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INTERNATIONAL UNION FOR THE PROTECTION OF NEW VARIETIES OF PLANTS

GENEVA

TECHNICAL COMMITTEE

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COMBINED OVER-YEARS CRITERION FOR DISTINCTNESS (COYD) AND UNIFORMITY (COYU)

Document prepared by experts from the United Kingdom according to the decisions of the Technical Working Party on Automation and Computer Programs

Combined Over-Years Criterion for Distinctness (COYD) and Uniformity(COYU)

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DESCRIPTION AND USE OF THE COYD CRITERION

Summary

The previous UPOV criterion for distinctness required that a difference between a pair of varieties should be statistically significant at the 1% probability level in at least 2 out of 3 years, in the same direction, for one or more measured characters. This is referred to as the 2 x 1% rule.

This rule was criticised because a difference between 2 varieties which just fails to achieve the 1% significance level contributes no more to the assessment of distinctness than, for instance, a zero difference or even a non-significant difference of the opposite sign. In an attempt to overcome this weakness a modification of the 2 x 1% criterion referred to as the t-score criterion was introduced. In this criterion distinctness is based on a calculation which permits differences at the 5% significance level to contribute but which also does not allow an extremely large difference in one year to dominate.

Although the previously used criteria included a requirement for reproducibility over years they were based on plot error within trials and hence do not take into account variety variation over years. It can be shown that some characteristics are less consistent than others over years. Hence with the 2 x 1% and t-score criteria the risks involved in making decisions are of varying magnitude depending on the over-years consistency of the characters on which distinctness is based. The combined over years distinctness (COYD) criterion was devised to overcome this difficulty. It provides probability levels of differences between variety means over years occurring by chance if no difference exists where the differences are compared with the over-year variation. An F ratio statistic, F_3, is included in this criterion to identify any excessive variation in the differences between a candidate variety and a control compared with the general varieties x years variation over the 2 or 3 years of test. The COYD criterion should be treated with caution where a significant value of F_3 occurs. A further refinement of the COYD analysis allows for any exceptional change in the spacing between variety means on a characteristic in any one of the test years due to environmental conditions eg. the convergence of heading dates in a late spring. This refinement is referred to as the Modified Joint Regression Analysis (MJRA) adjustment and should be applied where a significant change in spacing between variety means in one year has occurred.

1. Introduction

This note describes the COYD criterion and a modification of it involving the modified joint regression analysis (MJRA). The previously used criteria are also defined to provide a background to the reasons for the change to the COYD criterion. In addition a computer program to enable the criteria to be compared on actual data is described. This program is available on magnetic tape and PC disk to member States.

2. Previously Used Criteria

The original UPOV distinctness criterion was the 2 x 1% criterion. This was subsequently modified to the t-score criterion. The following is a brief description of these criteria.

2.1 2 x 1% Method

This criterion for distinctness of varieties was based on separate t-tests carried out in each year of test between a candidate variety and each other variety. These use the t-values defined by

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{2}\, SE(\bar{x})} \qquad (1)$$

where $\bar{x}_1, \bar{x}_2$ are the means on a measured characteristic of the two varieties being compared and $SE(\bar{x})$ is the standard error of a variety mean estimated from the plot error mean square. The significance level of a calculated t-value is obtained from t-tables using the degrees of freedom of the plot error mean square. For each comparison between a candidate variety and some other variety one test is available in each of the years that the candidate variety was grown in the trials, either 2 or 3 years. Under this criterion the candidate variety is considered to be distinct from another variety if in at least 2 years the t-value is significant at the 1% level in the same direction. This criterion established that repeatability of differences over years is an important part of distinctness.

2.2 t-score Method

A weakness of the 2 x 1% method is that a within-year difference which just fails to achieve the 1% significance level contributes no more to the separation of a variety pair than a zero difference or even a non-significant difference of the opposite sign. For example, 3 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 sufficient evidence for distinctness. The t-score method was introduced to overcome this weakness. In this method the t-value calculated according to the above formula (1) is converted to a t-score using constants k_1 and k_2, where these are the tabulated t-scores at the 5% and 0.1% levels respectively. The conversion from t-values to t-scores is then defined by:

(i) t-score = 0 if $k_1 < t < k_1$
(ii) t-score = t-value if $k_1 < t < k_2$ or $-k_2 < t < -k_1$
(iii) t-score = k_2 if $t > k_2$
(iv) t-score = $-k_2$ if $t < -k_2$

These conversion rules are illustrated in Figure 1.

Using t-score two varieties are distinct if the absolute sum of their t-scores over 3 years exceeds the critical value 5.2, which is equivalent to twice the tabulated t-value at the 1% significance level with a large number of degrees of freedom. As with the 2 x 1% criterion the t-score method requires more than a single large t-value for distinctness but the confirmatory evidence need not be so strong. Thus three 5% results, provided they are in the same direction are sufficient to ensure distinctness. With regard to the stringency of the t-score criterion compared with the 2 x 1% criterion, since all variety pairs distinct using the 2

x 1% criterion are also distinct using the t-score criterion and some additional pairs are distinct using t-score, the t-score criterion is less strict though in practice the relaxation in standard is not large.

3. The Combined Over-Years Distinctness Criterion (COYD)

Although the previously used criteria included a requirement for repeatability over years they were based on the plot error mean square and hence did not take into account variety variation over years. Variety measurements are less consistent on some characteristics over years than on others. A measure of inconsistency is indicated by large values of λ where

$$\lambda^2 = \frac{\text{varieties x years mean square}}{\text{plot error mean square}} \qquad (2)$$

and consistency by values of λ near to 1. Typical λ values are in the range 1.3 to 2.5.

In contrast the COYD criterion allows for variety variation over years. It is based on a single analysis of variance involving the variety means within each year for each characteristic. 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)

Using this criterion the ratio, F, defined as

$$F = \frac{\text{varieties mean square}}{\text{varieties x years mean square}} \qquad (3)$$

provides a measure of the discriminating power of a characteristic, high values of F indicating high discriminating power.

Using this criterion two varieties are distinct if the absolute value of

$$\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{2}\,SE\left(\bar{x}\right)} \qquad (4)$$

is larger than a specified critical percentage point in the distribution of t where $\bar{x}_1$, $\bar{x}_2$ are the means of the varieties over 3 years and $SE\left(\bar{x}\right)$ is the standard error of a variety mean calculated as:

$$\sqrt{\frac{\text{varieties x years mean square}}{\text{number of test years}}} \qquad (5)$$

With regard to the choice of the critical probability level to use with this criterion it has been determined from theoretical considerations that for a 3 year test the COYD criterion applied at the 1% probability level is of approximately the same stringency as the 2 x 1% criterion on a characteristic with a λ value of 1.7. Compared with the 2 x 1% criterion the COYD criterion applied at the 1% level is less stringent for characteristics with λ values less than 1.7 and more stringent for characteristics with λ values greater than 1.7. Since λ values occurring in practice are around 1.7 in grass trials it has been agreed to operate COYD at the 1% level for this species for both 2 and 3 year tests. Further details of the COYD criterion are given in Patterson and Weatherup (1984).

4. Homogeneity of Varieties x Years Variance

From the previous paragraphs it is recommended that the combined over-years criterion be used in preference to the 2 x 1% or the t-score methods with one qualification. The varieties x years mean square used in the combined over-years criterion is a pooled value calculated from a large number of varietal comparisons and hence may not be appropriate to any particular comparison. Hence to ensure that the specific within pair varieties x years mean square with 2 degrees of freedom is not larger than the pooled varieties x years mean square their ratio, F_3 say, should be calculated and tested for significance. The combined over-years criterion should be treated with caution where a significant F_3 ratio occurs.

5. Modified Joint Regression Analysis (MJRA) Adjustment to the COYD Analysis

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 causing 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 where 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 versus average variety means. Secondly a non-systematic effect 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 distinction between the total varieties x years variation and the varieties x years variation adjusted by MJRA is illustrated in Figure 2 where variety means in each of 3 years are plotted against average variety means over all years. The variation about 3 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, one 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 distinctness 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.

$$y_{ij} = u_j + b_j v_i + e_{ij} \qquad (6)$$

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:

$$\sum_{i=1}^{n} v_i y_{ij} = b_j \sum_{i=1}^{n} v_i^2 \qquad (7)$$

$$\sum_{j=1}^{m} b_j y_{ij} = v_i \sum_{j=1}^{m} b_j^2 \qquad (8)$$

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:

$$\sum_{j=1}^{m} \sum_{i=1}^{n} (y_{ij} - u_j - b_j v_i)^2 \qquad (9)$$

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

6. Computer Program

The COYD criterion over 2 or 3 test years is evaluated by the program TVAL. Sample outputs are given in the attached figures. These concern a PRG (Diploid) trial involving 40 reference varieties (C1 to C40) and 9 candidate varieties (R1 to R9) on which 8 characters

were measured over the 3 years 1988, 1989 and 1990. Figure 3 provides the varicty means over this period together with summaries of the analyscs of variance for each character. In this output F_1 corresponds to the F ratio defined in formula (3) and F_2 corresponds to λ^2 defined by formula (2). The test which is performed in comparing variety means, either COYD or COYD with MJRA, is listed for each character. Figure 4 provides an appraisal of the distinctness status of each candidate variety over all characters where D implies distinct and ND implies not distinct. Figure 5 provides the detailed results of a compariosn between varieties C1 and R1 on each character. The result on COYD is provided for each character with a reminder of whether or not MJRA was used with that character. A column containing D and ND indicates the distinctness status on each character. The individual t-values within each year are also listed to provide information on the separate years. Also the F_3 value is provided to give a warning of excessive year to year variation of the variety pair. In the case of the varieties C1 v R1 a significant F_3 value for character 8 draws attention to a marked change in the difference between these varieties from 1989 to 1990.

References

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

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

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21 May 1993

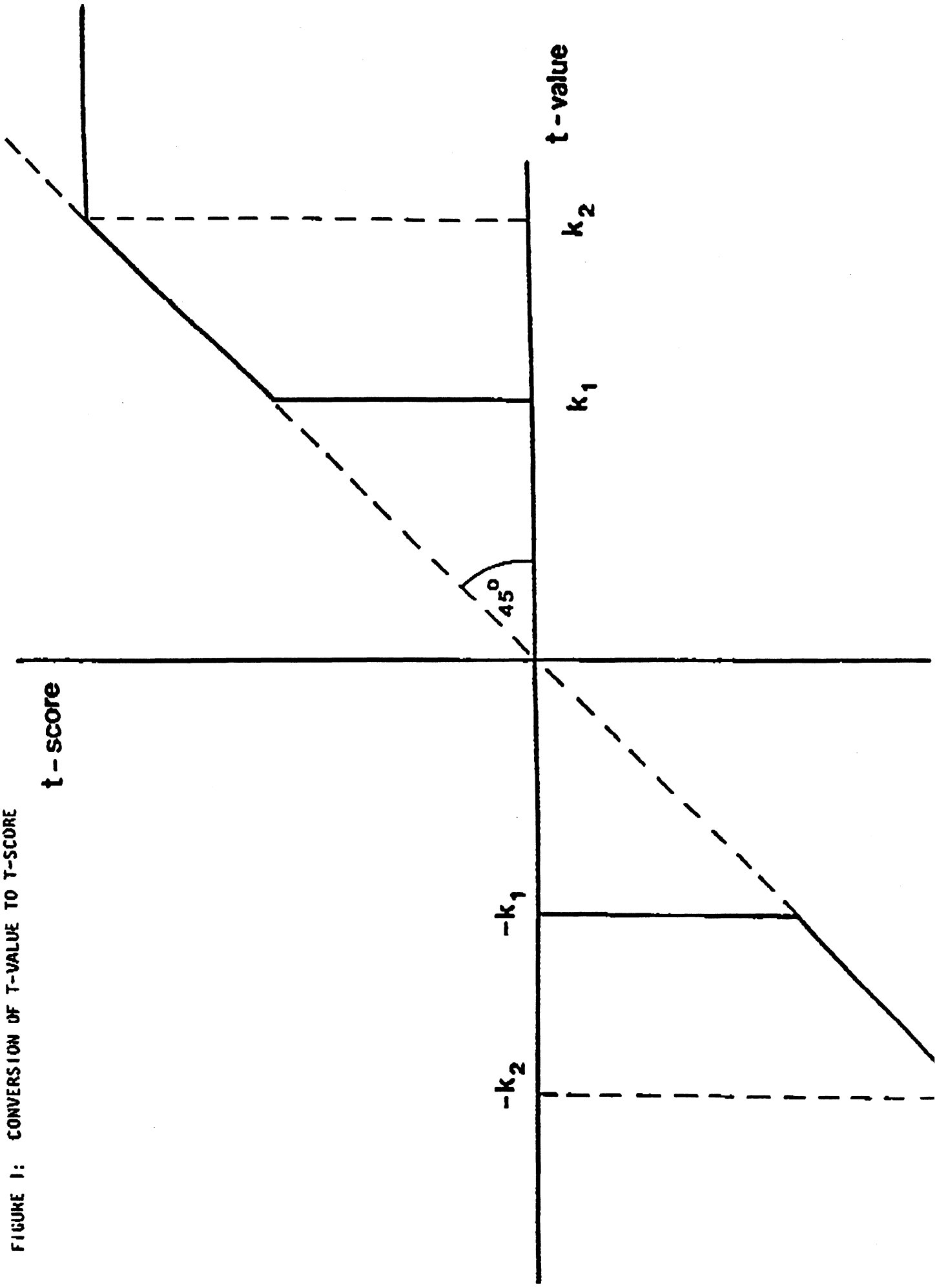


FIGURE 1: CONVERSION OF T-VALUE TO T-SCORE

Fig 2: Year v Over Year Means

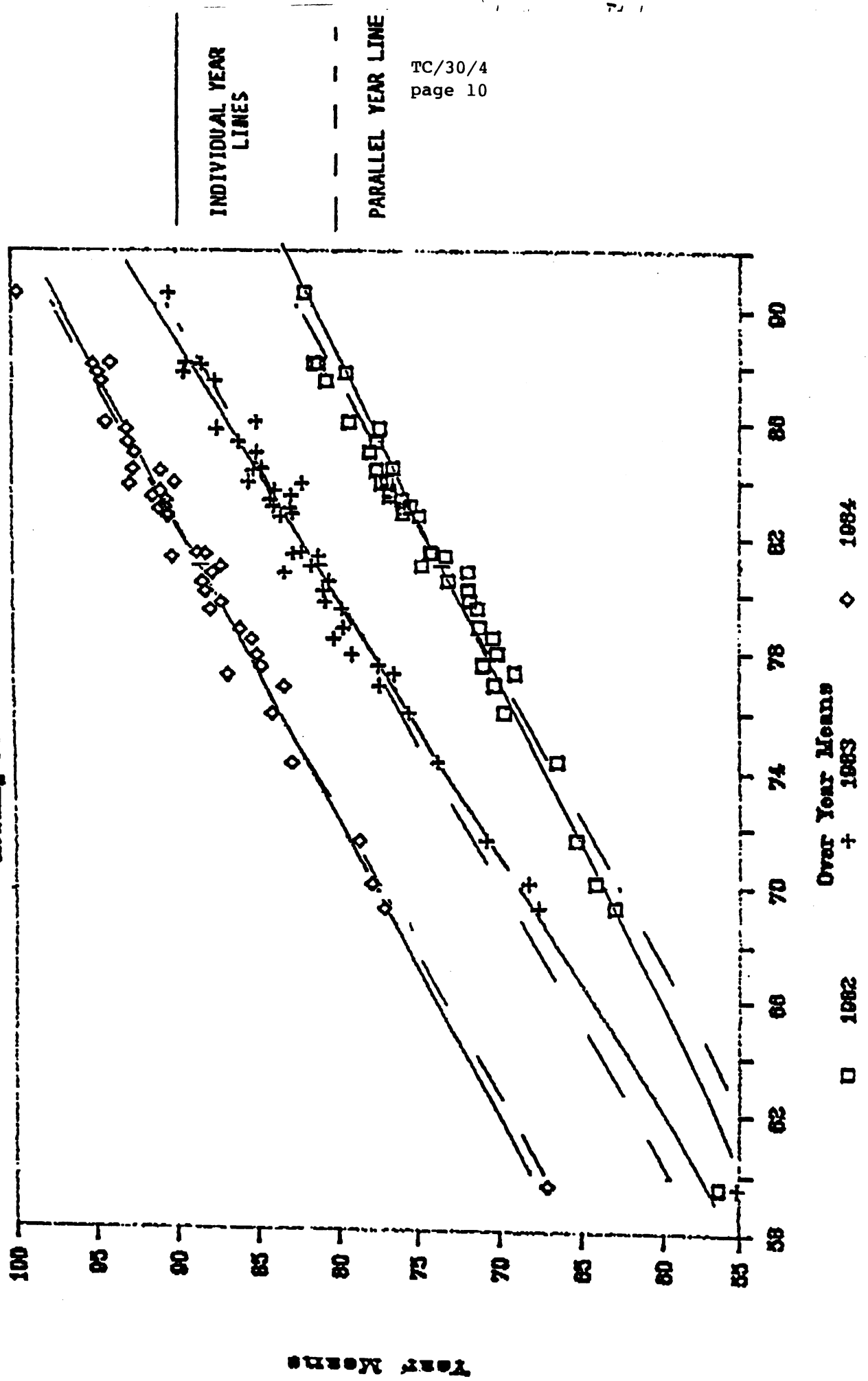


FIG 3: PRG (DIPLOID) EARLY N.I. UPOV 1988-90 FINAL
OVER YEAR VARIETY MEANS ON MEASURED CHARACTERS

		5	60	8	10	11	14	15	24
1	R1	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	22.18
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
VARIETY MS		909.2	476.7	1376.1	635.3	762.4	80.2	6.4	74.2
VAR.YEAR MS		23.2	18.9	14.1	23.2	46.6	4.8	0.3	2.7
F1 RATIO		39.3	25.3	97.4	27.4	16.4	16.8	22.8	27.2
VAR.REP MS		8.8	8.2	4.6	11.9	23.2	1.5	0.2	1.7
F2 RATIO		2.6	2.3	3.1	1.9	2.0	3.1	1.9	1.6
BETWEEN SE		1.134	1.024	0.886	1.134	1.609	0.514	0.125	0.390
TEST		COYD	MJRA	COYD	COYD	COYD	COYD	COYD	COYD

FIG 4: PRG (DIPLOID) EARLY N.I. UPOV 1988-90 FINAL

SUMMARY FOR COY CRITERION AT 1.0% LEVEL USING MJRA WHEN REGRESSION SIG AT 1%

CANDIDATE VARIETIES		41	42	43	44	45	46	47	48	49
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	R12	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	ND	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 VARIETIES		1	0	1	1	2	0	1	0	0
OVERALL DISTINCTNESS		ND	D	ND	ND	ND	D	ND	D	D
CANDIDATE VARIETIES		41	42	43	44	45	46	47	48	49

FIG 5: PRG (DIPLOID) EARLY N.I. UPOV 1988-90 FINA

CANDIDATE VARIETY: 41 C1 PROBLEM VARIETY : 1 R1
T VALUES POSITIVE IF C1 LARGER THAN R1

	CHARACTER	COY ANALYSIS T	PROB %	SIG		T VALUES 88	89	90	F3 VALUE	SIG	CR1
5	SP.HGHT	-1.78	-7.877	NS	ND	-1.05	-1.34	-2.64	0.2	NS	CC
60	NATSPHT	-2.02	-4.610	*	ND	-1.58	-2.61	-1.17	0.2	NS	MJ
8	DATEEE	-3.06	-0.286	**	D	-4.14	-6.33	0.80	4.0	*	CO
10	HGHT.EE	-3.11	-0.247	**	D	-2.79	-2.69	-2.06	0.1	NS	CO
11	WIDTHEE	-1.33	-18.577	NS	ND	-1.47	-1.80	-0.21	0.3	NS	CO
14	LGTHFL	0.47	63.609	NS	ND	0.17	1.83	-0.67	0.6	NS	CO
15	WIDTHFL	0.27	78.831	NS	ND	0.31	-0.41	0.67	0.2	NS	CO
24	EARLGTH	2.93	0.424	**	D	2.10	3.33	1.01	0.8	NS	CO

THE COMBINED-OVER-YEARS UNIFORMITY CRITERION

SUMMARY

Between-plant uniformity is often related to the expression of a character. For example, in some species varieties with larger plants tend to be less uniform than those with smaller plants. If a fixed uniformity standard is applied to all varieties then it is possible that some may have to meet very strict criteria while others face standards which are easy to satisfy.

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

The technique involves ranking reference and candidate varieties by the mean value of the character. The varieties are then taken in groups starting with those ranked 1 to 9 and their mean SD is calculated. This mean SD is subtracted from the variety ranked 5 (and higher). The same process is carried out on varieties ranked 2 to 10 and their mean SD is subtracted from that of variety 6. This procedure is continued to give for each variety a measure of its uniformity relative to the nine most similar varieties.

The results for each year are combined by forming a variety-by-years tables 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.

The COYU procedure 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 cross fertilized variety is a multiple concept comprising several aspects. In practice the assessment of uniformity is based on the univariate measures of features such as plant size. The aim is to ensure that the distribution of measurements on individual plants of a new variety is not excessive when compared with that of reference varieties.

To describe uniformity the procedure has been adopted of calculating the standard deviation of observations on individual plants within a plot. The within-plot SDs are averaged over all plots of the variety to give an average measure of uniformity for each variety.

THE PREVIOUS UPOV UNIFORMITY CRITERION

The tolerance standard 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 the average of the reference varieties.

Several deficiencies in this criterion have been reported:

i) The criterion assumed 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) A feature of between-plant uniformity is that it can change between varieties in response to the level of expression of the character which is being measured. For example, in some species early and late maturing varieties may be more uniform in time to ear emergence than varieties of medium maturity. See Figure 1. If a candidate variety of medium maturity is compared against the mean of a set of reference varieties which represent all maturities then it is likely to have a poorer chance of satisfying the criterion than an early or late variety. Similar considerations apply with plant size characters where smaller varieties tend to be more uniform than larger varieties.

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

Ad hoc solutions to some of these problems were considered, principally involving the grouping of varieties. However, such solutions pose their own problems: it is 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 and between countries.

THE OVER-YEARS UNIFORMITY CRITERION

The combined-over-years uniformity(COYU) procedure involves taking the SDs for each year, and adjusting for the relationship that 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. 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 straightforward Student's t-test derived from an analysis of variance of the variety x year table of SDs. Statistical details are given in Appendix A1.

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

The advantages of the COYU procedure are:

i) 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;

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

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

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

ACCEPTANCE STANDARDS

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

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

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 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).

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%

For countries that may encounter difficulties in reaching these standards a transitional period of not more than three years is suggested to change to probability levels of 0.1%, 0.1% and 1.0% and another two years to reach the levels proposed above.

IMPLEMENTING THE OVER-YEARS UNIFORMITY CRITERION

A computer program, UNIF, has been written to implement the procedure. The main output from the program is illustrated in Table 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 Appendix A2 where details of the analysis of a single character, date of ear emergence, are presented.

In Table 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. In the table the first 40 varieties are established varieties and serve as reference varieties.

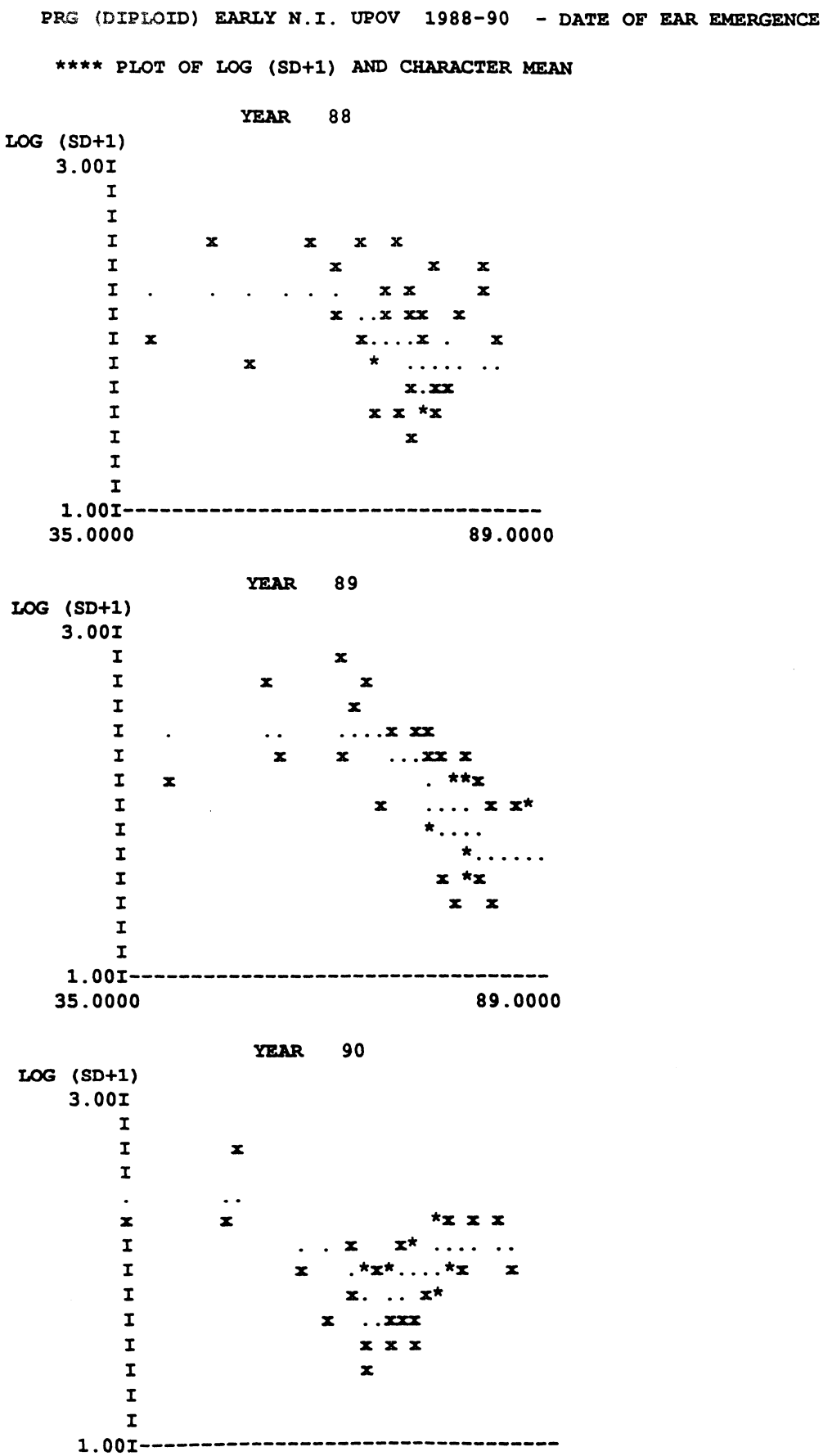
The symbols * and + to the right of percentages identify varieties whose SDs exceed the COYU criterion after 3 and 2 years respectively. The symbol : indicates that after two years uniformity is not yet acceptable and the variety should be considered for testing for a further year.

The program will operate with tables where information for some of the varieties is incomplete.

A copy of a stand-alone version of the software, for a PC or other machines, is available from the address below. The algorithm is also incorporated within the DUST package as part of a comprehensive system for statistical analysis of DUS data. Details of the DUST system are available from the Biometrics Division, DANI, Queens University, Belfast BT9 5PX, UK.

M Talbot, Scottish Agricultural Statistics Service, University of Edinburgh, Edinburgh EH9 3JZ, UK. September 1993

FIGURE 1: RELATIONSHIP BETWEEN SD AND MEAN



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

TABLE 1: EXAMPLE OF SUMMARY OUTPUT FROM PROGRAM UNIF

**** OVER-YEARS UNIFORMITY ANALYSIS SUMMARY ****

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

APPENDIX A1

STATISTICAL BASIS FOR COYU
DERIVATION OF THE WITHIN-PLOT STANDARD DEVIATION

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

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

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,

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

ADJUSTING THE STANDARD DEVIATIONS

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 varieites. 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_i variate) according to the character mean. For each point (Y_i, X_i) take the trend value $\hat{Y}_i$ to be the mean of the values Y_{i-4}, Y_{i-3}, ... , Y_{i+4} . For the four smallest and four largest Y_i, the mean of the extreme three values is used as the trend values.

Once the trend values for the reference varieites 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 $\hat{Y}_i$ and $\hat{Y}_{i+1}$ and the observed value for the candidate is Y_c where $X_i \le X_c \le X_{i+1}$, then the trend value for the candidate is derived as

$$\hat{Y}_c = \{(X_c - X_i)\, Y_{i+1} + (X_{i+1} - X_c)\, Y_i\} / \{(X_c - X_i) + (X_{i+1} - X_c)\}$$

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.

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 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 A2 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

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

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

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

APPENDIX A2: EXAMPLE OF OUTPUT FROM PROGRAM UNIF FOR SINGLE CHARACTER

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

	OVER-YEARS			INDIVIDUAL YEARS								
VARIETY	CHAR. MEAN	ADJ. LOG SD	UNADJ LOG SD	-- CHARACTER MEAN -- 88	89	90	---- LOG (SD+1) ---- 88	89	90	-- ADJ LOG(SD+1) -- 88	89	90
REFERENCE												
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	

[End of document]

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.