CHAPTER 4

RESULT AND DISCUSSION

4.1 Visual assessment for change in colour and staining

The obtained results, which a university student group assessed the colour contrast between the treated and untreated specimen against the contrast of a grey scale are shown in Appendices C and D.

4.2 Instrumental assessment for change in colour and staining

The colorimetric values of the specimens were calculated using colour fastness formulae for change in colour and staining assessments. The obtained results are shown in Appendices E and F.

4.3 The relationship between visual results and the change in colour formulae's predictions.

Based on linear regression, the correlation coefficients, r, obtained for CIELAB, ISO, $N_c^{\#}$ and F_c are over 0.900. The ISO colour difference formula gives the most satisfactory, showing the highest r-value at 0.941, and the lowest standard error value at 0.323, as shown in Table 4-1. CMC (1:1) and CMC (2:1) give the r values lower than other formulae. The relationships between visual results and the ones that calculated from those formulae are plotted in Figure 4-1.

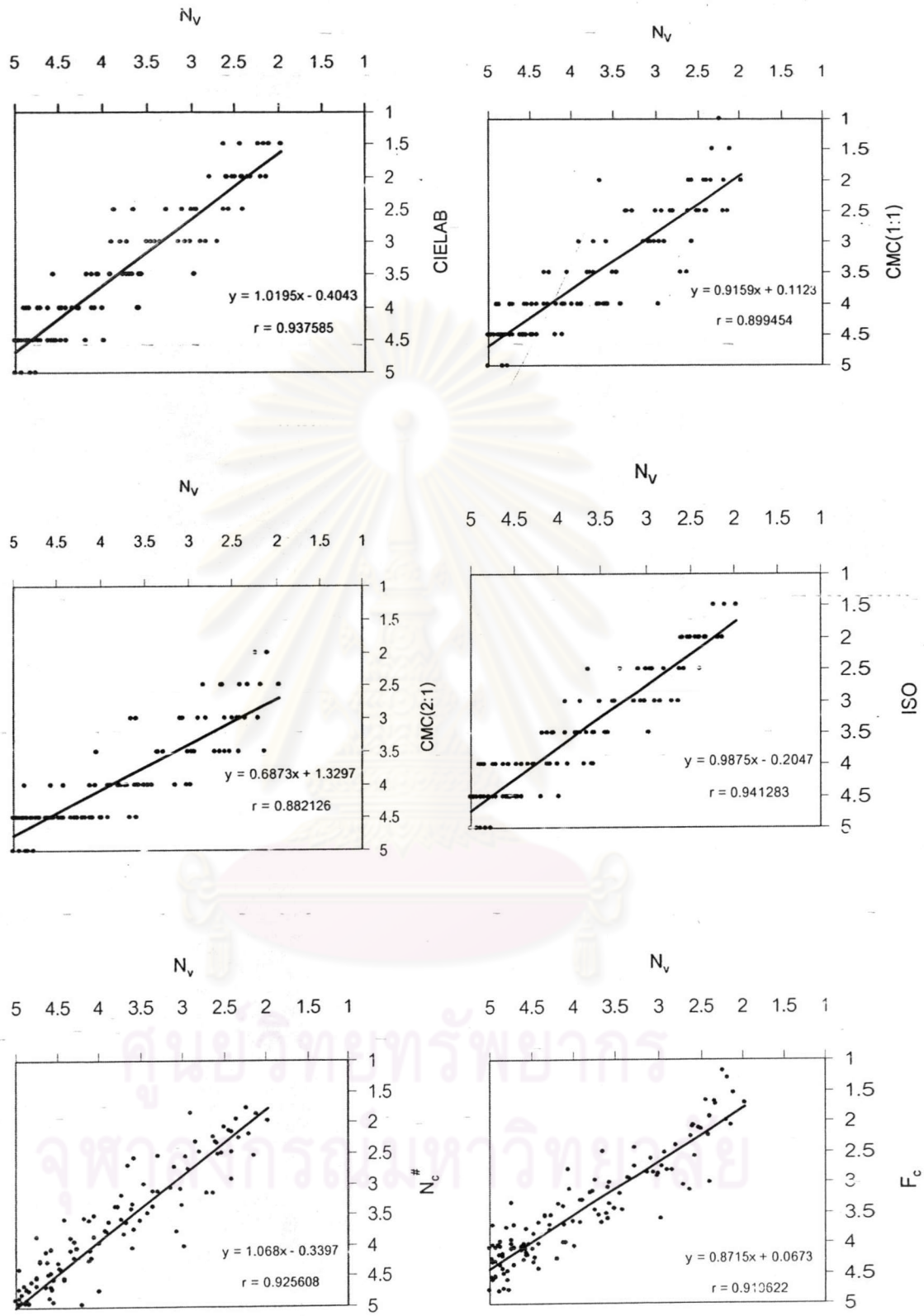

Figure 4-1 Relationship between the mean visual results (N_V) and predictions from different change in colour formulae

Table 4-1 Summary of change in colour formulae's performance

	CIELAB	CMC(1:1)	CMC(2:1)	ISO	$N_C^{\#}$	F_C
r	0.938	0.899	0.882	0.941	0.926	0.920
Standard error	0.345	0.406	0.335	0.323	0.399	0.340

In addition, specimens were classified by value and chroma into six groups i.e. V=8/C=2, V=5/C=2, V=3/C=2, V=7/C=6(4), V=4/C=6(4), and high chroma. The colour of specimens were well distributed in Munsell colour tree, as shown in Figure 4-2 (18). The relationship between visual results and the calculated results obtained from those formulae in each colour group are shown in Table 4-2.

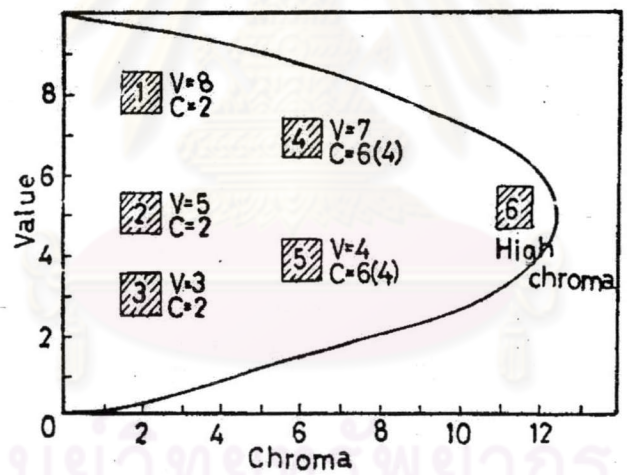

Figure 4-2 V/C values of the specimens selected from Munsell system.

Table 4-2 Change in colour formulae's performance with various Munsell values and chromas

V/C	CIELAB		CMC(1:1)		CMC(2:1)		ISO		$N_c^{\#}$		F_c	
	r	Std. error	r	std. error	r	std. error	r	std. error	r	std. error	r	std. error
V8/C2	0.921	0.338	0.870	0.428	0.873	0.423	0.925	0.330	0.884	0.406	0.851	0.457
V5/C2	0.955	0.302	0.952	0.312	0.889	0.466	0.955	0.302	0.947	0.327	0.934	0.363
V3/C2	0.939	0.345	0.947	0.325	0.929	0.373	0.939	0.345	0.945	0.330	0.955	0.298
V7/C6(4)	0.918	0.340	0.896	0.381	0.913	0.350	0.898	0.376	0.879	0.409	0.945	0.280
V4/C6(4)	0.976	0.201	0.982	0.175	0.966	0.240	0.980	0.187	0.977	0.200	0.981	0.180
high chroma	0.931	0.365	0.963	0.269	0.892	0.452	0.974	0.226	0.965	0.263	0.967	0.253

The results show that the obtained correlation coefficients for CIELAB are higher than 0.900 in all colour groups. For low chroma colours i.e. chroma = 2, the ISO and CIELAB formulae give the most satisfactory at value = 5, whereas CMC (1:1) gives the most satisfaction at value = 3. For middle value and chroma i.e. value=4 and chroma =6 (4), all formulae perform well with the highest correlation coefficient among all group (higher than 0.950). For high chroma colour of specimens, the ISO colour difference gives the most satisfactory with r value 0.974.

The colour specimens were also classified by Munsell hue into eight groups i.e. Y, GY, G, BG, P, RP, R and YR, to test the performance of the various colour fastness formulae. The relationship between visual results and the ones from those formulae are shown in Table 4-3.

Table 4-3 Change in colour formulae's performance with various Munsell hues

Hue	CIELAB		CMC(1:1)		CMC(2:1)		ISO		$N_c^{\#}$		F_c	
	r	std. error	r	std. error	r	std. error	r	std. error	r	std. error	r	std. error
Y	0.899	0.396	0.863	0.457	0.824	0.513	0.921	0.352	0.911	0.374	0.880	0.430
GY	0.955	0.245	0.955	0.245	0.990	0.119	0.955	0.245	0.681	0.603	0.830	0.459
G	0.956	0.275	0.949	0.294	0.938	0.324	0.956	0.273	0.955	0.277	0.940	0.319
BG	0.941	0.312	0.879	0.440	0.873	0.451	0.941	0.313	0.939	0.318	0.945	0.303
P	0.972	0.242	0.941	0.350	0.956	0.304	0.969	0.254	0.965	0.271	0.984	0.185
RP	0.997	0.116	0.998	0.086	0.983	0.258	0.997	0.116	0.978	0.297	0.989	0.215
R	0.914	0.369	0.832	0.504	0.872	0.445	0.934	0.326	0.951	0.281	0.931	0.332
YR	0.927	0.443	0.930	0.434	0.849	0.625	0.927	0.443	0.956	0.348	0.954	0.355

The results show that the obtained r value for ISO standard are higher than 0.900 in all groups. CIELAB colour difference also gives high r-value. The r values for each Munsell hues can be discussed as follows;

- Y; ISO standard and $N_c^{\#}$ give the r value higher than 0.900.
- GY; CMC(2:1), CIELAB, CMC(1:1), and ISO standard give r values higher than 0.900. $N_c^{\#}$ gives the lowest r, equal to 0.681.
- G; all formulae give the r values higher than 0.900.
- BG; F_c, CIELAB, ISO standard and $N_c^{\#}$ give the r values higher than 0.900.
- P; all formulae give the r values higher than 0.900.
- RP; all formulae give the r values higher than 0.900.
- R; $N_c^{\#}$, ISO standard, F_c, CIELAB give the r values higher than 0.900.
- YR, $N_c^{\#}$, F_c, CMC(1:1), CIELAB and ISO standard give the r values higher than 0.900.

To test the performance of the various colour fastness formulae, the lightness values of the specimens were classified into three groups i.e. 30, 50 and 70. The relationship between visual results and the ones from those formulae are shown in Table 4-4.

Table 4-4 Change in colour formulae's performance with various lightness values

L*	CIELAB		CMC(1:1)		CMC(2:1)		ISO		$N_C^{\#}$		F_C	
	r	std. error	r	std. error	r	std. error	r	std. error	r	std. error	r	std. error
30	0.940	0.349	0.951	0.317	0.927	0.383	0.940	0.349	0.951	0.318	0.957	0.297
50	0.958	0.274	0.952	0.292	0.904	0.407	0.967	0.242	0.949	0.301	0.952	0.292
70	0.925	0.328	0.882	0.407	0.889	0.396	0.927	0.324	0.889	0.396	0.861	0.440

The results show that the r values for all formulae at L*=70 are lower than the others. The obtained r-value for ISO standard and CIELAB colour difference are higher than 0.900 in all groups. The r-value for each lightness value can be discussed as follows;

- L* = 30; all formulae give the r values higher than 0.900. F_C gives the highest r-value.
- L* = 50; all formulae give the r values higher than 0.900. ISO standard gives the highest r-values.
- L* = 70; ISO standard and CIELAB give the r values higher than 0.900. F_C gives the lowest r-value.

4.3.1 Testing Colour Fastness Formulae by Using the Colour Specialists Data

Ten colour specialists, who are chief printers, were asked to assess colour fastness of the specimens. The relationship between visual results and the ones that calculated from those formulae were calculated. The results show that ISO colour difference formula gives the highest r and the lowest standard error values, as shown in

Table 4-5. CMC (2:1) gives the lowest r-value at 0.863. The correlation between the mean visual results of a Thai group and a colour specialists group which is shown in Figure 4-3 are high, with the r-value = 0.975.

Table 4-5 Change in colour formulae's performance using colour specialists data

	CIELAB	CMC(1:1)	CMC(2:1)	ISO	$N_C^{\#}$	F_C
r	0.942	0.921	0.863	0.950	0.923	0.933
Standard error	0.333	0.362	0.360	0.300	0.406	0.312

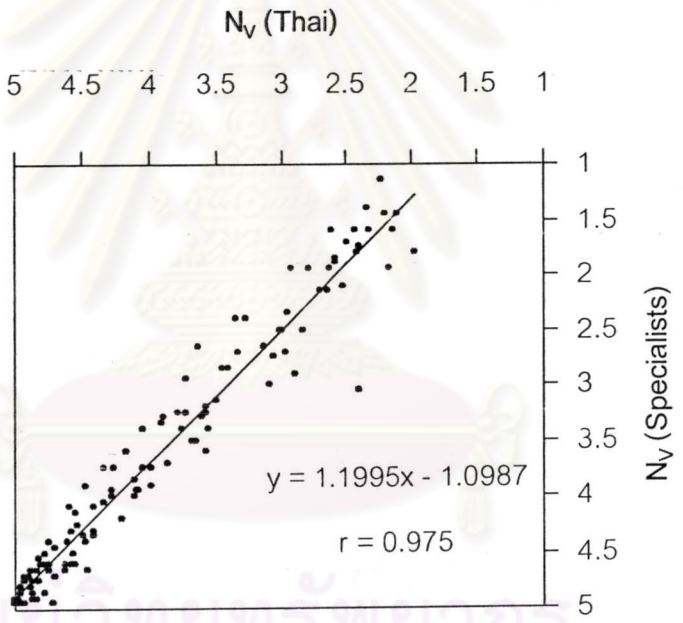

Figure 4-3 Relationship between the mean visual results of students group and colour specialists group in change in colour

4.3.2 Comparison between Thai and Japanese visual assessment in change in colour

In this research, attempts were made to test the differences of visual assessment between Thai and Japanese students. The results of Japanese visual assessment were accumulated by Nakamura et al.(1) from 30 Japanese students between 18 and 21

years old. The result shown that Japanese observers can distinguish the colour difference between treated and untreated specimens better than Thai observer for most of colour pairs, as shown in Figure 4-4.

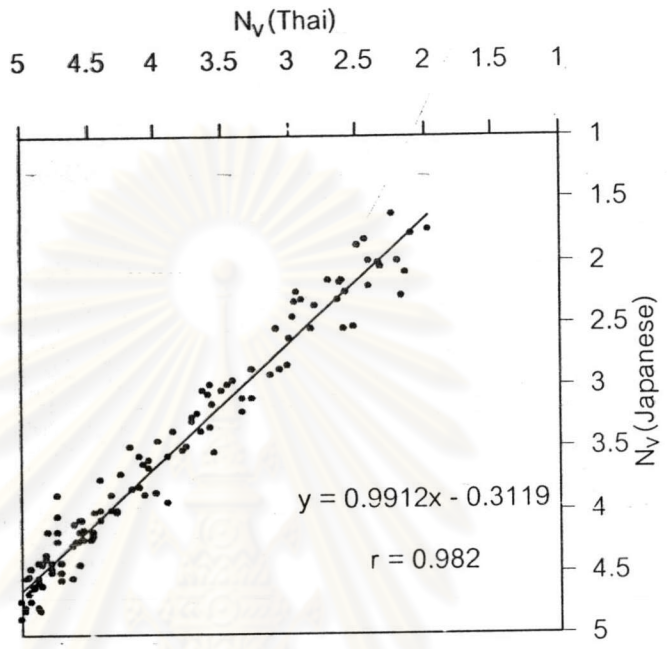

Figure 4-4 Relationship between the mean visual results of Thai and Japanese students groups in change in colour

4.4 The relationship between visual results and the staining formulae's predictions

Table 4-6 and Figure 4-5 show the relationship between the average value of visual results and the values obtained from assessing staining formulae. The results show that all formulae give very high r values, at higher than 0.960. F_S formula gives the highest r value and the lowest standard error value.

Table 4-6 Summary of staining formulae's performance

	CIELAB	SSR(UK)	SSR(ISO)	N_S	F_S
r	0.972	0.961	0.981	0.969	0.988
Standard error	0.239	0.281	0.199	0.251	0.157

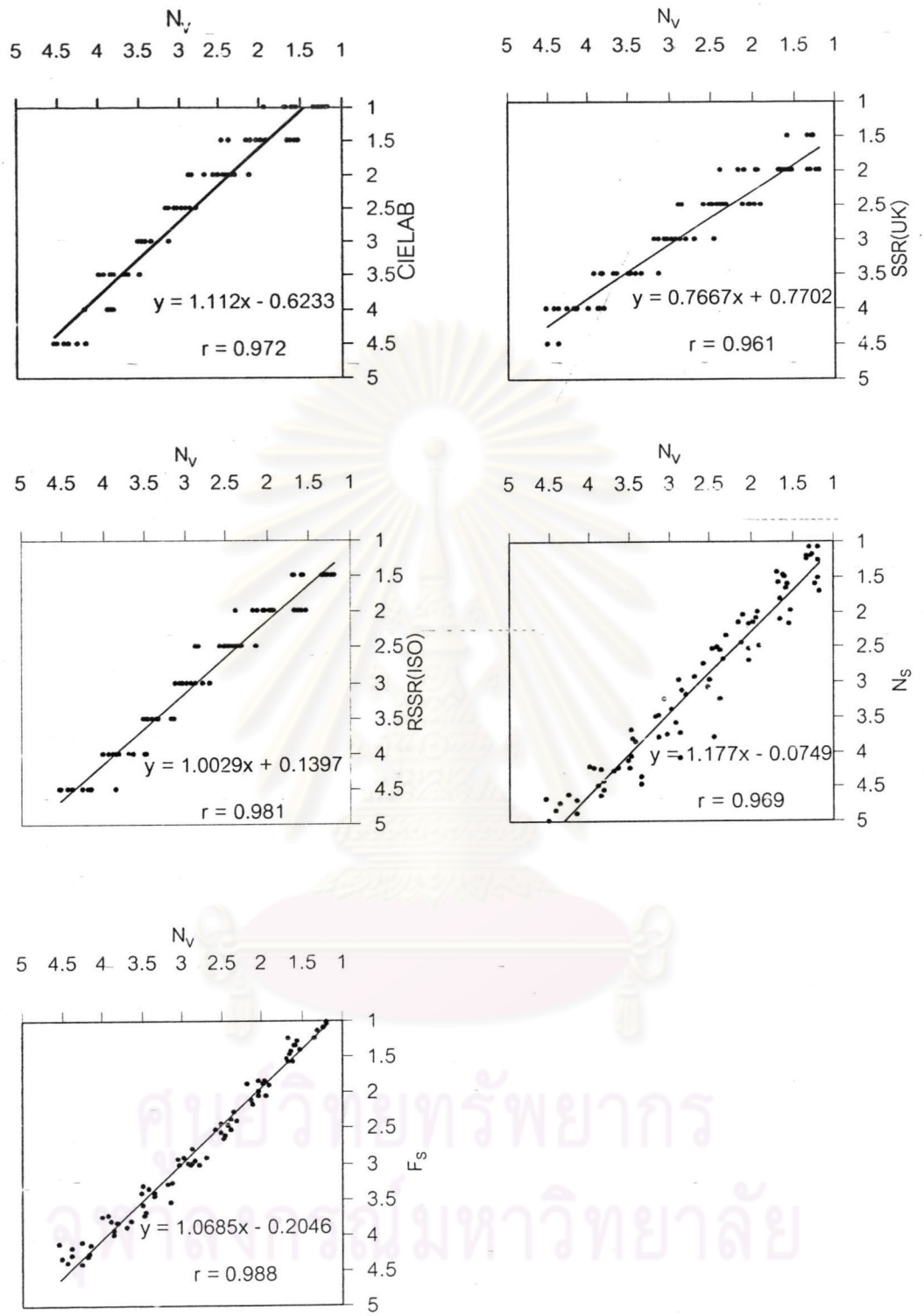

Figure 4-5 Relationship between the mean visual results and predictions from different staining formulae

The relationship between visual and staining formulae assessment for each hue are shown in Table 4-7. The r values was considered very high and coincided with the previous result.

Table 4-7 Staining formulae's performance for each hue

Hue	CIELAB		SSR(UK)		SSR(ISO)		N_S		F_S	
	r	Std. error	r	Std. error	r	Std. error	r	Std. error	r	Std. error
R	0.977	0.139	0.951	0.150	0.977	0.139	0.999	0.064	0.991	0.115
YR	0.974	0.182	0.973	0.157	0.974	0.182	0.990	0.175	0.993	0.127
Y	0.971	0.322	0.979	0.210	0.980	0.226	0.992	0.158	0.993	0.127
GY	0.976	0.277	0.976	0.185	0.977	0.229	0.971	0.298	0.980	0.108
G	0.977	0.193	0.962	0.178	0.987	0.145	0.997	0.096	0.988	0.153
BG	0.984	0.122	0.972	0.118	0.984	0.122	0.997	0.092	0.999	0.042
B	0.962	0.137	0.873	0.172	0.962	0.137	1.000	0.014	0.999	0.026
P	0.897	0.181	0.897	0.181	0.897	0.181	0.999	0.022	1.000	0.011

4.4.1 Testing staining Formulae by Using the Colour Specialists Data

Ten chief printers were asked to assess colour fastness of the specimens. The result show that the correlation between visual assessment and difference staining formula are high, with $r \geq 0.960$. FS formula still gives the highest r value and the lowest standard error at 0.986 and 0.174, respectively as shown in Table 4-8. Figure 4-6 is plotted between visual result of students group and chief printers group, giving high r value at 0.992.

Table 4-8 Staining formulae's performance using colour specialists data

	CIELAB	SSR(UK)	SSR(ISO)	N_S	F_S
r	0.960	0.975	0.980	0.967	0.986
Standard error	0.288	0.232	0.208	0.264	0.174

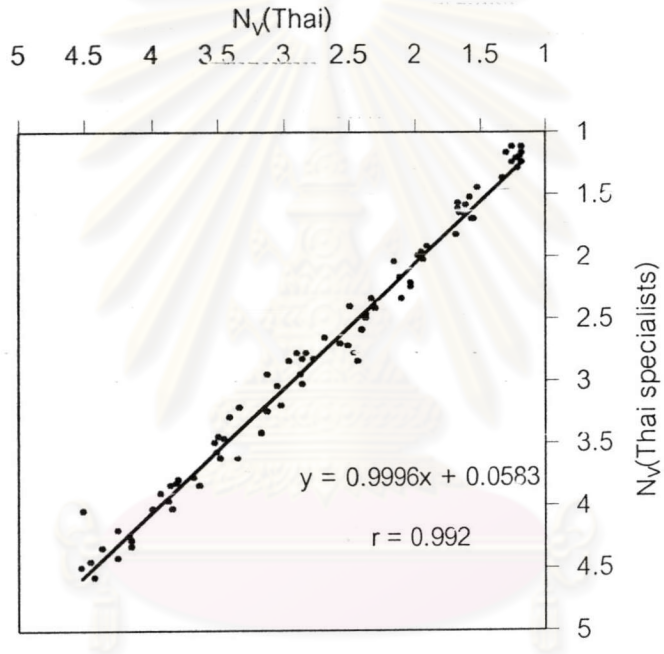

Figure 4-6 Relationship between the mean visual results of students group and colour specialists group in staining

4.3.2 *Comparison between Thai and Japanese visual assessment in staining*

Figure 4-7 shown the relationship between Thai and Japanese visual assessment. The r value is 0.996 and is considered very high. The Thai and Japanese visual assessment results are approximately same.

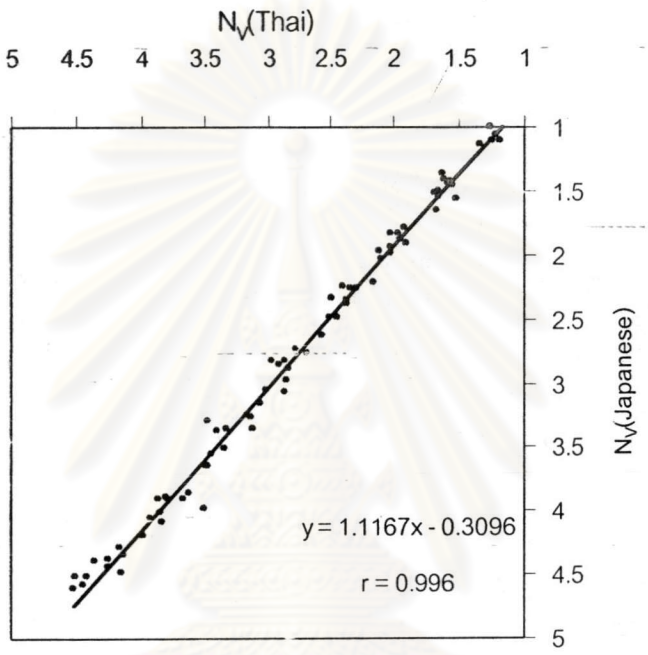

Figure 4-7 Relationship between the mean visual results of Thai and that of Japanese students groups in staining