Colorimetric Assessment of Pod Disease in Peanuts: Comparison with Visual Methods and Efficacy of Use in Selection[1]

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ABSTRACT

Colorimetry was evaluated as a method to assess pod disease in peanuts (*Arachis hypogaea* L.) caused primarily by *Pythium myriotylum* Drechs., *Sclerotium rolfsii* Sacc., and *Rhizoctonia solani* Kuhn. Data analyzed were from nineteen replicated tests conducted from 1982 to 1987, exclusive of 1985, in three South Texas locations. Each plot was scored for pod disease colorimetrically and visually. A negative linear relationship (R^2>96%) was found between Hunter color values (L and b) and percent infection measured visually for samples hand selected to approximate eleven disease levels varying from 0-100%. Variability among readings was less at extremes of infection. Correlation both between visual ratings and between visual and colorimetric ratings was affected by soil differences, pathogens infecting the pods, pod genotype, and level of infection present. Correlation among visual raters was generally higher than that between color value ratings. Two-thirds of the lines in these tests classified visually as being in the best 50% for pod disease were also in the best 50% according to colorimetric scores. Use of colorimetry in conjunction with a single visual rating was estimated to increase efficiency and reduce costs of evaluation compared to multiple visual ratings.

Key Words: *Arachis hypogaea*, groundnut, *Pythium myriotylum*, *Rhizoctonia solani*, pod rot correlation, *Sclerotium rolfsii*, white mold, fiber optic light, disease assessment.

Three of the more important soilborne diseases of peanut (*Arachis hypogaea* L.) in Texas are caused by *Pythium myriotylum* Drechs., *Sclerotium rolfsii* Sacc., and *Rhizoctonia solani* Kuhn. Economic losses from the diseases result from reductions in both yield and market grade. While yield loss due only to soilborne disease is difficult to determine, estimates of two to three percent per year are common in Texas (7). This equates to annual losses of approximately four million dollars. More importantly, individual growers may sustain a complete crop loss from soilborne diseases. Because of the economic importance of pod rot caused by *P. myriotylum, R. solani, and S. rolfsii* in Texas, and because host plant resistance offers a cost effective control measure, efforts have been underway to develop competitively-yield-

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ing, resistant peanut cultivars.

A part of this improvement program has included attempts to improve disease assessment methodologies for evaluating resistance of breeding material to the three pathogens (1,4). Our procedure has been to use two or three experienced raters, the mean of whose visual estimate of pod disease was used as the criterion for selection. Beginning in 1982, a colorimeter was used in addition to multiple visual ratings to evaluate levels of infection in samples. The potential advantages in pod rot evaluation were objective comparisons, improved accuracy and/or repeatability, reduction in time per evaluation, utilization of less skilled labor, and automation of data entry.

The objective of this study was to examine the efficacy of colorimetry to assess pod disease in breeding material with reference to the more traditional visual methods.

Materials and Methods

Experimental Material

Data analyzed were from nineteen replicated tests conducted from 1982 to 1987, exclusive of 1985, in Brazos (Patilo sandy loam), Wilson (Miguel fine sandy loam), and Lavaca (Tremona loamy fine sand) counties in southern Texas. The breeding lines entered in each test varied among tests and years. The number of entries in a test varied from twelve to forty. Two runner (*A. hypogaea hypogaea* var *hypogaea*) genotypes, Florunner and TxAG-3, and two spanish (*A. hypogaea fastigiata* var *vulgaris*) cultivars, Tamnut 74 and Toalson, were used in sixteen of nineteen tests as checks. In the other three tests, only runner entries and the two runner checks were grown. Florunner and Tamnut 74 were considered susceptible to pod disease, while TxAG-3 and Toalson were considered resistant.

Plots were harvested at maturity by digging and inverting with a two-row commercial digger-inverter followed by bagging whole plants in burlap bags. Hot-air dryers were used for drying to approximately 10% seed moisture. Plants were threshed with a stationary small-plot thresher. Pod samples were cleaned by hand and with a Hobb's stemmer. Random samples for disease determination were collected using a riffle divider.

From one to three people (designated R1, R2, R3) independently rated each plot sample for percentage of pod tissue discolored by pod disease. The number of raters was not the same for all tests. Rater 2 (R2) was the same individual in all nineteen tests, so his ratings were used in comparisons with colorimetric determinations of pod disease levels. Some comparisons also used the mean of all visual ratings of a plot sample (XR). The same plot sample was also rated colorimetrically using a Gardner XL865 tri-stimulus colorimeter. The Hunter color scale was used to evaluate samples. The three values, L, a_L, and b_L, hereafter represented by L,a, and b, respectively, represent axes in a three-dimensional color space. L is the black(0) - white(100) axis measuring lightness. Chromaticity, or the rectangular plane of color lying perpendicular to the L axis, is defined by the a (redness(+) - greenness(-)) and b(yellowness(+) - blueness(-)) axes. The a value was determined not to effectively separate test entries and was not used in data analysis. A yellowness index (YI), correlating with visual ratings of yellow and near-white materials and corresponding to ASTM Method E-313 was calculated using the formula:

$$YI = \frac{(142.9 * b_L)}{L}$$

YI increases as b_L increases at constant lightness (L) values.

Analyses

Linear Relationship between Colorimeter Value and Visual Rating - The association of colorimetric values with visually estimated values was examined by preparing hand-selected samples with various levels of disease incidence for colorimetric determinations. Diseased pods from a single genotype grown at two locations were each divided into eleven classes, hand selected to approximate visual differences of 10% in the amount of pod discoloration. One set of eleven samples was collected from a site in Wilson County where *P. myriotylum* was abundant. A second set of eleven samples was collected in Lavaca County where infection was primarily by *S. rolfsii*. Each sample was measured colorimetrically five times, the pods in a sample being redistributed between determinations. L, b, and YI values were regressed on percent visual infection in three ways. First, each determination was regressed separately, yielding five estimates of regression parameters for each set of samples. Second, regression parameters were estimated over all determinations. Using these two analyses, and equating the determinations to "treatments", the homogeneity of the regression coefficients based on individual determinations was calculated using the method described by Steel and Torrie (6). Finally, the mean colorimetric values were regressed on percent visual infection.

Correlation of Colorimetric Values and Visual Rating - The degree of association among visual ratings, and between colorimetric values and visual ratings was examined through correlation. Colorimetric values L, b and YI were compared to visual ratings (R2 and XR). A total of 1558 observations went into the correlations, representing plot observations from nineteen replicated tests. Similar comparisons were performed on each of the nineteen tests. Correlation analysis was performed on various subsets of the 1558 observations as described below. The colorimetric values L, b, and YI were compared only to R2 in these analyses.

Location Effects - The influence of location on the association of colorimetric and visual pod disease assessments was studied in two analyses. In the first analysis, observations were grouped by location, and correlations calculated over observations within each location. The second analysis used only those observations for which R2 visual ratings were less than or equal to ten percent. Observations in this subset were further grouped based on the location from which the observation was taken. Correlations among variables were calculated over observations in each of the three resultant groups. Homogeneity of correlation coefficients was evaluated using chi-square when more than two subgroups were compared. A z test was used for comparing two subgroups (6).

Disease Level Effects - The influence of overall disease pressure on the relationship between colorimetric and visual ratings was studied by grouping all observations into four classes based on R2 visual ratings; ≤10%, >10% to ≤20%, >20% to ≤30%, and >30%. The four groups contained 792, 497, 205, and 64 observations, respectively. Correlations among variables were calculated over observations within groups.

Genotypic Effects - Genotypic effects were examined by hand-selecting non-diseased pods of Tamnut 74, Toalson, Florunner, and TxAg-3 from two of four replicates of a 1987 test in Brazos County. Each of the eight samples was measured twice on the colorimeter, pods being redistributed between measures. Scores were analyzed using a randomized complete block analysis of variance with subsampling. Means were compared with the Waller-Duncan k-ratio t-test at k=100, roughly corresponding to p=.05.

Selection Based on Colorimetric Values Compared to Visual Method - Two methods were used to evaluate the efficacy of the colorimeter for use in a selection program. The first method was based on the normal use of replicated tests to assess pod disease and yield performance in order to make selections to grow the following year. Normally, selection is based on relative performance; either some percent of the best performing lines or entries in the top one or two statistical groupings based on a mean separation statistic are used as a basis for selection. For these studies, each of the nineteen experiments was analyzed separately using a randomized complete block analysis of variance with either two or four replications, depending on the test. Mean separation was performed using the Waller-Duncan test as described above. Variables analyzed included L, b, YI, and XR. The number of visual ratings in XR ranged from one to three independent evaluations. All test entries were included in the analysis. Those entries appearing in the top 50% of a test were identified for each of the four variables. Using this method, the same number of entries would be selected using each of the four methods, but the entries selected may differ. Using the entries selected based on XR, as a base, the percent of entries selected using each of the colorimetric values that also appeared in the XR list was calculated. For example, if ten entries were selected from a test based on XR, and eight of the ten entries were also selected using the L value, the "score" for L in the test would be 80%. Finally, the degree of relationship between this percentage score for a colorimetric value and the "r" value for the correlation between that colorimetric value and XR was determined by correlating the two values.

The second method used only data from the four checks. Mean colorimetric values, R2, and XR scores were computed for each check in each of the nineteen tests. Genotypes were ordered within each test based on each of the five scores (L, b, YI, R2, XR). Ranking was from most diseased to least diseased; colorimetric values were ranked from lowest to highest, while R2 and XR scores were ranked from highest to lowest. Because spanish and runner entries were dug at different dates, comparisons

were within market type. Within each test, the order of genotypes was compared based on each of the four disease scores to assess consistency.

Results and Discussion

Relationship between Colorimetric Value and Visual Rating - The usefulness of colorimetric readings to assess pod disease is predicated on a definable relationship between colorimetric and visual measures. Regression analysis and the homogeneity test indicated that a linear relationship existed between colorimetric values and percent pod disease measured visually for each of the determinations, and that the regression coefficients were homogeneous. This held true both for the sample from Wilson County and from Lavaca County. Regression of mean colorimetric values on pod disease measured visually (Fig. 1) yielded coefficients of determination greater than 96% for L and b for both samples, indicating good fit to a linear model. Coefficients of determination were lower for YI:/ 83.7% for the Wilson County sample, and 76.0% for the Lavaca county sample.

Disease symptom coloration apparently affected colorimetric ratings. After about 25% visual infection, L values were lower (darker color) for *Pythium*-infected samples (Wilson County) than for *Sclerotium*-infected samples (Lavaca County) at any given percent visual infection (Fig. 1a).

The variability of the five determinations at each of the 11 infection levels provided an indication of the repeatability of a colorimetric measure for a particular sample. While all coefficients of variability were low for each of the three colorimetric values calculated over five determinations, variation with changes in infection level in both the Wilson and Lavaca County samples was observed (Figs. 2 and 3, respectively). In the *Pythium*-infected sample from Wilson County, both L and b exhibited somewhat of a bell-shaped curve, with less variability at the extremes of infection and the most variability near the middle. These results are similar to those for human eye discernment which showed that small differences were more easily detected at low or high levels of leaf infection than at intermediate levels (3). Of interest was the slightly lower variation in L compared to b at almost all levels of infection. The relationship of the coefficient of variation in colorimetric values with visually-determined infection was less clear in the S. *rolfsii*-infected sample. While the same trend was exhibited as for the *Pythium* sample, an usually high amount of variation was exhibited by the 90% sample. The reason for this peak is not clear. Like the other sample, L exhibited slightly less variation at all levels of infection.

Correlation of Colorimetric Value and Visual Rating - Correlation among visual ratings was higher than the correlation between any of the three colorimetric values and either R2 or XR (Table 1). The coefficients of correlation ranged from 0.72 to 0.84 among the three visual ratings, while the highest correlation between a colorimetric value and visual rating was -0.59 between color value b and XR. Correlations of L and b with either R2 or XR were similar, and both exceeded those of YI with the same two variables.

The degree of correlation varied considerably from test to test (Table 1), although the mean of the correlations from individual tests corresponded closely with correlations calculated over all observations. Correlations among visual ratings were slightly less variable than between colorimetric

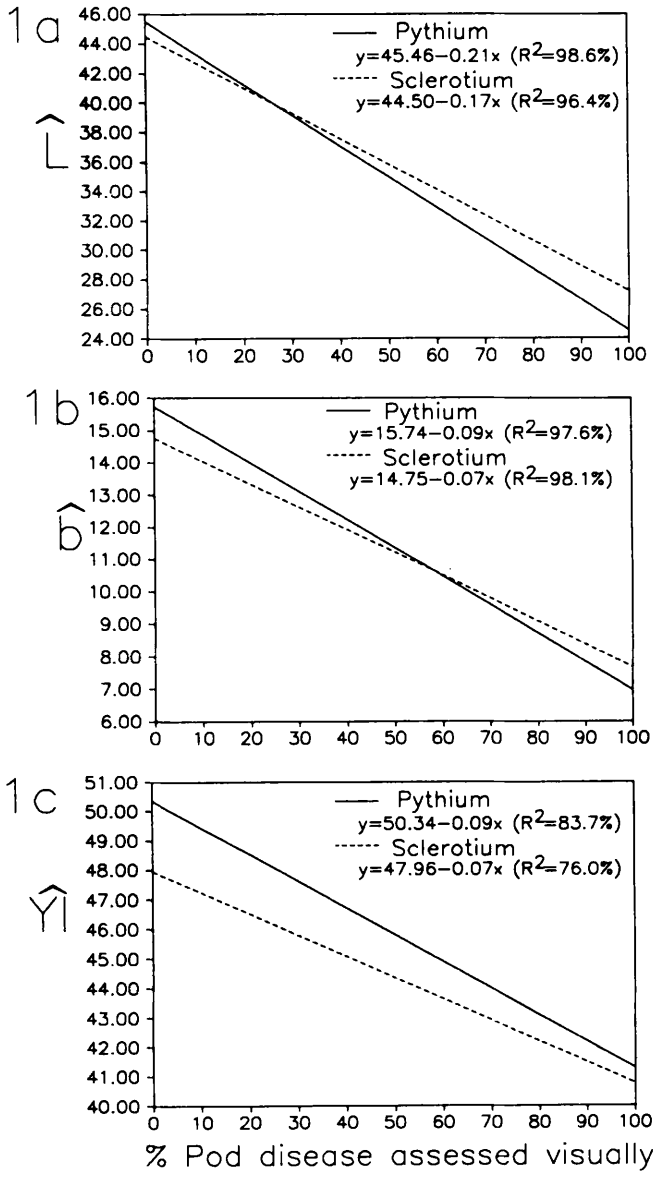

Fig. 1. Linear regression between colorimeter values and percent pod disease determined visually for Pythium and Sclerotium infected samples. 1a = Hunter color value L, 1b = Hunter color value b, and 1c = Yellowness Index. Mean of five determinations at each infection class was regressed on infection class (0%-100%). Pods were hand selected to approximate the eleven infection levels.

values and visual ratings as indicated by the smaller standard deviations. The highest correlation between colorimetric value and visual rating was lower than the highest among visual ratings. The lowest mean correlation among visual ratings was higher than the highest mean correlation between visual rating and colorimetric rating. Three variables were identified that could possibly affect the association between colorimetric and visual determinations of pod disease: location, level of disease pressure, and genotypic differences.

Location Effects - Location significantly affected the degree of correlation (Table 2). Location also influenced the magnitude of both visual and colorimetric ratings (Table 3). Except for the correlation of YI with R2 for the Brazos County data, correlations between colorimetric rating and visual rating, as well as correlations among visual ratings were highest for tests from Brazos County, intermediate

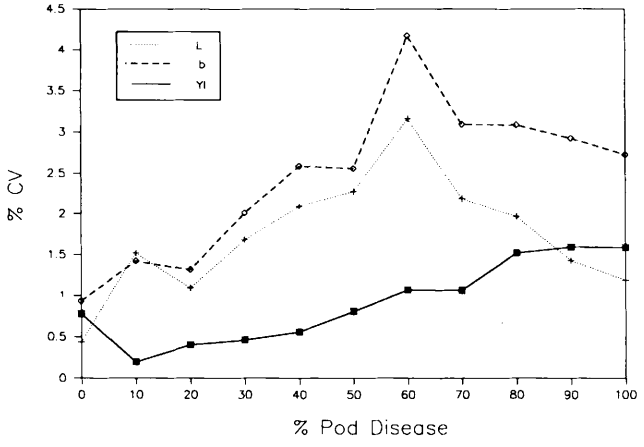

Fig. 2. Coefficients of variability in colorimeter reading at each of eleven visually-determined pod disease levels for a *Pythium* infected sample. L and b are Hunter color values; YI is a yellowness index. CV was calculated based on five measurements at each infection level. Pods were hand selected to approximate the eleven infection levels.

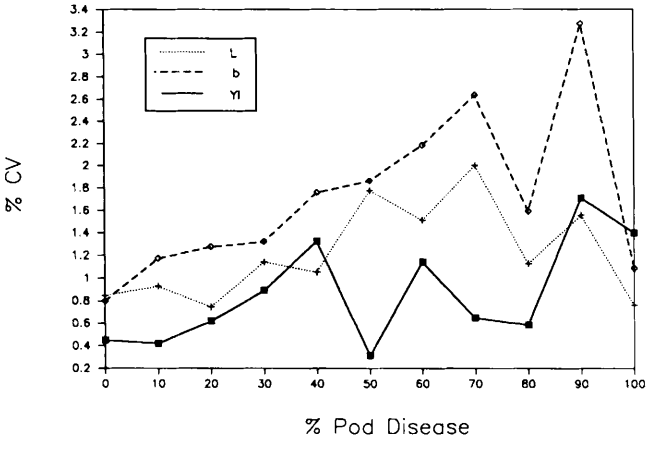

Fig. 3. Coefficients of variability in colorimeter reading at each of eleven visually-determined pod disease levels for a *Sclerotium* infected sample. L and b are Hunter color values; YI is a yellowness index. CV was calculated based on five measurements at each infection level. Pods were hand selected to approximate the eleven infection levels.

Table 1. Correlations among visual pod disease ratings, and between colorimeter values (L, b, and YI) and R2 and XR, calculated both over all plots and tests and over plots within each test.

		Summary of correlations over plots within each test[3]			
Correlates[1]	Over all tests[2]	Mean	SD	Min	Max
L-R2	-0.45	-0.49	0.20	-0.18	-0.81
b-R2	-0.51	-0.49	0.23	-0.04	-0.83
YI-R2	-0.35	-0.35	0.29	0.03	-0.64
L-XR	-0.56	-0.53	0.17	-0.22	-0.81
b-XR	-0.59	-0.51	0.19	-0.20	-0.83
YI-XR	-0.35	-0.35	0.29	0.06	-0.64
R1-R2	0.84	0.84	0.13	0.56	0.92
R1-R3	0.75	0.75	0.16	0.33	0.92
R2-R3	0.72	0.72	0.19	0.38	0.92

[1]L and b are Hunter color values; YI is a yellowness index; R1, R2, and R3 represent visual estimations of pod disease by different visual raters; and XR is the mean of plot ratings made visually by R1, R2, and/or R3.
[2]Values are correlation coefficients calculated using 1558 plots from all nineteen tests.
[3]Correlation coefficients calculated by test. Values represent mean, standard deviation, minimum and maximum of the resultant nineteen correlation coefficients.

Table 2. Correlations among visual pod disease ratings, and between colorimeter values (L, b, and YI) and R2, calculated both over all plots and tests at the same location.

	Correlation Coefficients[1]				
Variables Compared[2]	Lavaca	Wilson	Brazos	X^2[3]	z[4]
L-R2	-0.33	-0.42	-0.52	7.792	
b-R2	-0.33	-0.56	-0.68	42.576	
YI-R2	-0.23	-0.41	-0.30	14.761	
R1-R2	0.73	0.85			5.38
R1-R3	0.59	0.79			6.04
R2-R3	0.62	0.73			2.87

[1]All correlation coefficients significantly different from zero (p=0.001)
[2]L and b are Hunter color values; YI is a yellowness index; R1, R2, and R3 represent visual estimations of pod disease by different visual raters.
[3]Chi-square test for homogeneity of correlation coefficients among locations. Values greater than 5.99 are non-homogeneous (p=0.05)
[4]z-test for difference between correlation coefficients at each location. Values greater than 1.96 indicate less than a 5% probability that a larger difference would arise by chance when there is no difference between the two values.

from Wilson County, and lowest from Lavaca County, when correlations were calculated over all tests at each location. When correlations were computed on an individual test basis, the same trend was observed (Table 4).

Locations differed in soil type, and in pathogen prevalence and density. The predominant pathogens at the Lavaca County test site were *R. solani* and *S. rolfsii*. Lesions caused by these pathogens tend to be lighter in color than those caused by *P. myriotylum*, the predominant pathogen at the Wilson County test site. Lesions caused by *P. myriotylum* are almost black and often coalesce. A major factor contributing to the better correlations in samples from Wilson County between colorimetric ratings and visual infection was likely the better discrimination by the instrument, and perhaps by the raters, of the darker *P. myriotylum* symptoms.

Soil color differences existed among the three test locations. Soil at the Brazos County location was very light colored, soil at the Lavaca County site was light brown, and Wilson County test site soil was red-brown. While most soil adhering to pods was removed during the harvest and sampling process, soil dust often remained, since pods were not washed prior to evaluation. Comparing mean colorimetric values of samples harvested at each location using observations in which R2 visual ratings were ≤ 10% revealed distinct differences in L and b values among locations (Table 5). Differences among YI values were less distinct. The trend over location followed expectations based on soil color at each of the locations; higher colorimetric values were associated with lighter colored soils, and lower values were associated with darker colored soils. Therefore, at low infection levels, soil effects may confound differences among genotypes due to pod disease, particularly if soil color variation exists within a test and the variation is not controlled through

Table 3. Mean colorimeter value and visual pod disease rating over tests conducted at three locations in Texas.

Variable[1]	Mean Rating[2]		
	Lavaca	Wilson	Brazos
L	39.42	36.60	43.64
b	13.68	12.57	15.25
YI	49.56	49.08	49.98
R1	9.5	16.5	
R2	11.1	18.4	13.7
R3	13.4	18.8	

[1]L and b are Hunter color values; YI is a yellowness index; R1, R2, and R3 represent visual estimations of percent of pod disease by different visual raters.

[2]Mean of all plot measures from all tests at each location.

Table 4. Correlation among visual pod disease ratings and of colorimeter values L, b, and YI with R2 in pairs of tests in which identical genotypes were grown at two locations.

Year	Test	Location	N[2]	Correlation Coefficient[1] L-R2[3]		b-R2		YI-R2		R1-R2	R1-R3	R2-R3
1982	1	Wilson	88	-0.56		-0.60		-0.53		0.80	0.80	0.72
		Lavaca	88	-0.21	*	-0.18	ns	-0.10	ns	0.57	0.68	0.40
		z[4]		2.77		3.39		3.18		2.98	1.80	3.19
1983	1	Wilson	104	-0.46		-0.49		-0.30	**	0.88	0.74	0.72
		Lavaca	104	-0.34		-0.36		-0.20	*	0.76	0.68	0.76
		z		0.99		1.07		0.83		2.70	0.84	0.66
1983	2	Wilson	96	-0.49		-0.52		-0.32	**	0.78	0.73	0.80
		Lavaca	96	-0.18	ns	-0.04	ns	0.12	ns	0.57	0.33	0.38
		z		2.40		3.65		3.09		2.73	3.97	4.68
1984	1	Wilson	48	-0.73		-0.64		-0.34	*	0.78		
		Lavaca	88	-0.20	ns	-0.12	ns	0.04	ns	0.56		
		z		3.89		3.39		2.13		2.13		
1984	2	Wilson	48	-0.81		-0.83		-0.64				
		Lavaca	88	-0.46		-0.49		-0.34	**			
		z		3.32		3.51		2.18				
1986	1	Wilson	128	-0.56		-0.48		0.03	ns	0.87	0.92	0.89
		Lavaca	128	-0.34		-0.37		-0.10	ns	0.85	0.79	0.82
		z		2.22		1.08		1.08		0.68	3.84	2.02
1987	1	Brazos	55	-0.50		-0.48		-0.22	ns			
		Lavaca	56	-0.24	ns	-0.28	*	-0.17	ns			
		z		1.54		1.22		0.26				
1987	2	Brazos	64	-0.81		-0.83		-0.42				
		Lavaca	47	-0.59		-0.66		-0.53				
		z		3.34		2.80		1.11				

[1]All correlation coefficients significantly different from zero (p=0.001), except those marked by **(p=0.01), *(p=0.05), or ns(not significantly different from zero).
[2]Number of observations in the test.
[3]L and b are Hunter color values; YI is a yellowness index; R1, R2, and R3 represent visual estimations of pod disease by different visual raters.
[4]z-test for difference between correlation coefficients at each location. Values greater than 1.96 indicate less than a 5% probability that a larger difference would arise by chance when there is no difference between the two values.

appropriate experimental designs.

Disease Level Effects - The correlation both between visual rating and colorimetric values and among visual raters was definitely affected by the level of disease pressure (Figure 4). At low levels of disease pressure, there was little correlation between the two measures of pod disease or among raters. As disease levels increased (measured by R2), the association improved.

Several reasons for these results are possible. From the standpoint of visual assessment of disease, the eye can discern smaller differences in diseased area at very low or very high levels of disease (2,3). As the level of disease increases to 50%, the eye can discern only larger differences.

Table 5. Mean pod disease scores of samples for which pod disease as rated by R2 was equal or less than 10% in tests at three locations in Texas.

Disease Measure[1]	County		
	Brazos	Lavaca	Wilson
L	44.93	39.74	37.41
b	15.87	13.86	13.19
YI	50.54	49.81	50.43
R1		5.9	7.1
R2	7.0	7.1	7.8
R3		11.2	13.0
XR		7.6	9.1

[1]L and b are Hunter color values; YI is a yellowness index; R1, R2, and R3 represent visual estimations of percent of pod disease by different visual raters.

These reports were based primarily on assessment of foliar disease. The low correlations among visual raters at low levels of disease seem to contradict these findings. Differences in the size and surface of pod samples might affect repeatability of disease assessments. At lower levels of disease, more "healthy" pod tissue was exposed to the colorimeter; factors such as soil dust adhesion and genotype had a greater chance to influence colorimetric ratings. At higher levels of disease, the discoloration caused by the pathogen may have assumed more importance in terms of colorimeter response and tended to over-shadow the other factors mentioned. Another source of error might have been an inability of raters to distinguish small differences under low disease pressure.

Genotypic Effects - Differences among the four checks were significant (p=0.05) for the colorimetric values b and

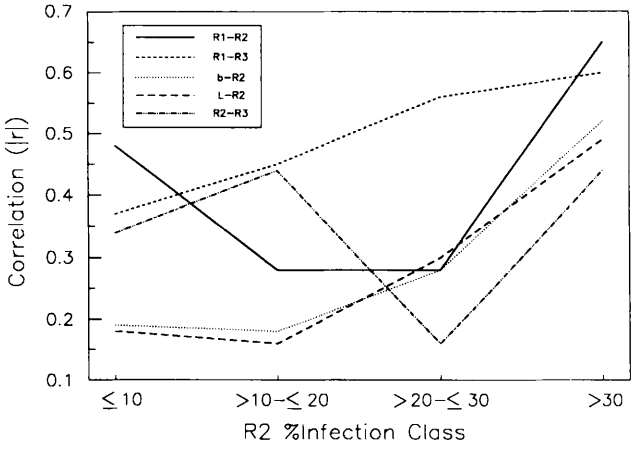

Fig. 4. Correlation among visual pod disease ratings, and between colorimeter values (L and b) and R2 within each of four ranges of pod infection determined visually by R2.

YI, but not for L. Differences in L among genotypes were significant at p=0.10. Variance among determinations was significantly less than that among replicates within genotypes for L and b, but not for YI. Based on F-ratios for genotypic differences, genotypes varied more in yellowness attribute (b), than for lightness (L). At low levels of infection, genotypic differences might contribute significantly to colorimetric-determined infection differences, and also might have contributed to the lower correlations observed.

Selection - The percentage of entries selected by L colorimetric value which were in the top half of entries selected visually varied from 41.7% to 100% (Table 6). The range was the same for b values. The mean and standard deviation percentages over the nineteen experiments was 67.2 ± 15.4% and 66.4 ± 13.5% for L and b, respectively. As expected, the percentage scores were associated with the degree of correlation between visual rating and colorimetric rating in a particular experiment: this correlation was 0.66 for L and 0.88 for b.

Table 6. Test parameters, percent of entries in top fifty percent as ranked by colorimeter values L and b that also were in the top fifty percent ranked by XR[1], and correlation of L and b with XR, for each of the nineteen tests.

		Number			Visual Raters	% Selected by XR also selected by:		Correlation of XR with:	
Year	Location	Test	Entries	Reps	no.[2]	L[3]	b[3]	L	b
1982	Lavaca	1	22	4	3	45.5	54.6	-0.22	-0.24
	Wilson	1	22	4	3	72.7	72.7	-0.63	-0.63
1983	Lavaca	1	26	4	3	76.9	61.5	-0.40	-0.37
		2	24	4	3	41.7	41.7	-0.36	-0.26
	Wilson	1	26	4	3	69.2	67.2	-0.51	-0.51
		2	24	4	3	75.0	66.7	-0.55	-0.55
1984	Lavaca	1	20	4	2	60.0	50.0	-0.32	-0.20
		2	22	4	1	81.8	81.8	-0.46	-0.49
	Wilson	1	24	2	3	75.0	75.0	-0.70	-0.64
		2	24	2	2	100.0	91.7	-0.81	-0.83
		3	20	2	2	60.0	70.0	-0.50	-0.57
		4	40	2	2	85.0	85.0	-0.79	-0.74
1986	Lavaca	1	32	4	3	75.0	68.8	-0.36	-0.38
		2	30	4	3	73.3	73.3	-0.60	-0.73
	Wilson	1	32	4	3	75.0	68.8	-0.62	-0.52
1987	Brazos	1	14	4	1	57.1	71.4	-0.50	-0.48
		2	16	4	1	100.0	100.0	-0.81	-0.83
	Lavaca	1	14	4	1	71.4	57.1	-0.24	-0.28
		2	12	4	1	50.0	67.7	-0.59	-0.66

[1]Mean of plot ratings made by individual visual raters.
[2]Number of individuals who visually rated each plot.
[3]L and b are Hunter color values.

As important as the percent selections by visual versus colorimetric methods is the rank of known resistant and susceptible genotypes; both visual and colorimetric methods should rank resistant genotypes as more resistant than a susceptible genotype. For the sixteen tests in which Toalson and Tamnut 74 were grown, in no test was Toalson ranked as having more pod disease than Tamnut 74 by R2 or XR; however, in seven and five tests for L and b, respectively, Toalson ranked higher than Tamnut 74 in pod disease. In none of these situations was the difference between the two cultivars significant. Among the sixteen tests, the two cultivars were significantly different in three tests for L and b, and in eight tests for R2 and XR. The three tests in which the two cultivars were significantly different for L and b values were the same. In two of these three tests the differences in visual ratings were significant.

Out of nineteen tests, Florunner and TxAg-3 differed significantly in eight, eleven, and eleven tests for L, b, and R2, respectively. Of the fourteen tests in which there was more than one visual rating, the difference in XR between the two genotypes was significant (p=.05) in eight tests. TxAg-3 ranked more susceptible than Florunner in three tests by L, but in only one using b. In the Lavaca County Pod Rot #1 1987 test, the L values for TxAg-3 were significantly lower than for Florunner, indicating more pod discoloration. The difference in b value was not significant. In this test, Florunner had significantly more pod disease than TxAG-3 assessed visually. In seven of the eight tests in which L differences were significant, b and R2 differences were also significant. In ten of eleven tests in which b differences were significant, R2 differences were also significant. Florunner ranked higher than TxAG-3 in pod disease assessed visually in all tests.

Several factors may have contributed to these results. Since the difference in pod disease susceptibility of Tamnut 74 and Toalson is less than the difference between Florunner and TxAg-3, it was not surprising that more reversals occurred between the two spanish checks. This is borne out by the higher number of tests in which significant differences were found between the resistant and susceptible check for runner versus spanish. The b value for undiseased pods from the 1987 Brazos County test was 1.10 units higher for TxAG-3 than for Florunner, while the L value was 1.36 units lower for TxAG-3 than for Florunner. High b and L values are associated with low pod disease. In the presence of low levels of pod disease, the genotype may affect interpretation of colorimeter-based pod disease determination.

The decision of what germplasm to keep or discard during the selection process is probably one of the most difficult decisions the plant breeder must make. Selection for pod disease resistance is generally not effective until the F_4 generation (5). In developing lines with improved resistance to pod disease, factors of grade and yield weigh heavily in addition to the level of resistance. Year to year and location to location differences in level of disease further complicate selection efforts. If low levels of pod disease in evaluated genotypes are confirmed to be a stable trait, it may not be necessary to find a method that can reliably distinguish between, for example, 3% and 7% pod infection. For other than in-shell peanuts, seed discoloration is of much greater importance in determining the value of the peanut harvest than is pod discoloration. It is likely that at low levels of pod disease, the seed within the pods may be unaffected, particularly if the low levels are due to slight discoloration on several pods rather than severe disease on a few pods. Further, only when seed discoloration (damage) equals or exceeds 2% is a penalty assessed.

Conclusions

The repeatability of colorimeter readings was affected by level of disease and intensity of discoloration. The accuracy of colorimetric values, using visual rating as a standard, was affected to some extent by the level of infection, the soil in which pods were produced (both soil color and predominant pathogen), and genotype of the pod. Colorimetry measures light reflectance. Any factor that affects light absorption, whether or not a result of the disease of concern, can affect the score. Thus, each sample should be visually examined to ascertain whether discoloration was the result of pod disease, other factors, or both disease and other factors.

The use of visual ratings as a standard with which to compare the accuracy of colorimetric ratings was based on visual rating being the "standard" method. The poor correlation among visual ratings at low levels of infection suggests shortcomings in this method also. Visual assessment can separate to some degree discoloration caused by disease from that caused by other factors. Unlike colorimetry, however, rater expertise, fatigue, and opinion, as well as lighting and other factors may affect subjective assessment of pod disease. Visual comparisons, like colorimetric, were more effective when disease development was adequate to produce distinct differences among samples. Marked color differences between diseased and healthy pod tissue is desirable. At higher levels of infection, differences of 10% infection are usually discernable; this magnitude of difference may reflect differences in susceptibility. At low levels of infection, the tendency is to try and resolve small differences of one to two percent among genotypes. These differences may reflect as much or more micro-environmental variation than genotypic differences.

Defensible conclusions as to the relative effectiveness of colorimetry and visual rating as criteria for selection are not possible from this study. Comparisons of the products of dual selection experiments using colorimetry and visual ratings would be required. Colorimetry appears to be a supplement to, rather than a replacement for, visual assessment. As a supplement, it would seem to reduce or eliminate the need for multiple visual ratings and enhance the defensibility of selection by a single rating. Colorimetry could be useful to eliminate susceptible segregates from further screening for agronomic characters. Secondly, colorimetry could be used in preliminary screening of germplasm for susceptibility to pod disease, reducing the number of entries to screen visually. The cost of scoring fifty plots with three visual raters was estimated to be four times that of using a colorimeter equipped with an automated recording device, and to take 1.75 times as long. Using only a single experienced rater would cost nearly twice as much as using only a colorimeter.

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