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Dyeing of Wool–Polyester Blends with Carboxylanthraquinonoid Disperse Dyes

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ABSTRACT

The synthesis of several series of anthraquinone acid dyes containing carboxyl group is described. The dyes were dyed on polyester, wool, polyamide, wool–polyamide and wool–polyester blends and their dyeing and fastness properties evaluated. The fastness properties of all the dyed samples were in accord with commercial requirements and two of the dyes dyed polyester and wool fabrics to approximately the same depth. © 1998 Elsevier Science Ltd. All rights reserved

Keywords: polyester, wool, polyamide, carboxylanthraquinonoid, 4-carboxylanilino-8(5)-nitro-1,5-dihydroxy-anthraquinone, 4-carboxylanilino-8(5)-amino-1,5-dihydroxy-anthraquinone, 1-(2′-carboxyl)ethyl-aminoanthraquinone.

1 INTRODUCTION

Wool–polyester blends have many advantageous properties compared to wool fabrics. Because of the vastly different nature of wool and polyester, two classes of dyes are employed in a two-bath process or together in a single bath containing some auxiliaries. Time and cost-saving is the main advantage of the single bath process for dyeing wool–polyester blends. Two significant disadvantages of this process are the staining of the wool component by the disperse dyes and that the proportions of the two dyes vary by the

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ratio of the component fibres in the blends. One obvious way to eliminate these disadvantages is to develop a single dye which exhibits equal affinity for, and high fastness properties on, both fibres of the blends.

Baumgarte found that wool rapidly adsorbed disperse dyes at low temperatures, and that these dyes were transferred to the polyester as the temperature was raised. The amount of dye remaining on the wool at equilibrium was controlled by the affinity of the dye for polyester fibre [1]. Cheetham also found that, in the case of wool and polyester, the uptake of disperse dye by the wool component reached a maximum at 90°C, but at higher temperatures was rapidly desorbed into the bath, from whence it was subsequently adsorbed by the polyester component [2]. Turner and Chanin, in a study of the distribution of disperse dye between triacetate and polyester, showed that the inclusion of a hydrophilic group in the disperse dye molecule increases the distribution ratio in the favour of the polar fibre [3]. Stapleton and Waters, who studied the dyeing behaviour of reactive disperse dyes on wool–polyester blends, found that an approximately equal uptake of dye by the two fibres could be achieved if the dye has part polar and part nonpolar characteristics [4, 5]

In contrast to dyes with a sulphonic acid group, the water-solubilizing and fibre-selective effects of dyes with a carboxylic group are weak. They dye wool from slightly acid baths, the wool being unimpaired with excellent levelling and very good wet fastness properties. We report here the synthesis of a series (I–VI) of carboxylanthraquinonoid disperse dyes obtained by condensation of carboxylanilines with dinitrodihydroxy-anthraquinones (I and II), reduction of these (III and IV), and by reaction of aminoanthraquinones with acrylic acid (V) or methacrylic acid (VI).

2 EXPERIMENTAL

2.1 4-Carboxylanilino-8-nitro-1,5-dihydroxyanthraquinones (I)

4,8-Dinitro-1,5-dihydroxyanthraquinone (DNAR), 3.30 g, 0.01 mole), anthranilinic acid (3.43 g, 0.025 mole) and sodium acetate (1.23 g, 0.015 mole) were refluxed in nitrobenzene (100 ml) for 33 h. The liquor was cooled to room temperature and then diluted with ethanol (100 ml) and left to stand overnight. The crystalline material which separated was filtered and washed with water until the washings were neutral. Recrystallization from 2-methoxyethanol afforded 2.42 g (yield 58%) of 4-(2-carboxyl)anilino-8-nitro-1,5-dihydroxyanthraquinone (dye I.1). (m.p. above 420°C).

Dyes I.2–I.4 (see Figure 1) were synthesized by similar procedures as detailed in Table 1.

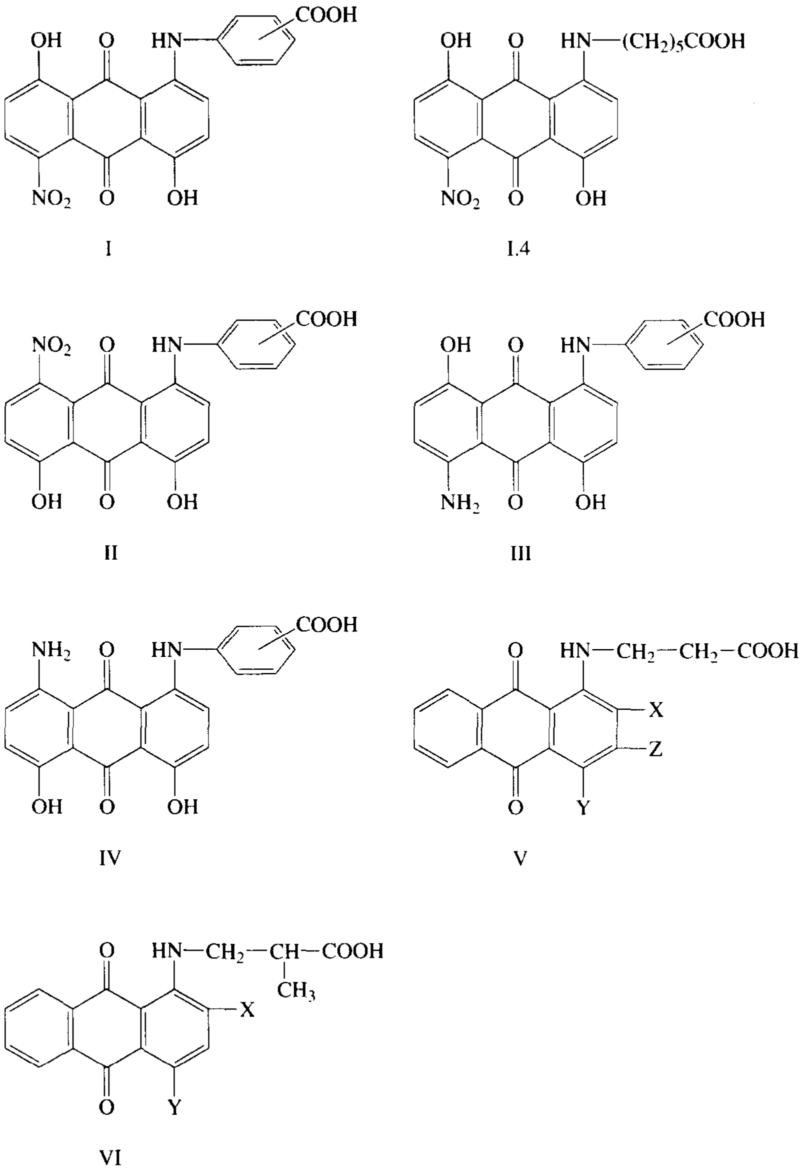

Fig. 1.

2.2 4-Carboxylanilino-5-nitro-1,8-dihydroxyanthraquinones (II)

The above procedures (Section 2.1) were repeated, except that DNAR was replaced by DNCZ (4,5-dinitro-1,8-dihyoxy-anthraquinone). Relevant data on yield and m.p. are given in Table 1.

TABLE 1
Synthesis and Characterisation Data of Dyes

Dye	*Intermediates (g)*	*Reagents*	*Reaction time (h)*	*Weight (% yield) (g)*	*m.p. (°C)*
I.2	DNAR (3.00)	3-aminobenzoic acid (3.12 g)	36	2.83 (75)	>420
I.3	DNAR (3.00)	4-aminobenzoic acid (3.12 g)	32	2.00 (53)	>420
I.4	DNAR (2.00)	6-aminohexanoic acid (3.18 g)	40	1.51 (60)	>420
II.1	DNCZ (2.00)	2-aminobenzoic acid (2.08 g)	34	1.30 (51)	>420
II.2	DNCZ (2.00)	3-aminobenzoic acid (2.08 g)	36	1.78 (70)	>420
II.3	DNCZ (2.00)	4-aminobenzoic acid (2.08 g)	33	1.22 (48)	>420
III.1	I.1 (2.00)	sodium sulphide (4.73 g)	3	1.58 (86)	>420
III.2	I.2 (2.00)	sodium sulphide (4.73 g)	3	1.60 (86)	>420
III.3	I.3 (2.00)	sodium sulphide (4.73 g)	3	1.49 (80)	>420
IV.1	II.1 (1.00)	sodium sulphide (2.37 g)	3	0.81 (87)	>420
IV.2	II.2 (1.00)	sodium sulphide (2.37 g)	3	0.81 (87)	>420
IV.3	II.3 (1.00)	sodium sulphide (2.37 g)	3	0.78 (84)	>420
V.2	1-amino-2-bromo-4-hydroxy-anthraquinone (2.00)	acrylic acid (1.8 ml)	7(70–75°C)	2.19 (90)	190–192
V.3	1,4-diamino-2,3-dichloroanthraquinone (2.00)	acrylic acid (1.9 ml)	8(65–70°C)	2.27 (92)	168–170
V.4	1-amino-2,4-dibromoanthraquinone (2.00)	acrylic acid (1.5 ml)	15(80–85°C)	2.10 (89)	180–182
VI.1	1-aminoanthraquinone (2.00)	methacrylic acid (3.0 ml)	24(90–95°C)	2.44 (88)	158–160
VI.2	1-amino-2,4-dibromoanthraquinone (2.00)	methacrylic acid (1.8 ml)	25(90–95)	2.29 (94)	220–222

2.3 Preparation of dyes III and IV

A mixture of dye I.1 (2.00 g), 95% sodium suphide (5.00 g) and ethanol (100 ml) was refluxed for 3 h. The liquor was cooled, diluted with water (100 ml) and filtered to give the greenish blue 4-(2-carboxyl)anilino-8-amino-1,5-dihydroxy-anthraquinone (III.1), (1.60 g, yield 86%) m.p. above 420°C (2-methoxyethanol).

By using a similar procedure, dyes III.2 and III.3, and dyes IV.1, IV.2 and IV.3 (Table 1) were obtained.

2.4 Preparation of dyes V and VI

A mixture of 1-aminoanthraquinone (2.23 g, 0.01 mole), boric acid (0.40 g) and concentrated sulphuric acid (100 ml) was stirred at 30–35°C for 0.5 h. Acrylic acid (3.0 ml) was dropwisely added and the liquor then stirred at 80–85°C for 12 h, after cooling to room temperature and then adding to water (300 ml). The precipitate was filtered and washed neutral with water. Recrystallization from 2-methoxyethanol gave 1-(2-carboxyl)ethylamino-anthraquinone (V.1), (2.70 g, yield 93%) m.p. 170–172°C.

Dyes V.2, V.3 and V.4 were synthesized by a similar procedure, except that 1-aminoanthraquinone was replaced by the appropriate 1-aminoanthraquinone derivative. Replacing acrylic acid in the above procedure by methacrylic acid gave Dyes VI. Characterization data for the products are shown in Table 1.

2.5 General

All dyes were purified by TLC on Kieselgel 60 (Merck). Electronic spectra were recorded on a Shimadzu UV 240 from dye solutions in N,N-dimethylformamide (DMF) at a concentration of 5×10^{-5} g ml^{-1}. Structure and purity were confirmed by mass (Hitachi M-52), infrared (Hitachi 260-50) and elemental analysis (Perkin-Elmer 240C) (Table 2).

Dyeing of wool, polyamide (Nylon 6) and wool/polyamide blend (85/15) fabrics was carried out in a liquor ratio (L.R.) of 50:1 at 100°C at pH 5.0–5.5 for 1 h; the samples were then cooled to room temperature and washed with an aqueous solution of detergent (2 g litre^{-1}) at 50°C for 20 min. Dyeing of polyester was carried out using biphenyl carrier at 100°C (L.R. 50:1, pH 5.0–5.5) for 1 h; the dyed samples were washed with an aqueous solution of 10 ml litre^{-1} 32.5% Na_2CO_3 and 5 g litre^{-1} $Na_2S_2O_4$ at 70°C for 20 min. Dyeing of wool–polyester blends (45/55) was carried out at 100°C (L.R. 50:1, pH 5.0–5.5) for 1 h by a one bath–one stage process with biphenyl carrier; the samples were then cooled to room temperature and washed with an aqueous

TABLE 2
Spectroscopic Data

Dye	*Mass*^{a}*(m/e)*	*IR*^{b}*(cm*$^{-1}$*KBr)*	*Element analysis* *% found (calculated)*
I.1 2-COOH	420(M$^+$) 390(M-NO)$^+$	3420(b,Ar-NH),3350(b,OH),1610,1578 (C=O),1545,1375(Ar-NO$_2$),1565, 1515, 1460 (Ar ring),1315,1275(Car-N),1225,1160(Car-OH).	C:60.51(60.00), H:3.15(2.86) N:6.35(6.67)
I.2 3-COOH	420(M$^+$) 390(M-NO)$^+$	3430(b,Ar-NH),3330(b,OH),1688,1600,1590 (C=O),1545,1370(Ar-NO$_2$),1550,1460 (Ar ring),1320,1270(Car-N),1220,1165(Car-OH)	C:59.05(60.00), H:3.50(2.86) N:6.20(6.67)
I.3 4-COOH	420(M$^+$) 390(M-NO)$^+$	3400(b,Ar-NH),3300(b,OH),1682,1600 (C=O),1535,1385(Ar-NO$_2$),1525,1455(Ar ring),1325,1255(Car-N),1215,1160(Car-OH)	C:59.85(60.00), H:3.75(2.86) N:6.35(6.67)
I.4	414(M$^+$) 384(M-NO)$^+$	3400(b,Ar-NH),3300(b,OH),1725,1600 (C=O),1550,1460(Ar ring),1528, 1370(Ar-NO$_2$),1270(Car-N),1220,1170(Car-OH)	C:58.03(57.97), H:5.00(4.35) N:6.46(6.76)
II.1 2-COOH	420(M$^+$) 390(M-NO)$^+$	3405(b,Ar-NH),3200(b,OH),1620,1581 (C=O),1503,1465(Ar ring),1315, 1250 (Car-N),1210,1170(Car-OH))	C:59.20(60.00), H:3.65(2.86) N:6.25(6.67)
II.2 3-COOH	420(M$^+$) 390(M-NO)$^+$	3410(b,Ar-NH),3250(b,OH),1690,1615,1577 (C=O),1535,1385(Ar-NO$_2$), 1320,1260 (Car-N),1215,1165(Car-OH)	C:59.35(60.00), H:3.40(2.86) N:6.38(6.67)
II.3 4-COOH	420(M$^+$) 390(M-NO)$^+$	3350(b,Ar-NH),3250(b,OH),1680,1630,1610 (C=O),1530,1375(Ar-NO$_2$), 1315, 1265 (Car-N),1210,1160(Car-OH)	C:59.75(60.00), H:3.75(2.86) N:6.48(6.67)
III.1 2-COOH	390(M$^+$)	3450(b,Ar-NH),3350(b,OH),1700,1630 (C=O),1540,1460(Ar ring),1215, 1165(Car-OH)	C:63.85(64.62), H:4.60(3.59) N:6.59(7.18)
III.2 3-COOH	390(M$^+$)	3400(b,Ar-NH),3320(b,OH),1610(C=O),1560 (Ar ring),1220,1165(Car-OH)	C:64.52(64.62), H:4.75(3.59), N:6.93(7.18)
III.3 4-COOH	390(M$^+$)	3350(b,Ar-NH),3250(b,OH),1685,1590 (C=O),1550,1500(Ar ring), 1170(Car-OH)	C:64.03(64.62), H:4.15(3.59) N:6.78(7.18)
IV.1 2-COOH	390(M$^+$)	3350(b,Ar-NH),3200(b,OH),1685,1620,1580 (C=O), 1505(Ar ring),1215,1170(Car-OH)	C:64.15(64.62), H:4.08(3.59) N:6.92(7.18)

(continued)

Table 2—*contd*

Dye	*Mass*[a] *(m/e)*	*IR*[b] *(cm^{-1}KBr)*	*Element analysis % found (calculated)*
IV.2 3-COOH	390(M^+)	3380(b,Ar-NH),3270(b,.OH),1700,1580(C = O), 1500(Ar ring),1220,1165(Car-OH)	C:63.88(64.62), H:4.78(3.59) N:6.69(7.18)
IV.3 4-COOH	390(M^+)	3400(b,Ar-NH),3280(b,OH),1600,1570(C = O), 1460(Ar ring),1225,1170(Car-OH)	C:63.96(64.62), H:4.61(3.59) N:6.72(7.18)
V.1 X = Y = Z = H	295(M^+),277(M-H_2O)$^+$, 236(M-CH_2COOH)$^+$, 223(M-C_2H_3COOH)$^+$, 208(Aq)$^+$	2750(b,OH),1720,1660,1636(C = O),1598,1510 (Ar ring)	C:68.78(69.15), H:5.35(4.41) N:4.66(4.75)
V.2 X = Br Y = OH Z = H	389/391(M^+), 372/374(M-OH)$^+$ 330/332(M-CH_2COOH)$^+$ 317/319(M-C_2H_3COOH)$^+$, 208(Aq)$^+$	3400(b,Ar-NH),3300(b,OH),1710,1625, 1577(C = O),1495(Ar ring),1220(Car-OH)	C:51.86(52.31), H:3.97(3.08) N:3.40(3.59)
V.3 X = Z = Cl Y = H	378/380/382(M^+), 332/334/336(M-HCOOH)$^+$ 317/319/321(M-HCOOH-NH)$^+$	3472(Ar-NH),2750(b,OH),1740,1622,1575(C = O), 1500(Ar ring),1060,1038(Ar-Cl)	C:52.61(53.83), H:4.26(3.17) N:6.88(7.39)
V.4 X = Z = Br Y = H	451/453/455(M^+) 378/380/382(M-C_2H_4COOH)$^+$	3400(Ar-NH),1668,1625,1575(C = O),1500(Ar ring)	C:44.53(45.03), H:3.13(2.43) N:2.78(3.09)
VI.1 X = Y = H	309(M^+), 236(M-C_2H_4COOH)$^+$ 223(M-C_3H_5COOH)$^+$, 208(Aq)$^+$	2750(b,OH),1705,1660,1625(C = O),1575, 1500 (Ar ring),1378(CH_3)	C:69.10(69.60), H:5.75(4.85) N:4.17(4.53)
VI.2 X = Y = Br	465/467/469(M^+), 379/381/383(M-C_3H_5COOH)$^+$	3410(Ar-NH),1670,1632,1585(C = O), 1515 (Ar ring),1441,1380(CH_3)	C:45.75(46.25), H:3.53(2.78) N:2.90(3.00)

[a] Aq, anthraquinone;
[b] Ar and ar , aromatic; b, broad.

solution of detergent (2 g litre^{-1}) at 50°C for 20 min. The dye uptake was evaluated by extracting the dye from a known weight of dyed material by DMF (polyester) and DMF/formic acid (9/1) (wool, polyamide, wool–polyamide blend and wool–polyester blend fabrics) and determining the absorbance of the solution using a Shimadzu UV 240. Dye uptake was calculated from the calibration curve of absorbance vs concentration of dye.

The wash fastness was tested according to CNS 1494-A3, similar to AATCC 61-1989-1 A, except that the test conditions were replaced by 100 ml liquor (5 g litre^{-1} detergent and 2 g litre^{-1} anhydrous Na_2CO_3) at 60°C ± 2°C for 30 min. Sublimation and light fastness assessments were carried out as for a previous investigation [6].

3 RESULTS AND DISCUSSIONS

3.1 Electronic spectra

Electronic spectral data of the dyes are shown in Table 3. Comparison of λ_{max} values of dyes I, II, III and IV shows the dyes to be bathochromic in the order III > IV > I > II, differences being 9–17, 3–17 and 8–25 nm, respectively. This can be interpreted in terms of intramolecular hydrogen bonding and electron donation factors, viz (a) dyes III: greater intramolecular

TABLE 3
Colour and TLC Data

Dye	*Rf*[a] *(TLC) and colour*	λ_{max} *(nm) in Acetone*	λ_{max} *(nm) (ε) in DMF*
I.1	0.57, blue	600	621 (4921)
I.2	0.55, blue	592	628 (9125)
I.3	0.55, blue	588	610 (5075)
I.4	0.59, blue	584	590 (12004)
II.1	0.60, blue	586	619 (7205)
II.2	0.57, blue	584	620 (3830)
II.3	0.56, blue	563	600 (4595)
III.1	0.55, blue	620	630 (6150)
III.2	0.56, blue	611	651 (9453)
III.3	0.57, blue	610	622 (6388)
IV.1	0.55, blue	603	625 (1915)
IV.2	0.55, blue	602	645 (3520)
IV.3	0.56, blue	601	615 (2350)
V.1	0.64, red	495	505 (5477)
V.2	0.62, purple	543	564 (5454)
V.3	0.62, violet	556	570 (4706)
V.4	0.62, red	487	495 (6890)
VI.1	0.63, red	485	491 (6883)
VI.2	0.79, scarlet	523	526 (7404)

[a] Eluent; toluene: ethyl acetate: glacial acetic acid = 8:2:1.

hydrogen bonding (two hydroxy groups) and electron donation from an amino group; (b) dyes IV: electron donation from an amino group; (c) dyes I: greater intramolecular hydrogen bonding. Based on the λ_{max} values in acetone, the intramolecular hydrogen bonding of dyes with an o-carboxy group produces a larger bathochromic shift than the intermolecular hydrogen bonding of dyes with a m-carboxy group, viz dye I.1 > I.2 > I.3, dye II.1 > II.2 > II.3, dye III.1 > III.2 > III.3 and dye IV.1 > IV.2 > IV.3. However, the influence of dipole-dipole interaction between dyes with a m-carboxy group and polar solvents (e.g. DMF) on λ_{max} values is higher than those of intramolecular hydrogen bonding of dyes with an *o*-carboxy group, viz dye I.2 > I.1 > I.3, dye II.2 > II.1 > II.3, dye III.2 > III.1 > III.3 and dye IV.2 > IV.1 > IV.3.

3.2 Dyeing and fastness properties

All dyes in the six series gave level colouration on polyester, wool, polyamide, polyester–wool blend and wool-polyamide blend fabrics. Dyes with an *o*-carboxy group, e.g. dye I.1, II.1, III.1 and IV.1, have lower dye-uptake on polyester fabrics than dyes with *m*- and *p*-carboxy groups, viz dye I.2 > I.3 > I.1, dye II.2 > II.3 > II.1, dye III.2 > III.3 > III.1 and dye IV.2 > IV.3 > IV.1 (Table 4). This might be due to the interaction of the carboxy group with the anthraquinone nucleus of dyes hindered the formation of intermolecular hydrogen bond between arylamino groups and the carboxy groups of dyes and ester groups of fibres. Comparison of the dye-uptake of dyes I, II, III and IV, I > II and III > IV, indicates that dyes with more hydrophobic groups and which form more intermolecular hydrogen bond with fibres have a higher substantivity than those of others [7] (Table 4).

Monosulphonated dyes of relative molecular mass 500–600 that are somewhat more hydrohobic than levelling acid dyes also migrate and cover well, but they are a little inferior to milling dyes in wet fastness and thus are sometimes described as half-milling dyes [8].

Thus, all the dyes reported here have a weak water-solubilizing carboxy group and molecular weight about 400 and might therefore be regarded as half-milling dyes. They dye wool from an almost neutral dyebath at pH 5.5, which is higher than the pH of the isoelectric point for wool (pH 4.9). Above the isoelectric point, the fibre is negatively charged and the electrostatic repulsion forces increase with increase in the solubility of the dyes in water [8]. Hydrophobic interaction and intermolecular hydrogen bond between the dyes and fibres permit adsorption of acid dyes onto the fibre surface in such a way that the charged group is directed outwards towards the dyebath phase [8]. From Table 4 it is apparent that the dye-uptake on wool fabrics of the four shades of dyes I–IV is in the order I > III > II > IV (except for dye III.3).

TABLE 4
Dyeing Properties

o.w.f.	*Dye uptake (g kg⁻¹ polyester fabrics)*				*Dye uptake (g kg⁻¹ polyamide fabrics)*				*Dye uptake (g kg⁻¹ wool fabrics)*			
Dye	*0.1%*	*0.5%*	*1.0%*	*2.5%*	*0.1%*	*0.5%*	*1.0%*	*2.5%*	*0.1%*	*0.5%*	*1.0%*	*2.5%*
I.1	0.84	3.03	4.59	11.81	0.79	3.76	7.15	16.40	0.79	3.56	6.31	14.30
I.2	0.88	3.71	6.61	15.66	0.70	3.31	6.15	14.52	0.80	3.98	7.68	16.65
I.3	0.71	3.05	4.68	12.04	0.73	3.50	6.72	15.61	0.81	3.95	7.13	15.73
I.4	0.85	3.38	6.19	15.02	0.76	3.66	7.02	16.91	0.79	3.78	7.09	15.95
II.1	0.68	2.31	4.17	11.04	0.80	3.96	7.40	16.51	0.81	3.27	5.78	12.89
II.2	0.79	3.40	6.12	15.18	0.89	3.55	6.73	14.76	0.83	3.49	6.11	13.95
II.3	0.73	2.73	4.41	11.51	0.82	3.75	7.05	15.64	0.66	3.32	6.03	13.38
III.1	0.87	3.54	6.97	15.88	0.81	3.70	6.86	15.28	0.86	3.37	6.38	13.75
III.2	0.70	2.83	4.46	11.55	0.86	3.65	6.03	13.94	0.87	3.44	6.71	14.96
III.3	0.67	2.81	4.38	11.39	0.80	3.66	6.38	14.61	0.58	2.80	4.84	10.87
IV.1	0.42	1.71	3.03	7.41	0.83	3.78	6.62	15.91	0.60	2.64	5.03	12.09
IV.2	0.65	2.89	4.53	11.71	0.76	3.33	5.90	12.85	0.65	3.01	5.89	13.39
IV.3	0.62	2.45	4.21	10.98	0.82	3.53	6.30	14.52	0.61	2.89	5.74	13.02
V.1	0.61	1.77	3.35	8.01	0.68	2.86	5.15	12.03	0.72	3.33	6.30	14.52
V.2	0.68	2.87	4.88	12.02	0.80	3.44	6.13	13.78	0.59	2.77	4.74	8.30
V.3	0.88	4.15	8.08	18.97	0.90	3.74	6.84	15.91	0.84	3.06	4.42	7.83
V.4	0.70	2.91	4.98	12.12	0.92	4.26	7.24	15.61	0.71	2.75	4.70	8.02
VI.1	0.70	3.00	4.99	12.17	0.83	3.94	7.66	18.36	0.64	2.25	4.04	8.82
VI.2	0.87	3.87	7.13	17.07	0.78	3.40	6.06	13.43	0.77	3.06	4.50	9.63

The increase in dye-uptake could demonstrate the contribution of hydrophobic interaction and intermolecular hydrogen bond to the substantivity of acid milling dyes for wool fibres. From Table 4, that dye-uptake on wool fabrics of dyes with a *m*-carboxy is higher than those of dyes with a *p*-carboxy group (I.2 > I.3, II.2 > II.3, III.2 > III.3 and IV.2 > IV.3). It can also be seen from Table 4 that the dye-uptake on wool fabrics of dyes with an *o*-carboxy group is lower than those of dyes with a *p*-carboxy (I.3 > I.1, II.3 > II.1, III.3 > III.1 , IV.3 > IV.1). This indicates that dyes with a *m*-carboxy group have a better molecular configuration to form more intermolecular hydrogen bonds with the fibre. The uptake of all dyes on polyester–wool blends were found to be between those on wool and those on polyester (Tables 4 and 5). Comparision of the dye-uptake of dyes I with III and of dyes II with IV indicates that the more hydrophobic dyes (e.g. dyes I and II) have better substantivity on polyamide (Table 4). It can also be seen from Table 4 that dyes with an *o*-carboxy group have higher dye-uptake than other dyes, and that (Tables 4 and 5) that all dyes, except V.2, V.3, V.4, VI.1 and VI.2 dye wool–polyamide blends and wool fabrics to approximately the same depth. Tables 6–8 show that the sublimation, wet and light fastness of all the dyes on polyester, wool, polyamide, wool–polyester blend and wool–polyamide blend fabrics are of an acceptable order to meet commercial requirements.

TABLE 5
Uptake* of Dyes on Polyester–Wool Blends and Wool–Polyamide Blends

o.w.f. *Dye*	*Polyester–Wool blends*				*Wool–Polyamide blends*			
	0.1%	*0.5%*	*1.0%*	*2.5%*	*0.1%*	*0.5%*	*1.0%*	*2.5%*
I.1	0.82	2.65	4.58	13.68	0.78	3.07	6.46	14.32
I.2	0.84	3.80	7.02	16.10	0.79	3.74	7.38	14.63
I.3	0.75	3.34	6.08	14.43	0.81	3.88	7.14	15.71
I.4	0.84	3.72	7.02	16.33	0.79	3.57	6.44	16.94
II.1	0.74	3.01	5.54	12.76	0.81	3.29	5.89	13.03
II.2	0.83	3.42	6.51	15.31	0.84	3.50	6.13	13.82
II.3	0.67	2.84	4.98	11.66	0.67	3.03	5.58	12.93
III.1	0.86	3.59	6.52	15.11	0.85	3.61	6.55	13.79
III.2	0.72	3.16	5.48	12.51	0.87	3.55	6.70	14.86
III.3	0.66	2.79	5.87	11.09	0.60	2.83	5.04	11.14
IV.1	0.50	2.24	3.84	8.42	0.61	2.74	5.22	12.36
IV.2	0.61	2.99	5.25	11.88	0.67	3.15	5.91	13.84
IV.3	0.59	2.79	5.10	11.35	0.62	2.96	5.68	13.42
V.1	0.64	2.70	5.04	11.97	0.71	3.10	6.22	14.55
V.2	0.65	3.01	5.44	12.01	0.60	2.65	4.85	9.03
V.3	0.85	3.56	6.59	14.98	0.85	3.05	4.60	9.04
V.4	0.70	2.70	4.89	10.96	0.74	2.95	5.08	8.41
VI.1	0.69	2.94	5.31	11.95	0.67	2.58	4.58	10.15
VI.2	0.85	3.55	6.67	15.59	0.77	2.57	4.51	10.11

*g dyes kg^{-1} fibres.

TABLE 6
Fastness on Polyester Fabrics

o.w.f. *Dye*	*Sublimation fastness (S.P./C.C.)*[a]				*Sublimation temp (°C)*[b]	*Wet fastness (S.P./C.C.)*[a]				*Light fastness*			
	0.1%	*0.5%*	*1.0%*	*2.5%*		*0.1%*	*0.5%*	*1.0%*	*2.5%*	*0.1%*	*0.5%*	*1.0%*	*2.5%*
I.1	5/5	5/5	5/5	5/5	190	5/5	5/5	5/5	5/5	6	6	6	6
I.2	5/5	5/5	5/5	5/5	210	5/5	5/5	5/5	5/5	6	6	7	7
I.3	5/5	5/5	5/5	4–5/4–5	180	5/5	5/5	5/5	5/5	6	6	6	6
I.4	5/4–5	5/4–5	5/4–5	5/4–5	180	5/5	5/5	5/5	5/5	6	6	7	7
II.1	5/5	5/5	4–5/5	4–5/5	170	5/5	5/5	5/5	5/5	7	7	7	7
II.2	5/5	5/5	5/5	5/5	220	5/5	5/5	5/5	5/5	7	7	7	7
II.3	5/5	5/5	5/5	5/5	180	5/5	5/5	5/5	5/5	7	7	7	7
III.1	5/5	5/5	5/4–5	5/4–5	180	5/5	5/5	5/5	5/5	6	6	6	7
III.2	5/5	5/4–5	5/4–5	5/4–5	220	5/5	5/5	5/5	5/5	6	6	6	6
III.3	5/5	5/5	5/5	5/4–5	210	5/5	5/5	5/5	5/5	6	6	7	7
IV.1	5/5	5/5	5/5	5/5	200	5/5	5/5	5/5	5/5	6	6	6	6
IV.2	5/5	5/4-5	5/4-5	5/4-5	220	5/5	5/5	5/5	5/5	6	7	7	7
IV.3	5/4–5	5/4–5	5/4–5	5/4–5	210	5/5	5/5	5/5	5/5	7	7	7	7
V.1	5/5	4–5/4–5	4/4–5	3–4/4–5	120	5/5	5/5	5/5	5/5	6	6	7	7
V.2	4–5/4–5	4–5/4–5	4/4–5	3–4/4–5	120	5/5	5/5	5/5	5/5	7	7	7	7
V.3	4–5/4–5	4/4–5	3–4/4–5	3–4/3–4	130	5/5	5/5	5/5	5/5	5	6	6	7
V.4	5/4–5	5/4–5	4–5/4–5	4/4–5	160	5/5	5/5	5/5	5/5	6	6	6	6
VI.1	4–5/4–5	4/4–5	3–4/4–5	3–4/4–5	130	5/5	5/5	5/5	5/5	6	6	6	6
VI.2	4–5/4–5	4/4–5	3–4/4–5	3–4/4–5	120	5/5	5/5	5/5	5/5	7	7	7	7

[a] S.P., staining on polyester; C.C., colour change.
[b] Initial temperature/°C of mark-off (2.5% o.w.f.).

TABLE 7
Fastness on Wool

o.w.f. *Dye*	*Sublimation fastness (S.W./C.C.)*[a]				*Wet fastness(S.W./C.C.)*[a]				*Light fastness*			
	0.1%	*0.5%*	*1.0%*	*2.5%*	*0.1%*	*0.5%*	*1.0%*	*2.5%*	*0.1%*	*0.5%*	*1.0%*	*2.5%*
I.1	5/5	5/5	5/5	5/5	5/4–5	4–5/4	4–5/4	4/4	4	4	4	5
I.2	5/4–5	5/4–5	5/4–5	5/4–5	4/4–5	4/4	3–4/3–4	3–4/3–4	4	4	5	5
I.3	5/5	5/5	5/4–5	4–5/4–5	4–5/4–5	4/4–5	3–4/4–5	3–4/4	4	4	4	5
I.4	5/4–5	5/4–5	5/4–5	5/4–5	3–4/4	3–4/4	3–4/3–4	3–4/3–4	4	5	5	5
II.1	5/4–5	4–5/4–5	4–5/4–5	4–5/4–5	5/4	4–5/4	4/4	3–4/4	4	4	4	5
II.2	5/5	5/4–5	5/4–5	5/4–5	4–5/4	4–5/4	4/4	4/4	4	4	5	5
II.3	5/4–5	5/4–5	5/4–5	5/4–5	4–5/4	4/4	3–4/4	3–4/4	4	4	5	5
III.1	5/4–5	5/4–5	4/4–5	4/4–5	4–5/4	4/4	3–4/4	3–4/4	4	4	4	4
III.2	5/4–5	5/4–5	5/4–5	5/4–5	3–4/4	3–4/4	3–4/4	3–4/3–4	5	5	5	5
III.3	5/4–5	5/4–5	5/4–5	5/4–5	4–5/4	4–5/4	4/4	3–4/4	4	4	4	4
IV.1	5/4–5	5/4–5	5/4–5	5/4–5	4–5/4	4/4	3–4/3–4	3–4/3–4	4	4	4	5
IV.2	5/4–5	5/4–5	5/4–5	5/4–5	4–5/4	4–5/3–4	4/3–4	3–4/3–4	5	5	6	7
IV.3	5/4–5	5/4–5	5/4–5	5/4–5	5/4	4/4	3–4/4	3–4/4	5	5	5	5
V.1	5/4–5	5/4–5	5/4	4–5/4	4/3–4	4/3–4	3–4/3–4	3–4/3–4	4	4	4	4
V.2	5/4–5	5/4–5	4/4–5	4/4–5	5/4–5	4–5/4–5	4/4–5	4/4–5	3	3	4	4
V.3	4–5/4–5	4/4–5	4/4–5	3–4/4–5	5/4–5	5/4–5	5/4–5	5/4–5	4	4	4	5
V.4	5/4–5	5/4–5	5/4–5	5/4–5	5/4	4–5/4	4–5/3–4	4–5/3–4	4	5	5	5
VI.1	5/4–5	4–5/4–5	4/4–5	4/4	4/4	4/4	3–4/3–4	3–4/3–4	4	4	4	5
VI.2	4–5/4–5	4/4–5	3–4/4–5	3–4/4–5	4–5/4–5	4/4–5	4/4–5	4/4–5	4	4	4	5

[a] S.W., staining on wool; C.C., colour change.

TABLE 8
Fastness on Polyamide

o.w.f. Dye	Sublimation fastness (S.N./C.C.)[a]				Wet fastness(S.N./C.C.)[a]				Light fastness			
	0.1%	0.5%	1.0%	2.5%	0.1%	0.5%	1.0%	2.5%	0.1%	0.5%	1.0%	2.5%
I.1	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	4	4	4	5
I.2	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	4	4	5	5
I.3	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	4	4	4	5
I.4	5/4–5	5/4–5	5/4–5	5/4–5	5/5	5/5	5/5	5/5	4	5	5	5
II.1	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	4	4	4	5
II.2	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	4	4	5	5
II.3	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	4	4	5	5
III.1	5/5	4–5/4–5	4–5/4–5	4–5/4–5	5/5	4–5/4–5	4/4–5	4/4–5	4	4	4	4
III.2	5/5	5/5	5/5	5/5	5/5	4–5/4–5	4–5/4–5	4–5/4	5	5	5	5
III.3	5/5	5/5	5/5	5/5	5/5	5/5	4–5/4–5	4–5/4	4	4	4	4
IV.1	5/5	5/5	5/5	5/5	5/5	5/4–5	5/4–5	4–5/4–5	4	4	4	5
IV.2	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/4–5	5	5	6	7
IV.3	5/5	5/5	5/5	5/5	5/5	5/5	5/4–5	4–5/4–5	5	5	5	5
V.1	4–5/4–5	4–5/4–5	4/4–5	4/4–5	5/4–5	4–5/4–5	4/4–5	4/4	4	4	4	4
V.2	4–5/4–5	4/4–5	3–4/4–5	3–4/4–5	4–5/4–5	4/4–5	3–4/4–5	3–4/4	4	4	4	4
V.3	4–5/4–5	4/4–5	3–4/4–5	3–4/4–5	4–5/4–5	4/4–5	4/4–5	3–4/4–5	4	4	4	5
V.4	4–5/4–5	4–5/4–5	4–5/4–5	4–5/4–5	5/5	5/5	5/4–5	5/4–5	4	5	5	5
VI.1	4–5/4–5	4/4–5	3–4/4–5	3–4/4–5	4–5/4–5	4/4–5	3–4/4–5	3–4/4	4	4	4	5
VI.2	4/4–5	3–4/4–5	3–4/4–5	3–4/4–5	4–5/4–5	4/4	3–4/4	3–4/4	4	4	4	5

[a] S.N., staining on polyamide; C.C., colour change.

It can be concluded that dyes I.4 and III.3 dye polyester and wool fabrics to approximately the same depth. From Table 4, it is apparent that dyes I.3, II.2 and IV.2 and dye II.2 and III.1 dye wool and polyamide fabrics, and polyester and polyamide fabrics, to approximately the same depth.

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