E

TWC/18/10
ORIGINAL: English
DATE: May 19, 2000

UPOV

INTERNATIONAL UNION FOR THE PROTECTION OF NEW VARIETIES OF PLANTS

GENEVA

TECHNICAL WORKING PARTY ON AUTOMATION AND COMPUTER PROGRAMS

Eighteenth Session
Kyiv, June 12 to 15, 2000

THE COMBINED-OVER-YEARS DISTINCTNESS AND UNIFORMITY CRITERIA
(REVISED PAPER TWC/15/7)

Document revised by experts from the United Kingdom

THE COMBINED-OVER-YEARS DISTINCTNESS AND UNIFORMITY CRITERIA

Table of Contents

THE COMBINED-OVER-YEARS DISTINCTNESS CRITERION

Revised by M Talbot, Biomathematics & Statistics, Scotland

SUMMARY

To distinguish varieties on the basis of a measured character we need to establish a minimum allowable distance between varieties so that a pair of varieties showing a difference greater than the minimum might be regarded as 'distinct' in respect of that character. There are several possible ways of establishing minimum distances from Distinctness, Uniformity and Stability (DUS) trials data. Here is described what is known as the Combined-Over-Years Distinctness (COYD) criterion.

The COYD method involves:

- for each character, taking the variety means from the two or three years of trials for candidates and established varieties and producing over-year means for the varieties;

- applying the technique of analysis of variance to the variety-by-years table in order to calculate a least significant difference (LSD) for comparing variety means;

- if the over-years mean difference between two varieties is greater than the LSD then the varieties are said to be distinct in respect of that character.

The main advantages of the COYD method are:

- it combines information from several seasons into a single criterion in a simple and straightforward way;

- it ensures that judgements about distinctness will be reproducible in other seasons; in other words, the same genetic material should give similar results within reasonable limits from season-to-season.

- the risks of making a wrong judgement about distinctness are constant for all characters.

INTRODUCTION

In order to decide if two varieties are distinct in respect of a measured character, a criterion is needed which will determine whether the differences found in DUS trials are sufficiently clear and reproducible. The Combined-Over-Years Distinctness (COYD) method provides such a criterion.

This paper describes:

- the principles underlying the COYD method;
- details of ways in which the procedure can be adapted to deal with special circumstances;
- UPOV recommendations on the application of COYD to individual species;
- the computer software which is available to apply the procedure.

THE COYD METHOD

The COYD method aims to establish for each character a minimum difference, or distance, which if achieved by two varieties in trials over a period of two or three years, it should be possible to say that those varieties are clearly distinct with a specified degree of confidence.

The method uses variation in variety expression of a character from year-to-year to establish the minimum distance. Thus, characters which show consistency in variety ranking between years will have smaller minimum distances than those with marked changes in ranking.

Calculation of the COYD criterion involves an analysis of variance of a variety-by-year table of means for a character. Data for all candidate and established varieties that appeared in trials over the two or three years are included in the table.

A critical, or least significant, difference (LSD) between two varieties is then calculated from the varieties-by-years mean square in the analysis of variance as

$$LSD_p = t_p * \sqrt{2} * SE(\bar{x})$$

where

- $SE(\bar{x})$ is the standard error of a variety's over-year mean calculated as:

$$\sqrt{\frac{\text{varieties - by - years mean square}}{\text{number of test years}}}$$

- t_p is the value in Student's t table appropriate for a two-tailed test with probability p and with degrees of freedom associated with the variety-by-years mean square. The probability level p that is appropriate for individual species is discussed under UPOV RECOMMENDATIONS ON COYD below.

Usually the LSD serves as the minimum distance. However, there may be situations where a crop expert decides to use a minimum distance that is larger than the LSD, e.g. in rounding up to whole units. A discussion of the statistical aspects of minimum distances between varieties is provided by Talbot, 1990.

An example of the application of COYD to a small data set is given in Figure 1. Statistical details of the method are in Appendix A and further information about the COYD criterion can be found in Patterson and Weatherup (1984).

UPOV RECOMMENDATIONS ON COYD

COYD is recommended for use in assessing distinctness of varieties

- when observations are made on a plant (or plot) basis over two or more years;

- when there are some differences between plants (or plots) of a variety but, nevertheless, this variation is sufficiently small to allow us to distinguish between varieties;

- in general COYD is recommended for use in the testing of allogamous species.

A pair of varieties is considered to be distinct if their over-years means differ by more than the COYD LSD in at least one character.

It has been agreed to operate the COYD LSD at the 1% level for grass species for both two and three-year tests. Experience with spring onion has shown that a 5% level may be appropriate (Laidig 1988) and with leek the 1% level has been found to be acceptable (van der Heijden and van Marrewijk 1989).

ADAPTING COYD TO SPECIAL CIRCUMSTANCES

i) Differences between years in the range of expression of a character

Occasionally, there can occur marked differences between years in the range of expression of a character. For example, in a late spring, the heading date of grasses can converge. To take account of this effect it is possible to fit extra terms, one for each year, in the analysis of variance. Each term represents the linear regression of the observations for the year against the variety means over all years. The method is known as modified joint regression analysis (MJRA) and is recommended in situations where there is a statistically significant (p # 1%) contribution from the regression terms in the analysis of variance. Statistical details, and a computer program to implement the procedure, are described in the appendices.

Figure 1: Illustrating the calculation of the COYD criterion

Character: Days to ear emergence in perennial ryegrass varieties

Varieties	Years 1	2	Over Year 3	Means	*Difference (Varieties compared to C2)*	
Reference			Means			
R1	38	41	35	38	*35*	*D*
R2	63	68	61	64	*9*	*D*
R3	69	71	64	68	*5*	*D*
R4	71	75	67	71	*2*	
R5	69	78	69	72	*1*	
R6	74	77	71	74	*-1*	
R7	76	79	70	75	*-2*	
R8	75	80	73	76	*-3*	
R9	78	81	75	78	*-5*	*D*
R10	79	80	75	78	*-5*	*D*
R11	76	85	79	80	*-7*	*D*
Candidate						
C1	52	56	48	52	*21*	*D*
C2	72	79	68	73	*0*	-
C3	85	88	85	86	*-13*	*D*

ANALYSIS OF VARIANCE

Source	df	Mean square
Year	2	174.93
Variety	13	452.59
Variety-by-year	26	2.54

$LSD_p = t_p * \sqrt{2} * SE(\overline{X})$

$LSD_{0.01} = 2.779 * 1.414 * \sqrt{(2.54/3)} = 3.6$

where t_p is taken from Student's t table with p = 0.01 (two-tailed) and 26 degrees of freedom.

To assess the distinctness of a candidate, the difference between it and all other varieties is computed. In practice a column of differences is calculated for each candidate. In this case, varieties with mean differences greater than, or equal to, 3.6 can be regarded as clearly distinct (marked *D* above).

ii) Small numbers of varieties in trials

It is recommended that there should be at least 20 degrees of freedom for the residual term in the COYD analysis of variance in order to provide a reliable estimate for the over-years LSD (twenty degrees of freedom corresponds to 10 varieties present in three years of trials or 20 varieties in two years). In some situations there may not be enough varieties in test over the two or three years to give the recommended minimum degrees of freedom. In such cases data for earlier years, and including other established varieties if necessary, can be used to produce a long-term estimate of variety-by-years variation. This residual term can be used in deriving the LSD for comparing means of the current varieties. The long-term COYD, as it is known, should be applied to all characters when any of the characters fails to provide sufficient degrees of freedom.

iii) Marked year-to-year changes in an individual variety's character

Occasionally, a pair of varieties may be declared distinct on the basis of a t-test which is significant solely due to a very large difference between the varieties in a single year. To monitor such situations a check statistic is calculated, called F_3, which is the variety-by years mean square for the particular variety pair expressed as a ratio of the overall variety-by-years mean square. This statistic should be compared with F-distribution tables with 1 and g, or 2 and g, degrees of freedom, for tests with 2 or 3 years of data respectively where g is the degrees of freedom for the variety-by-years mean square. If the calculated F_3 value exceeds the tabulated F value at the 1% level then an explanation for the unusual result should be sought before reaching a decision on distinctness.

IMPLEMENTING COYD

The COYD criterion can be applied using the DUST software package for the statistical analysis of DUS data that is available from the Biometrics Division, Department of Agricultural and Rural Development for Northern Ireland (address below). Sample outputs are given in Appendix B.

REFERENCES

Digby, P.G.N. (1979). Modified joint regression analysis for incomplete variety x environment data. J. Agric. Sci. Camb. 93, 81-86.

Laidig, F. (1988). Application of the COY analysis to onion data. UPOV TWC Paper TWC/VI/11, UPOV, Geneva.

Patterson, H.D. & Weatherup, S.T.C. (1984). Statistical criteria for distinctness between varieties of herbage crops. J. Agric. Sci. Camb. 102, 59-68.

Talbot, M. (1990). Statistical aspects of minimum distances between varieties. UPOV TWC Paper TWC/VIII/9, UPOV, Geneva.

van der Heijden, G. and van Marrewijk, N. (1989). Application of COY analysis to leek in the Netherlands. UPOV TWC Paper TWC/VII/11, UPOV, Geneva.

S. Watson
Biometrics Division
Department of Agricultural and Rural Development for Northern Ireland
Newforge Lane
Belfast BT9 5PX, UK
Email: sally.watson@dardni.gov.uk

M. Talbot
Biomathematics & Statistics Scotland
JCMB, King's Buildings
Edinburgh EH9 3JZ, UK
Email: m.talbot@bioss.sari.ac.uk

May 2000

APPENDIX A : COYD STATISTICAL METHODS

i) Analysis of Variance

The standard errors used in the COYD criterion are based on an analysis of variance of the variety-by-years table of a characteristic's means. For m years and n varieties this analysis of variance breaks down the available degrees of freedom as follows:

Source	DF
Years	m-1
Varieties	n-1
Varieties x years	(m-1)(n-1)

The terms YEAR MS and VARIETY MS in Appendix Table 1 below correspond to the years and variety mean squares from the analysis of variance. The term F1 RATIO is defined as:

$$F_1 = \frac{\text{varieties mean square}}{\text{varieties x years mean square}}$$

It provides a measure of the discriminating power of a characteristic, large values of F_1 indicating high discriminating power.

ii) Modified Joint Regression Analysis (MJRA) Adjustment

As pointed out above, the COYD criterion uses the varieties x years variation on which to base the SE of a variety mean. When considering the varieties x years interaction, two sources of variation can be identified. Firstly, a systematic effect can cause the occurrence of different slopes of the regression lines relating variety means in individual years to the average variety means over all years. Such an effect can be noted for the heading date characteristic in a year with a late spring: the range of heading dates can be compressed compared with the normal, leading to a reduction in the slope of the regression line for variety means in that year relative to average variety means. Secondly, a non-systematic effect may be represented by the variation about these regression lines. Where only non-systematic varieties x years variation occurs, the slope of the regression lines have the constant value 1.0 in all years, but when systematic variation is present, slopes differing from 1.0 occur but with an average of 1.0. When the MJRA is used, the SE of a variety mean is based on the non-systematic part of the varieties x year variation.

The distinctness between the total varieties x years variation and the varieties x years variation adjusted by MJRA is illustrated in Appendix B Figure 1, where variety means in each of three years are plotted against average variety means over all years. The variation about three parallel lines fitted to the data, one for each year, provides the total varieties x years variation as used in the COYD criterion described above. These regression lines have the common slope 1.0. This variation may be reduced by fitting separate regression lines to the data for each year. The resultant residual variation about the individual regression lines provides the MJRA-adjusted varieties x years mean square. It can be seen that this

adjustment is only effective where the slopes of the variety regression lines differ between years such as can occur in heading dates.

The use of this technique in determining distinctness has been included as an option in the COYD computer program. It is recommended that it is only applied where the slopes of the variety regression lines are significantly different between years at the 1% significance level. This level can be specified in the computer program.

To calculate the adjusted variety means and regression line slopes the following model is assumed.

$$y_{ij} = u_j + b_j v_i + e_{ij}$$

where y_{ij} is the value for the i^{th} variety in the j^{th} year.

u_j is the mean of year j (j = 1, ..., m)

b_j is the regression slope for year j

v_i is the effect of variety i (i = 1, ..., n)

e_{ij} is an error term.

From equations (6) and (7) of Digby (1979), with the meaning of years and varieties reversed, the following equations relating these terms are derived for the situation where data are complete:

$$\sum_{i=j}^{n} v_i y_{ij} = b_j \sum_{i=1}^{n} v_i^2$$

$$\sum_{j=1}^{m} b_j y_{ij} = v_i \sum_{j=1}^{m} b_j^2$$

These equations are solved iteratively taking all b_j values to be 1.0 as a starting point to provide values for the v_i's. The MJRA residual sum of squares is then derived from:

$$\sum_{j=1}^{m} \sum_{i-1}^{n} \left(y_{ij} - u_j - b_j v_i \right)^2$$

The standard error for a variety mean is based on this sum of squares with (m-1)(n-1) - m + 1 degrees of freedom.

iii) The 2 x 1 % Criterion

Another distinctness criterion was known as the 2x1% criterion. For two varieties to be distinct, this requires the varieties to be significantly different in the same direction at the 1% level in at least 2 out of 3 years in one or more measured characters. The tests in each year

are based on Student's two-tailed t-test of the variety means with standard errors estimated using the plot residual mean square.

The main criticisms of the 2x1% criterion are that:

- Information is lost because the criterion is based on the accumulated decisions arising from the results of t-tests made in each of the test years. Thus a difference which is not quite significant at the 1% level contributes no more to the separation of a variety pair than a zero difference or a difference in the opposite direction. For example, three differences in the same direction, one of which is significant at the 1% level and the others at the 5% level would not be regarded as significant evidence for distinctness.

- Variety measurements on some characteristics are less consistent over years than on others. However, beyond requiring differences to be in the same direction in order to count towards distinctness, the 2x1% criterion takes no account of consistency in the size of the differences from year to year.

It can be shown that, for a 3-year test, the COYD criterion applied at the 1% probability level is of approximately the same stringency as the 2x1% criterion for a characteristic where the square root of the ratio of the variety-by-years mean square to the variety-by-replicates-within-trials mean square (8) has a value of 1.7. The COYD criterion applied at the 1% level is less stringent than the 2x1% criterion if $8 < 1.7$, and more stringent if $8 > 1.7$.

APPENDIX B : COYD SOFTWARE

An example of the output from the COYD program is given in Appendix Tables 1-3 and is taken from a perennial ryegrass (diploid) trial involving 40 reference varieties (R1 to R40) and 9 candidate varieties (C1 to C9) in 6 replicates on which 8 characters were measured over the years 1988, 1989 and 1990.

Analysis of variance is performed on the variety-by-years table of means of each of the 8 characters. The results are given in Table B 1. Apart from the over-year variety means there are also presented:

YEAR MS:	the mean square term for years in this ANOVA table;
VARIETY MS:	the mean square for varieties;
VAR.YEAR MS[1]:	the mean square for interaction of varieties and years;
F1 RATIO:	the ratio of VARIETY MS and VAR.YEAR MS i.e. a measure of the discriminating power of the character;
VAR.REP MS:	average of the variety x replicate mean squares from each year;
LAMBDA VALUE (8):	square root of the ratio of the VAR.YEAR MS to the VAR.REP MS;
BETWEEN SE:	the standard error of variety means over trials on a plot basis i.e. the square root of the VAR.YEAR MS divided by 18 (3 years x 6 replicates);
WITHIN SE:	the standard error of variety means within a trial on a plot basis i.e. the square root of the VAR.REP MS divided by 18;
DF:	the degrees of freedom for varieties x years term in the ANOVA table;
MJRA SLOPE:	the slope of the regression of a single years variety means on the means over the three years;
REGR F VALUE:	the mean square due to MJRA regression as a ratio of the mean square about regression;
REGR PROB:	the statistical significance of the REGR F VALUE;
TEST:	indicates whether MJRA adjustment was applied (REG) or not (COY).

Each candidate variety is compared with every other variety, both candidate and reference. The mean differences between pairs of varieties are compared with the LSD for the character. The results for the variety pair R1 and C1 are given in Table B 2. The individual within year t-values are listed to provide information on the separate years. Varieties R1 and C1 are distinct since, for at least one character, a mean difference is significant at the 1% level. The significance for character 8 would not have counted towards distinctness if the F_3 ratio had been significant at the 1% level rather than the 5% level.

The outcome in terms of the tests for distinctness of each candidate variety from all other varieties is given in Table B 3, where D indicates ‘distinct’ and ND denotes ‘not distinct’.

[1] NOTE: As this analysis of variance is of the variety x year x replicate data, this mean square is 6 (= number of replicates) times the size of the VAR.YEAR MS of the analysis of variance of the variety x year data referred to in the main body of this paper

Table B 1: An example of the output from the COYD program showing variety means and analysis of variance of characters

PRG (DIPLOID) EARLY N.I. UPOV 1988-90

VARIETY MEANS OVER YEARS

	5 SP.HT	60 NSPHT	8 DEEE	10 H.EEWEE	11 LFL	14 WFL	15 LEAR	24	
1 R		45.27	34.60	67.87	45.20	70.05	20.39	6.85	24.54
2 R2		42.63	31.84	73.85	41.96	74.98	19.68	6.67	24.44
3 R3		41.57	27.40	38.47	27.14	57.60	17.12	6.85	22.57
4 R4		33.35	21.80	77.78	30.77	78.04	18.25	6.40	21.09
5 R5		37.81	25.86	50.14	27.24	62.64	16.41	6.41	16.97
6 R6		33.90	21.07	78.73	32.84	79.15	19.44	6.46	21.79
7 R7		41.30	31.37	73.19	41.35	71.87	20.98	6.92	24.31
8 R8		24.48	19.94	74.83	32.10	62.38	15.22	6.36	19.46
9 R9		46.68	36.69	63.99	44.84	68.62	18.11	7.02	22.58
10 R10		25.60	20.96	75.64	32.31	57.20	14.68	5.51	20.13
11 R11		41.70	30.31	74.60	40.17	76.15	19.45	6.79	22.72
12 R12		28.95	21.56	66.12	27.96	59.56	14.83	5.53	20.55
13 R13		40.67	29.47	70.63	36.81	74.12	19.97	7.04	24.05
14 R14		26.68	20.53	75.84	34.14	63.29	15.21	6.37	20.37
15 R15		26.78	20.18	75.54	30.39	66.41	16.34	6.01	20.94
16 R16		42.44	27.01	59.03	30.39	72.71	17.29	6.47	22.48
17 R17		27.94	21.58	76.13	32.53	68.37	16.72	6.11	22.03
18 R18		41.34	30.85	69.80	37.28	69.52	20.68	7.09	25.40
19 R19		33.54	23.43	73.65	30.35	75.54	18.97	6.37	22.43
20 R20		44.14	34.48	68.74	42.60	64.17	18.63	6.56	22.02
21 R21		27.77	21.53	80.52	31.59	69.41	16.81	5.81	22.35
22 R22		38.90	27.83	75.68	43.25	75.08	19.63	7.46	23.99
23 R23		42.43	31.80	72.40	42.07	74.77	20.99	6.78	23.57
24 R24		38.50	27.73	73.19	37.12	75.76	19.28	6.91	22.77
25 R25		43.84	29.60	68.82	39.79	74.83	20.63	7.08	22.65
26 R26		49.48	36.53	63.45	42.01	70.46	22.14	7.84	25.91
27 R27		25.61	19.25	78.78	29.81	56.81	15.81	5.07	18.94
28 R28		26.70	20.31	79.41	32.75	66.54	16.92	6.00	21.91
29 R29		27.90	20.94	72.66	29.85	67.14	16.85	6.28	21.79
30 R30		43.07	30.34	70.53	40.51	73.23	19.49	7.28	23.70
31 R31		38.18	25.47	74.23	36.88	80.23	20.40	7.09	25.21
32 R32		35.15	27.56	71.49	37.26	63.10	18.18	6.80	23.13
33 R33		42.71	31.09	67.58	39.14	70.36	19.85	7.12	23.35
34 R34		23.14	18.05	72.09	24.29	59.37	13.98	5.63	18.91
35 R35		32.75	25.41	77.22	38.90	67.07	17.16	6.42	21.49
36 R36		41.71	31.94	77.98	44.33	73.00	19.72	7.09	23.45
37 R37		44.06	32.99	74.38	45.77	71.59	20.88	7.40	24.06
38 R38		42.65	32.97	74.76	44.42	74.13	20.29	7.38	24.32
39 R39		28.79	22.41	76.83	35.91	64.52	16.85	6.34	22.24
40 R40		44.31	31.38	72.24	43.83	74.73	21.53	7.60	25.46
41 C1		42.42	31.68	64.03	40.22	67.02	20.73	6.90	26.16
42 C2		41.77	32.35	86.11	46.03	75.35	20.40	6.96	22.99
43 C3		41.94	31.09	82.04	43.17	74.04	19.06	6.26	23.44
44 C4		39.03	28.71	78.63	45.97	70.49	21.27	6.67	23.37
45 C5		43.97	30.95	72.99	39.14	77.89	19.88	6.68	25.44
46 C6		37.56	27.14	83.29	39.16	81.18	19.47	6.97	25.25
47 C7		38.41	28.58	83.90	42.53	76.44	19.28	6.00	23.47
48 C8		40.08	27.25	83.50	43.33	80.16	22.77	7.92	26.81
49 C9		46.77	34.87	51.89	37.68	61.16	19.25	6.92	24.82
YEAR MS		1279.09	3398.82	3026.80	2278.15	8449.20	672.15	3.36	51.32
VARIETY MS		909.21	476.72	1376.10	635.27	762.41	80.21	6.44	74.17
VAR.YEAR MS		23.16	18.86	14.12	23.16	46.58	4.76	0.28	2.73
F1 RATIO		39.26	25.27	97.43	27.43	16.37	16.84	22.83	27.16
VAR.REP MS		8.83	8.19	4.59	11.95	23.23	1.52	0.15	1.70
LAMBDA VALUE		1.62	1.52	1.75	1.39	1.42	1.77	1.37	1.27
BETWEEN SE		1.13	1.02	0.89	1.13	1.61	0.51	0.13	0.39
WITHIN SE		0.70	0.67	0.50	0.81	1.14	0.29	0.09	0.31
DF		96	94	96	96	96	96	96	96
MJRA SLOPE 88		0.90	0.86	0.99	0.91	0.99	1.09	0.97	0.95
MJRA SLOPE 89		1.05	1.08	1.01	0.99	1.06	0.97	1.02	0.98
MJRA SLOPE 90		1.05	1.06	1.00	1.10	0.95	0.94	1.01	1.07
REGR F VAL		4.66	6.17	0.06	4.48	0.76	1.62	0.29	1.91
REGR PROB		1.17	0.30	93.82	1.39	47.08	20.27	74.68	15.38
TEST		COY	REG	COY	COY	COY	COY	COY	COY

Table B 2: An example of the output from the COYD program showing a comparison of varieties R1 and C1

PRG (DIPLOID) EARLY N.I. UPOV 1988-90

41 C1 VERSUS 1 R1 *** USING REGR WHERE SIG ***

(T VALUES + VE IF 41 C1 > 1 R1)

	SIG LEVELS YEARS				COYD			T VALUES YEARS			T SCORE	F3	
	88	89	90	T	PROB%	SIG		88	89	90			
5 SP.HGHT	-	-	-1	ND	-1.78	7.88	NS	-1.05	-1.34	-2.64	-2.64	0.23	NS
60 NATSPHT	-	-1	-	ND	-2.02	4.61	*	-1.58	-2.61	-1.17	-2.61	0.22	NS
8 DATEEE	-1	-1	+	D	-3.06	0.29	**	-4.14	-6.33	0.80	-6.74	3.99	*
10 HGHT.EE	-1	-1	-5	D	-3.11	0.25	**	-2.79	-2.69	-2.06	-7.55	0.06	NS
11 WIDTHEE	-	-	-	ND	-1.33	18.58	NS	-1.47	-1.80	-0.21	0.00	0.32	NS
14 LGTHFL	+	+	-	ND	0.47	63.61	NS	0.17	1.83	-0.67	0.00	0.56	NS
15 WIDTHFL	+	-	+	ND	0.27	78.83	NS	0.31	-0.41	0.67	0.00	0.17	NS
24 EARLGTH	5	1	+	ND	2.93	0.42	**	2.10	3.33	1.01	5.43	0.84	NS

Notes: 1. The three columns headed COYD, T PROB% SIG give the COYD T value, its significance probability and significance level. The T value is the test statistic formed by dividing the mean difference between two varieties by the standard error of that difference. The T value can be tested for significance by comparing it with appropriate values from Students t-table. Calculating and testing a T value in this manner is equivalent to deriving an LSD and checking to see if the mean difference between the two varieties is greater than the LSD.

2. The two right-hand columns give the F_3 ratio and its significance level.

3. The sections in boxes refer to earlier distinctness criteria. The three columns headed T VALUES, YEARS, 88 89 90 are the individual within year t-test values, and the three columns headed SIG LEVELS, YEARS, 88 89 90 give their direction and significance levels. The column containing D and ND gives the distinctness status of the two varieties by the 2 x 1% criterion. The column headed T SCORE gives the obsolete T Score statistic.

Table B 3: An example of the output from the COYD program showing the distinctness status of the candidate varieties

PRG (DIPLOID) EARLY N.I. UPOV 1988-90

SUMMARY FOR COYD AT 1.0% LEVEL *** USING REGR ADJ WHEN SIG ***

CANDIDATE VARIETIES	C1	C2	C3	C4	C5	C6	C7	C8	C9	
1	R1	D	D	D	D	D	D	D	D	D
2	R2	D	D	D	D	ND	D	D	D	D
3	R3	D	D	D	D	D	D	D	D	D
4	R4	D	D	D	D	D	D	D	D	D
5	R5	D	D	D	D	D	D	D	D	D
6	R6	D	D	D	D	D	D	D	D	D
7	R7	D	D	D	D	D	D	D	D	D
8	R8	D	D	D	D	D	D	D	D	D
9	R9	D	D	D	D	D	D	D	D	D
10	R10	D	D	D	D	D	D	D	D	D
11	R11	D	D	D	D	D	D	D	D	D
12	R1	D	D	D	D	D	D	D	D	D
13	R13	D	D	D	D	ND	D	D	D	D
14	R14	D	D	D	D	D	D	D	D	D
15	R15	D	D	D	D	D	D	D	D	D
16	R16	D	D	D	D	D	D	D	D	D
17	R17	D	D	D	D	D	D	D	D	D
18	R18	D	D	D	D	D	D	D	D	D
19	R19	D	D	D	D	D	D	D	D	D
20	R20	D	D	D	D	D	D	D	D	D
21	R21	D	D	D	D	D	D	D	D	D
22	R22	D	D	D	D	D	D	D	D	D
23	R23	D	D	D	D	D	D	D	D	D
24	R24	D	D	D	D	D	D	D	D	D
25	R25	D	D	D	D	D	D	D	D	D
26	R26	D	D	D	D	D	D	D	D	D
27	R27	D	D	D	D	D	D	D	D	D
28	R28	D	D	D	D	D	D	D	D	D
29	R29	D	D	D	D	D	D	D	D	D
30	R30	D	D	D	D	D	D	D	D	D
31	R31	D	D	D	D	D	D	D	D	D
32	R32	D	D	D	D	D	D	D	D	D
33	R33	D	D	D	D	D	D	D	D	D
34	R34	D	D	D	D	D	D	D	D	D
35	R35	D	D	D	D	D	D	D	D	D
36	R36	D	D	D	ND	D	D	D	D	D
37	R37	D	D	D	D	D	D	D	D	D
38	R38	D	D	D	D	D	D	D	D	D
39	R39	D	D	D	D	D	D	D	D	D
40	R40	D	D	D	D	D	D	D	D	D
41	C1	-	D	D	D	D	D	D	D	D
42	C2	D	-	D	D	D	D	D	D	D
43	C3	D	D	-	D	D	D	ND	D	D
44	C4	D	D	D	-	D	D	D	D	D
45	C5	D	D	D	D	-	D	D	D	D
46	C6	D	D	D	D	D	-	D	D	D
47	C7	D	D	ND	D	D	D	-	D	D
48	C8	D	D	D	D	D	D	D	-	D
49	C9	D	D	D	D	D	D	D	D	-
NO OF ND VARS		0	0	1	1	2	0	1	0	0
DISTINCTNESS		D	D	ND	ND	ND	D	ND	D	D
CANDIDATE VAR		C1	C2	C3	C4	C5	C6	C7	C8	C9

THE COMBINED-OVER-YEARS UNIFORMITY CRITERION

SUMMARY

When the uniformity of plants of a variety is to be judged on the basis of measurements then the standard deviation (SD) can be used to summarise the spread of the observations. A new variety can then be tested for uniformity by comparing its SD with that of reference varieties. However, uniformity is often related to the expression of a character. For example, in some species varieties with larger plants tend to be less uniform in size than those with smaller plants. If the same standard is applied to all varieties then it is possible that some may have to meet very strict criteria while others face standards that are easy to satisfy.

The Combined-Over-Years Uniformity (COYU) criterion addresses this problem by adjusting for any relationship that exists between uniformity, as measured by the plant-to-plant SD, and the expression of the characteristic, as measured by the variety mean, before setting a standard.

The technique involves ranking reference and candidate varieties by the mean value of the character. Each variety's SD is taken and the mean SD of the varieties most similar, i.e. those varieties which are ranked with it most closely, is subtracted. This procedure gives for each variety a measure of its uniformity expressed relative to that of comparable varieties.

The results for each year are combined by forming a variety-by-years table of adjusted SDs and applying an analysis of variance. The mean adjusted SD for the candidate is compared with the mean for the reference varieties using a standard t-test.

COYU, in effect, compares the uniformity of a candidate with that of the reference varieties most similar in relation to the character being assessed. The main advantages of COYU are that all varieties can be compared on the same basis and that information from several years of testing may be combined into a single criterion.

INTRODUCTION

Uniformity of plants of a variety is a complex concept made up of many features. In Distinctness, Uniformity and Stability (DUS) testing, the assessment of uniformity is sometimes done by measuring individual characters e.g. leaf length, and calculating the standard deviation (SD) of the measurements on individual plants within a replicate. The SDs are averaged over all replicates to provide a single measure of uniformity for each variety in a trial.

This paper outlines a procedure known as the combined-over-years uniformity (COYU) procedure which summarises SDs from trials over several years to provide a criterion for judging the uniformity of one variety relative to other varieties. A feature of the method is that it takes account of possible relationships from variety-to-variety between the expression of a character and its uniformity.

THE COYU METHOD

The COYU procedure involves taking the SDs for each year, and adjusting for the relationship which occurs between the SD and character means. The relationship is estimated by calculating moving averages of the SDs when the varieties are ranked in order of their character means. A simple example in Figure 1 illustrates this procedure. The points marked 0 in Figure 1a represent, for 16 varieties, the SDs (transformed by adding 1 and converted to natural logarithms) and the corresponding character means. The X are the 9-point moving-averages which are calculated by taking, for each point, its SD and the four on either side, and averaging the nine SDs to give the moving average for that point. At the extremities the moving average is based on the mean of 3, 5, or 7 values.

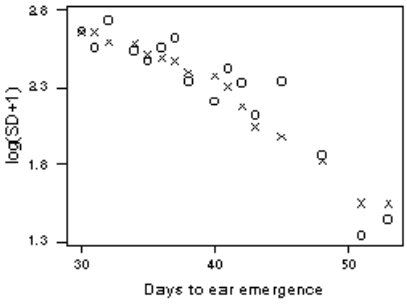
The adjustment involves subtracting the moving average value from the corresponding observed value and adding back the mean SD for all varieties. The results are shown in Figure 1b.

The adjusted SDs are averaged over years for each variety and the resulting mean SD of the candidate variety is compared with the average SD of all reference varieties. This difference is tested using a Student's t-test derived from an analysis of variance of the variety x year table of SDs for the reference varieties. Statistical details are given in Appendix A.

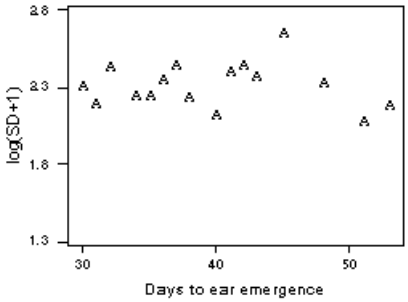
The procedure is equivalent to forming for each candidate variety a group of comparable reference varieties based on their similarity of character mean and then comparing the uniformity of the candidate against the mean uniformity of these comparable varieties.

Figure 1: Adjusting for association between variety SD and character mean - days to ear emergence in cocksfoot varieties

(a) Observed SD (O) and moving average SD (X)



(b) Adjusted SD (A) i.e. observed minus moving average plus mean



The advantages of the COYU procedure are:

- it provides a method for assessing uniformity which is largely independent of the varieties that are under test; it should be possible to use all reference varieties as uniformity standards;

- standards based on the method are likely to be stable over time;

- the method combines information from several trials to form a single criterion for uniformity;

- the statistical model on which it is based reflects the main sources of variation which influence uniformity.

CALCULATION OF ACCEPTANCE STANDARDS

The maximum allowable standard deviation (the uniformity criterion) is derived as follows

$$UC = SD_r + t_p * \sqrt{} [V * (1 / Y + 1 / (Y*R))] \quad (1)$$

where,

SD_r is the mean of SDs for the reference varieties;

V is the variance of the SDs for the reference varieties after removing year-differences;

t_p is the one-tailed Students t-value for probability p with degrees of freedom as for V;

Y is the number of years on which the mean is based;

R is the number of reference varieties.

Separate criteria have been established to assist with the following decisions:

a) reject after three years;
b) reject after two years;
c) accept after two years;

Equation (1) is applied in each case but the t-value probabilities vary along with the number of years (Y).

Details of the calculations involved in deriving the COYU criterion are illustrated in Figure 2.

For authorities which may encounter difficulties in reaching these standards a transitional period of not more than three years is suggested with probability levels of 0.1%, 0.1% and 1.0%.

Note: the 2-year probability levels are strictly only appropriate when the normal test is for three years and occasionally the results for some varieties are so clear as to permit an earlier decision. If the test is changed to be a two-year one with occasional extensions to a third year then the probability levels should be re-considered.

Figure 2: Illustrating the calculation of COYU with days to ear emergence in perennial ryegrass - eleven reference varieties and one candidate

(i) DATA

Varieties		Character Means			Between Plant SD			LOG (SD + 1)	
	Years 1	2	3	1	2	3	1	2	3
R1	38	41	35	8.5	8.8	9.4	2.25	2.28	2.34
R2	63	68	61	8.1	7.6	6.7	2.21	2.15	2.04
R3	69	71	64	9.9	7.6	5.9	2.39	2.15	1.93
R4	71	75	67	10.2	6.6	6.5	2.42	2.03	2.01
R5	69	78	69	11.2	7.5	5.9	2.50	2.14	1.93
R6	74	77	71	9.8	5.4	7.4	2.38	1.86	2.13
R7	76	79	70	10.7	7.6	4.8	2.46	2.15	1.76
R8	75	80	73	10.9	4.1	5.7	2.48	1.63	1.90
R9	78	81	75	11.6	7.4	9.1	2.53	2.13	2.31
R10	79	80	75	9.4	7.6	8.5	2.34	2.15	2.25
R11	76	85	79	9.2	4.8	7.4	2.32	1.76	2.13
C1	52	56	48	8.2	8.4	8.1	2.22	2.24	2.21

(ii) CALCULATING ADJUSTED LOG (SD+1) FOR YEAR 1:

Variety	Mean (X)	Ranked (SD+1) (Y)	Log	Trend Value	Adj. Log (SD+1)
R1	38		2.25	(2.25 + 2.21 + 2.39)/3 = 2.28	2.25 - 2.28 + 2.39 = 2.36
R2	63		2.21	(2.25 + 2.21 + 2.39)/3 = 2.28	2.21 - 2.28 + 2.39 = 2.32
R3	69		2.39	(2.25 + . . . + 2.42)/5 = 2.35	2.39 - 2.35 + 2.39 = 2.42
R5	69		2.50	(2.25 + . . . + 2.48)/7 = 2.38	2.50 - 2.38 + 2.39 = 2.52
R4	71		2.42	(2.25 + . . . + 2.32)/9 = 2.38	2.42 - 2.38 + 2.39 = 2.43
R6	74		2.38	(2.21 + . . . + 2.53)/9 = 2.41	2.38 - 2.41 + 2.39 = 2.36
R8	75		2.48	(2.39 + . . . + 2.34)/9 = 2.42	2.48 - 2.42 + 2.39 = 2.44
R7	76		2.46	(2.42 + . . . + 2.34)/7 = 2.42	2.46 - 2.42 + 2.39 = 2.43
R11	76		2.32	(2.48 + . . . + 2.34)/5 = 2.43	2.32 - 2.43 + 2.39 = 2.28
R9	78		2.53	(2.32 + 2.53 + 2.34)/3 = 2.40	2.53 - 2.40 + 2.39 = 2.52
R10	79		2.34	(2.32 + 2.53 + 2.34)/3 = 2.40	2.34 - 2.40 + 2.39 = 2.33
Mean	70		2.39		
C1	52		2.22	= 2.28(i)	2.22 – 2.28 + 2.39 = 2.32

(i) Trend value for candidate is obtained by interpolation between values for varieties R1 and R2, since the character mean for C1 (i.e. 52) lies between the means for R1 and R2 (i.e. 38 and 63)

i.e. $\{(X_c - X_i)\, Y_{i+1} + (X_{i+1} - X_c)\, Y_i\} / \{X_c - X_i) + (X_{i+1} - X_c)\}$ = {(52 - 38) 2.28 + (63 - 52) 2.28} / {(52 - 38) + (63 - 52)} = 2.28

Figure 2 (Cont'd): Illustrating the calculation of COYU with days to ear emergence in perennial ryegrass - eleven reference varieties and one candidate

(iii) ADJUSTED LOG (SD + 1) FOR THREE YEARS:

Variety	Char. Mean	Mean Log (SD + 1)	Adj. LOG (SD + 1) Yr1	Yr2	Yr3
R1 38	2.26	2.36	2.13	2.30	
R2 64	2.10	2.32	2.00	2.00	
R3 68	2.16	2.42	2.10	1.95	
R4 71	2.15	2.43	1.96	2.06	
R5 72	2.20	2.52	2.14	1.96	
R6 74	2.12	2.36	1.84	2.16	
R7 75	2.14	2.43	2.19	1.80	
R8 76	2.02	2.44	1.70	1.91	
R9 78	2.30	2.52	2.16	2.24	
R1078	2.22	2.33	2.23	2.09	
R1180	2.01	2.28	1.78	1.96	
Mean	70	2.15	2.40	2.02	2.04
C1 52	2.19	2.32	2.08	2.17	

(iv) ANALYSIS OF VARIANCE OF ADJUSTED LOG (SD + 1):

Source	df	Mean square
Year	2	0.5098
Varieties within Years	30	0.0202

(v) UNIFORMITY CRITERION (3 - YEAR):

$$UC_p = SD_r + t_p * \sqrt{[V * (1/3 + 1 / (3 *R))]}$$

$$UC_{0.001} = 2.15 + 3.118 * \sqrt{[0.0202 * (1/3 + 1/(3 * 11))]} = 2.42$$

where t_p is taken from Student's t table with p = 0.002 (one-tailed) and 30 degrees of freedom;

SD_r is mean of adjusted log (SD + 1) for reference varieties;
V is varieties within years means square;
R is number of reference varieties.

Varieties with mean adjusted log (SD + 1) less than, or equal to, 2.44 can be regarded as uniform. The candidate variety C1 satisfies this criterion.

UPOV RECOMMENDATIONS ON COYU

The probability levels recommended for application to all cross-fertilized agricultural species are:

For rejection after 3 years : 0.2%
For rejection after 2 years : 0.2%
For acceptance after 2 years : 2.0%

IMPLEMENTING COYU

A computer program has been written in Fortran to implement the procedure and an example of the output is provided in Appendix B. The algorithm is also incorporated within the DUST software package as part of a comprehensive system for statistical analysis of DUS data. Details of the DUST system are available from Dr Sally Watson, Biometrics Division, DARD, Queens University, Belfast BT9 5PX, UK.

M Talbot
Biomathematics and Statistics Scotland
Edinburgh EH9 3JZ, UK
Email: m.talbot@bioss.sari.ac.uk

May 2000

APPENDIX A: COYU STATISTICAL METHODS

i) Derivation of the within-plot standard deviation

For each group of plants within a plot, the between-plants SD is calculated as,

$$sd_j = \sqrt{\sum_{i=1,n_j} \left(y_{ij} - \bar{y}_j\right)^2 / \left(n_j - 1\right)}$$

where y_{ij} is the observation on the i th plant in the j th plot;

$\bar{y}_j$ is the mean of the observations from the j th plot;

n_j is the number of plants in the j th plot.

For each variety in a trial the within-plot SDs are averaged over the r plots to give an estimate of that variety's uniformity,

$$SD = \sum_{j=1,r} sd_j / r.$$

ii) Adjusting the standard deviation

The constant 1 is added to each standard deviation before it is converted to the scale of natural logarithms. The purpose of this transformation is to make the SDs more amenable to statistical analysis.

For each year separately, the form of the average relationship between SD and character mean is estimated for the reference varieties. The method of estimation is a 9-point moving average. The method involves ranking the SDs (the Y variate) and the character mean (the X variate) according to the character mean. For each point (Y_i, X_i) take the trend value Y_i to be the mean of the values Y_{i-4}, Y_{i-3}, ..., Y_{i+4} where i represents the rank of the X value and Y_i is the corresponding Y value. For X values ranked 1 and 2 the trend value is taken to be the mean of the first three values. In the case of the X value ranked 3 the mean of the first five values are taken and for the X value ranked 4 the mean of the first seven values are used. A similar procedure operates for the four highest-ranked X values.

Once the trend values for the reference varieties have been determined, the trend values for candidates are estimated using linear interpolation between the trend values of the nearest two reference varieties as defined by their character mean. Thus if the trend values for the two reference varieties on either side of the candidate are T_i and T_{i+1} and the observed value for the candidate is Y_c where $X_i \# X_c \# X_{i+1}$, then the trend value for the candidate is derived as

$$T_c = \{(X_c - X_i)\, T_{i+1} + (X_{i+1} - X_c)\, T_i\} / \{(X_c - X_i) + (X_{i+1} - X_c)\}$$

To adjust the SDs for their relationship with the character mean the estimated trend values are subtracted from the SDs and the grand mean is added back.

iii) Derivation of uniformity criterion

An estimate of the variability in the uniformity of the reference varieties is got by applying a one-way analysis of variance to the adjusted log SDs, i.e. with years as the classifying factor.

The maximum allowable standard deviation (the uniformity criterion), based on three years of trials, is as follows,

$$UC = SD_r + t * \sqrt{[V * (1/Y + 1/(Y * R))]}$$

where,

SD_r is the mean of adjusted log SDs for the reference varieties;
V is the variance of the adjusted log SDs after removing year effects;
t is the one-tailed t-value for probability p with degrees of freedom as for V;
Y is the number of years;
R is the number of reference varieties;

Example: In Appendix Table 2 below, for p = 0.002, 0.002 and 0.020 respectively with 39+78=117 degrees of freedom, and V = (39 * 0.11440 + 78 * 0.0226) / (39 + 78) = 0.0530

$$UC_{3R} = 1.988 + 2.936 * \sqrt{[0.0530 (1/3 + 1/(3*40))]} = 2.383$$

$$UC_{2R} = 1.988 + 2.936 * \sqrt{[0.0530 (1/2 + 1/(2*40))]} = 2.471$$

$$UC_{2A} = 1.988 + 2.074 * \sqrt{[0.0530 (1/2 + 1/(2*40))]} = 2.329$$

iv) 1.26 x SD criterion

The tolerance standard previously recommended in UPOV Tests Guidelines [TG/1/2] is that "a variety is considered not to be homogeneous in the measured characteristic concerned if its variance exceeds 1.6 times the average of the variance of the varieties used for comparison". This means that the standard deviation should not be greater than 1.26 times the average of the reference varieties.

There are several perceived weaknesses in this approach:

i) It assumes that established varieties all have approximately the same uniformity. In practice, studies have shown that there can be real differences in uniformity between established varieties. Since the criterion is based only on within-variety variation it represents a very stringent standard. It is possible for a candidate variety to fail the criterion even though it has a level of uniformity that is well within the range of the reference varieties.

ii) As mentioned previously, uniformity can change between varieties in response to the level of expression of the character which is being measured. Application of a

constant standard could lead to varieties with certain levels of expression having a poorer chance of satisfying the criterion than others.

iii) The criterion provides no guidance on how results of uniformity assessments over several years might be combined into a single criterion.

It may be possible to group varieties of similar types. However, such solutions pose their own problems: it can be difficult to define appropriate groupings for varieties and this must be done separately for each character; also, to establish stable and common standards it would be necessary for the groupings to be maintained from year-to-year.

APPENDIX B : COYU SOFTWARE

The main output from the COYU program is illustrated in Table B 1 which summarises the results of analyses of within-plot SDs for 49 perennial ryegrass varieties assessed over a three-year period. Supplementary output is in Table B 2 where details of the analysis of a single character, date of ear emergence, are presented.

In Table B 1 the adjusted SD for each variety is expressed as a percent of the mean SD for all reference varieties. A figure of 100 indicates a variety of average uniformity; a variety with a value less than 100 shows good uniformity; a variety with a value much greater than 100 suggests poor uniformity in that character. Lack of uniformity in one character is often supported by evidence of disuniformity in related characters.

The symbols * and + to the right of percentages identify varieties whose SDs exceed the COYU criterion after 3 and 2 years respectively. The symbol: indicates that after two years uniformity is not yet acceptable and the variety should be considered for testing for a further year.

The program will operate with a complete set of data or will accept some missing values.

Table B 1: Example of summary output from COYU program

WITHIN-PLOT STANDARD DEVIATIONS AS % MEAN OF REFERENCE VARIETY SDS

CHARACTER NUMBER

	5	60	8	10	11	14	15	24
R1	100	100	95 1	100	97	97	103	98
R2	105	106	98	99	104	101	106	104
R3	97	103	92 1	103	96	98	101	109
R4	102	99	118 2	105	101	101	99	105
R5	102	99	116 3	95	104	110	100	98
R6	103	102	101	99	97	104	98	103
R7	100	95	118 2	102 1	98	99	108 1	100
R8	97	98	84	95	97	93	99	96
R9	97	105	87	99	101	99	93	94
R10	104	100	96	105 1	96	102	95	99
R11	99	96	112	99	101	98	108	105
R12	100	97	99 1	103	105	106	103	98
R13	95	96	101	100	96	101	94	101
R14	105	103	90	97	101	97	105	99
R15	102	100 1	89	105	105 1	101	98	104
R16	99	98	92 1	98	102	98	96	96
R17	97	101	98	101	101	95	98	96
R18	99	97	96	96	102	99	93	95
R19	103	101	105	102	100	98	103	104
R20	104	99	93	91	100	102	92	102
R21	97	94	103	97	100	102	99	100
R22	101	110*1	112	107 1	103 1	101	104	100
R23	94	101	107	99	104	97	103	92
R24	99	97	95	99	100	103	103	101
R25	104 1	103	93 1	99	101	96	99	101
R26	98	97	111 2	96	102 1	106 2	101 1	100
R27	102	99	106 1	99	103	107	103	106
R28	101	106	90	95	101	101	96	94
R29	101	105	83	102	94	93	97	93
R30	99	96	97	99	95	100	92	97
R31	99	102	107	107 1	102	99	101	104 1
R32	98	93	111 2	102	98	103	99	102
R33	104	102 1	107 1	103	100	97	98	100
R34	95	94	82	95	97	96	99	98
R35	100	102	95	100	99	94	105	100
R36	99	98	111 1	99	100	103	105 1	99
R37	100	107 1	107	101	100	107 1	98	100
R38	95	97	102	107 1	97	101	103	100
R39	99	99	90	98	101	100	102	101
R40	104	102	112 1	100	101	97 1	101 1	108 2
C1	100 1	106	113 2	104 1	106 1	106 1	95	104 1
C2	103	101	98	97	101	109 2	99	96
C3	97	93	118 2	98	99	109	111	109 1
C4	102	101	106	103	99	101	97	105
C5	100	104	99	103	100	107 1	107 1	106 1
C6	101	102	103	100	103	107	105	100
C7	96	98	106	97	102	103	108	98
C8	101	105 1	116 2	103	103	93	97	106
C9	99	99	90 2	91	97	98	98	101

CHARACTER KEY :

5	SPRING HEIGHT	60	NATURAL SPRING HEIGHT
8	DATE OF EAR EMERGENCE	10	HEIGHT AT EAR EMERGENCE
11	WIDTH AT EAR EMERGENCE	14	LENGTH OF FLAG LEAF
15	WIDTH OF FLAG LEAF	24	EAR LENGTH

SYMBOLS :

* - SD EXCEEDS OVER-YEARS CRITERION AFTER 3 YEARS WITH PROBABILITY 0.002
\+ - SD EXCEEDS OVER-YEARS CRITERION AFTER 2 YEARS WITH PROBABILITY 0.002
: - SD NOT YET ACCEPTABLE AFTER 2 YEARS WITH PROBABILITY 0.020
1,2,3 - THE NUMBER OF OCCASIONS THE WITHIN-YEARS SD EXCEEDS THE UPOV CRITERION

Table B 2: Example output from UNIF for date of ear emergence (character B)

**** UNIFORMITY ANALYSIS OF BETWEEN-PLANT STANDARD DEVIATIONS (SD) ****

VARIETY	OVER-YEARS CHAR. MEAN	OVER-YEARS ADJ. LOG SD	OVER-YEARS UNADJ LOG SD	INDIVIDUAL YEARS -- CHARACTER MEAN -- 88	89	90	---- LOG (SD+1) --- 88	89	90	-- ADJ LOG(SD+1) -- 88	89	90
R3	38.47	1.823	2.179	39.07	41.21	35.12	2.02	2.18	2.34X	1.73	1.78	1.96
R5	50.14	2.315	2.671	48.19	53.69	48.54	2.52X	2.74X	2.76X	2.23	2.33	2.39
R16	59.03	1.833	2.179	57.25	63.33	56.50	2.28X	2.24	2.01	1.96	1.73	1.81
R26	63.44	2.206	2.460	61.00	66.53	62.81	2.50X	2.75X	2.13	2.18	2.33	2.11
R9	63.99	1.739	1.994	62.92	68.32	60.72	2.21	2.03	1.74	1.96	1.64	1.62
R12	66.12	1.964	2.086	67.89	65.35	65.12	2.07	2.58X	1.60	1.97	2.14	1.78
R33	67.58	2.124	2.254	66.66	71.54	64.53	2.55X	2.26	1.95	2.32	1.92	2.12
R1	67.87	1.880	1.989	69.07	70.64	63.90	1.60	2.45X	1.93	1.60	2.08	1.96
R20	68.74	1.853	1.893	67.17	74.31	64.74	2.05	1.95	1.68	1.92	1.75	1.89
R25	68.82	1.853	1.905	68.28	72.38	65.81	1.83	2.39X	1.49	1.75	2.09	1.72
R18	69.80	1.899	1.853	68.61	75.22	65.58	1.88	1.84	1.84	1.82	1.80	2.08
R30	70.53	1.919	1.864	70.36	75.08	66.15	2.04	1.84	1.71	2.00	1.78	1.98
R13	70.63	2.005	2.000	70.23	75.00	66.66	1.97	2.03	2.01	1.91	1.86	2.24
R32	71.49	2.197	2.238	70.03	74.98	69.44	2.32X	2.45X	1.94	2.31	2.27	2.01
R34	72.09	1.630	1.545	71.32	77.35	67.59	1.57	1.49	1.58	1.54	1.58	1.78
R40	72.24	2.222	2.178	72.71	75.07	68.95	2.25X	2.26	2.03	2.29	2.16	2.22
R23	72.40	2.122	2.058	69.72	78.39	69.10	2.11	2.14	1.93	2.16	2.14	2.06
R29	72.66	1.657	1.580	73.13	75.80	69.04	1.46	1.63	1.65	1.47	1.69	1.81
R7	73.19	2.341	2.342	72.23	75.80	71.52	2.62X	2.30X	2.10	2.61	2.30	2.11
R24	73.19	1.888	1.796	74.00	76.37	69.20	1.62	1.84	1.93	1.71	1.91	2.04
R19	73.65	2.083	2.049	73.32	76.06	71.57	1.96	2.05	2.14	1.96	2.13	2.16
R2	73.85	1.946	1.897	72.98	78.16	70.42	1.76	1.96	1.97	1.79	2.02	2.03
R31	74.23	2.119	2.012	73.73	78.23	70.71	2.05	1.86	2.13	2.25	1.94	2.17
R37	74.38	2.132	2.020	74.87	76.95	71.32	1.97	2.04	2.04	2.23	2.11	2.06
R11	74.60	2.224	2.150	73.87	78.07	71.87	2.21	2.08	2.16	2.36	2.10	2.21
R38	74.76	2.029	1.916	76.11	78.24	69.93	1.84	2.15	1.75	1.98	2.24	1.87
R8	74.83	1.677	1.593	74.27	78.77	71.45	1.62	1.55	1.61	1.75	1.64	1.64
R15	75.54	1.760	1.682	75.72	78.68	72.22	1.53	1.79	1.73	1.64	1.84	1.80
R10	75.64	1.915	1.847	73.47	79.24	74.23	1.87	1.66	2.00	1.99	1.78	1.98
R22	75.68	2.228	2.133	74.57	79.17	73.32	2.18	2.21	2.01	2.40	2.26	2.03
R14	75.84	1.797	1.688	74.53	79.56	73.43	1.54	1.63	1.90	1.70	1.76	1.93
R17	76.13	1.942	1.832	75.34	79.09	73.96	1.65	2.04	1.81	1.90	2.10	1.83
R39	76.83	1.781	1.676	75.49	80.50	74.50	1.56	1.51	1.96	1.72	1.70	1.92
R35	77.22	1.886	1.773	76.67	80.85	74.15	1.73	1.67	1.92	1.88	1.85	1.93
R4	77.78	2.349	2.268	76.80	81.22	75.33	2.36X	2.13	2.31X	2.52	2.33	2.20
R36	77.98	2.209	2.173	78.97	79.85	75.11	2.13	2.15	2.25X	2.24	2.21	2.18

R6	78.73	2.009	1.935	77.53	82.88	75.78	2.00	1.75	2.06	2.03	2.09
1.91											
R27	78.78	2.116	2.098	77.61	80.03	78.69	1.80	2.25	2.24X	1.87	2.39
2.09											
R28	79.41	1.785	1.722	78.28	81.99	77.97	1.68	1.43	2.05	1.79	1.67
1.89											
R21	80.52	2.045	1.950	77.43	85.02	79.11	1.98	1.75	2.13	2.07	2.09
1.98											
CANDIDATE											
C1	64.03	2.252	2.438	63.85	63.33	64.92	2.49X	2.81X	2.02	2.25	2.29
2.21											
C2	86.11	1.940	1.837	84.83	88.63	84.85	1.79	1.71	2.01	1.90	2.05
1.87											
C3	82.04	2.349	2.248	82.26	87.45	76.40	2.37X	2.03	2.35X	2.48	2.37
2.20											
C4	78.63	2.104	2.033	78.01	82.17	75.72	2.05	2.01	2.04	2.15	2.27
1.90											
C5	72.99	1.973	1.869	71.98	79.40	67.59	1.95	1.78	1.88	1.93	1.90
2.08											
C6	83.29	2.050	1.947	84.10	85.57	80.21	2.05	1.69	2.10	2.16	2.03
1.96											
C7	83.90	2.100	1.997	84.12	87.99	79.60	1.93	1.95	2.11	2.04	2.29
1.97											
C8	83.50	2.304	2.201	82.43	85.98	82.08	2.27X	2.00	2.34X	2.38	2.33
2.20											
C9	51.89	1.788	2.157	52.35	55.77	47.56	1.83	2.34X	2.31X	1.52	1.91
1.93											
MEAN OF REFERENCE	71.47	1.988		70.78	74.97	68.65	1.97	2.03	1.96	1.99	1.99
1.99											

UNIFORMITY CRITERION

		PROB. LEVEL
3-YEAR REJECTION	2.383	0.002
2-YEAR REJECTION	2.471	0.002
2-YEAR ACCEPTANCE	2.329	0.020

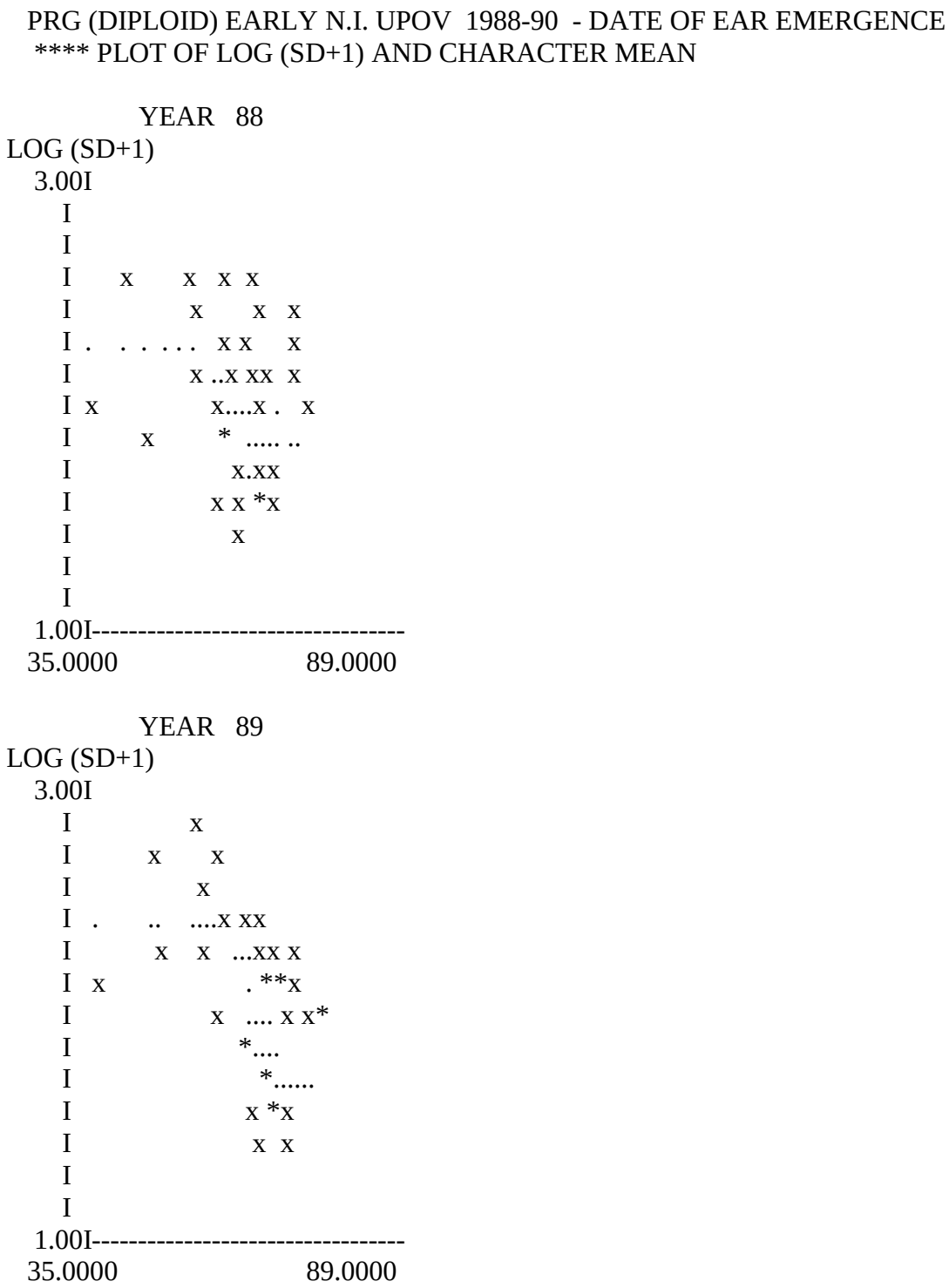
**** ANALYSIS OF VARIANCE OF ADJUSTED LOG(SD+1) *** *

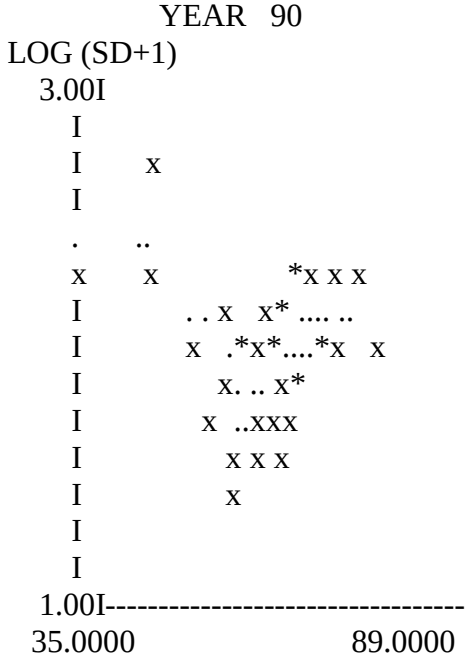
	DF	MS	F RATIO
YEARS	2	0.06239	
VARIETIES	39	0.11440	5.1
RESIDUAL	78	0.02226	
TOTAL	119	0.05313	

SYMBOLS

* - SD EXCEEDS OVER-YEARS UNIFORMITY CRITERION AFTER 3 YEARS.
+ - SD EXCEEDS OVER-YEARS UNIFORMITY CRITERION AFTER 2 YEARS.
: - SD NOT YET ACCEPTABLE ON OVER-YEARS CRITERION AFTER 2 YEARS.
X - SD EXCEEDS 1.265 TIMES MEAN OF REFERENCE VARIETIES

Appendix Figure 1: Relationship between SD and character mean





MEAN DATE OF EAR EMERGENCE

Note : x denotes a value for a reference or candidate variety and . is the trend value.

[End of document]