wool (2.0 g), Silk (2.0 g) and Nylon (2.0 g)
Medium of spectral study: Conc. Sulfuric acid

Dye No.	Wavelength (nm)	Absorbance of dye solution at specified wavelength				Slop of linear plot K*
		Concentration × 10^{-3} mg mL^{-1}				
		4.0	8.0	12.0	16.0	
D$_{11}$	475	0.075	0.150	0.255	0.300	18.75
D$_{15}$	480	0.085	0.170	0.254	0.340	21.25
D$_{19}$	493	0.100	0.200	0.300	0.400	25.00

Absorbance = K* (Concentration × 10^{-3} mg mL^{-1})

Conclusion

The difference in the colour of newly synthesized dyes depends upon the position of the substituents present and/or the position of the substituents on the naphthalene ring. The dyes **D**$_{3}$, **D**$_{4}$, **D**$_{8}$, **D**$_{12}$ **and D**$_{17}$ gave fair to very good light fastness on wool, while **D**$_{3}$, **D**$_{11}$, **D**$_{15}$ and **D**$_{19}$ gave good to very good light fastness on silk fabric. **D**$_{12}$, **D**$_{15}$ and **D**$_{19}$ gave fair to good rubbing fastness on wool, while **D**$_{7}$, **D**$_{11}$ and **D**$_{19}$ gave good to very good rubbing fastness on nylon.

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