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EFFECTS OF ERRORS OF VARIABLES ON THE STABILITY ANALYSIS OF A GROUP OF MAIZE EXPERIMENTS*

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ABSTRACT

A group of 42 maize cultivars was evaluated in 16 localities of the State of Rio Grande do Sul. Yield data were submitted to a joint analysis of variance and to a stability analysis based on a discontinuous bi-segmented regression model with and without corrections to compensate for measurement errors of the independent variable and for the covariance between the errors of the dependent and independent variables. Results indicated that the effect of corrections on estimates of angular and discontinuity parameters was neglegible. Ignoring corrections, however, resulted in a downwards bias (average of 14%) of the variance due to deviations from the model. The importance of the corrected analytical procedure increased as the number of treatments and or replications was reduced.

INTRODUCTION

Cultivar x environment interaction studies, through stability analysis, have been increasingly used by researchers. This procedure is useful as guide for selecting and/or discarding genotypes in a breeding program. A well known stability analysis considers a regression model such that the among environments within cultivars source of variation

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is partioned into components due to regression and deviations from regression. In this case, the independent variable (I) is, in general, taken as an environmental index or as the difference between the mean of all cultivars in a given environment, minus the overall mean.

The simple linear regression procedure, introduced by Finlay and Wilkinson (1963) was later improved by Eberhart and Russell (1966), who incorporated deviations from regression as a measure of response predictability of a cultivar. Improving the concepts, Verma *et al.* (1978) defined an ideal cultivar as one with acceptable yielding potential and stability of response in poor environments and ability to respond positively to environmental improvements. Basically these authors proposed the adjustment of two separate regression segments, for poor and favorable environments, respectively, with a common point to both segments as a linkage value. This originated the idea of a non-linear stability analysis of responses. An adjustment procedure with only one equation with two linear segments, joined at the zero value of the environmental index was later proposed by Silva and Barreto (1985). Estimates of the two regression coefficients in this case, however, were found to be always negatively correlated. A reparametrization was then worked out by Cruz *et al.* (1989) to eliminate this correlation, but an undesirable discontinuity between both segments resulted from the model. Storck (1989) consequently, incorporated an additional discontinuity parameter in the bi-segmented model, maintaining the zero correlation between estimates of the two regression coefficients. This parametrization was very efficient at explaining continuous trends of response of cultivars in changing environments. Proper agronomic interpretations were given by this author for all the parameters of his extended model, under different types of responses. In this last publication measurement errors in the independent variable (I) and of covariance due to error between I and the error of dependent variable Y were also investigated. Proper estimates and test criteria were given by Storck (1989) under the proposed discontinuous bi-segmented model. We: a) analysed a set of maize yield trials with and without the corrections recommended by Storck (1989); b) evaluated the relative effects of measurement errors of the independent variable and of its covariance with the error of the dependent variable in a stability analysis of actual data.

MATERIAL AND METHODS

Yield data of a group of maize experiments from the 1987/88 trials of the State of Rio Grande do Sul (RS-IPAGRO) were taken. In randomized complete blocks, with K = four replications and I = 42 cultivars, these experiments covered J = 16 localities in RS, namely: Aratiba, Chapada, Cruz Alta, Dom Pedrito, Encantado, Encruzilhada do Sul, Júlio de Castilhos, Não-Me-Toque, Nova Prata, Passo Fundo, Pelotas, Santa Cruz do Sul, Santa Rosa, Santo Augusto, Vacaria and Veranópolis. Table I shows the list of cultivars

Table I - Maize cultivars and corresponding origins.

No.	Cultivar	Origins
1.	AG 64 A	Sementes Agroceres S/A
2.	AG 84	Sementes Agroceres S/A
3.	AG 3511	Sementes Agroceres S/A
4.	AG 3611	Sementes Agroceres S/A
5.	AG 3613	Sementes Agroceres S/A
6.	AGN 2001	Agromen Sementes Ltda
7.	AGN 2003	Agromen Sementes Ltda
8.	AGN 2005	Agromen Sementes Ltda
9.	XL 540	Braskalb Agropecuária Brasileira
10.	XL 560	Braskalb Agropecuária Brasileira
11.	DK 564	Braskalb Agropecuária Brasileira
12.	XL 599	Braskalb Agropecuária Brasileira
13.	CONTI 322	Continental de Cereais Contibrasil Ltda
14.	CONTI 521	Continental de Cereais Contibrasil Ltda
15.	CONTI 611	Continental de Cereais Contibrasil Ltda
16.	CMS 202*	Empresa Brasil. de Pesquisa Agropec.
17.	CMS 5205*	Empresa Brasil. de Pesquisa Agropec.
18.	CMS 5229*	Empresa Brasil. de Pesquisa Agropec.
19.	EMPASC 151	Empresa Catarinense de Pesq. Agropec.
20.	EMPASC 152	Empresa Catarinense de Pesq. Agropec.
21.	CEP 304	Fecotrigo - Centro de Exper. e Pesquisa
22.	CEP 8616	Fecotrigo - Centro de Exper. e Pesquisa
23.	P X 307	Pioneer Agricultura Ltda
24.	P 515	Pioneer Agricultura Ltda
25.	P 3230	Pioneer Agricultura Ltda
26.	P 6875	Pioneer Agricultura Ltda
27.	SAVE 342	Secr. da Agric. e Abast./Veranópolis
28.	SAVE 394	Secr. da Agric. e Abast./Veranópolis
29.	SAVE 458	Secr. da Agric. e Abast./Veranópolis
30.	SAVE 463	Secr. da Agric. e Abast./Veranópolis
31.	SAVE 464	Secr. da Agric. e Abast./Veranópolis
32.	C 125	Sementes Cargill Ltda
33.	C 501	Sementes Cargill Ltda
34.	C 511	Sementes Cargill Ltda
35.	C 511-A	Sementes Cargill Ltda
36.	C 511-B	Sementes Cargill Ltda
37.	C 521	Sementes Cargill Ltda
38.	C 525	Sementes Cargill Ltda
39.	C 601	Sementes Cargill Ltda
40.	C 606	Sementes Cargill Ltda
41.	G 20-S	Sociedade Agrícola Germinal
42.	G 5555	Sociedade Agrícola Germinal

* - CMS are populations under selection.

and corresponding origins. Data here considered included grain yield means (t/ha) of cultivars, plus means squares for blocks and error for each trial.

Data were analysed according to the methodology described by Storck (1989). After the joint analysis of variance over locations, cultivars x locations source of variation was partitioned into 16 locations within cultivars components. Subsequent stability analysis was based on the following discontinuous bi-segmented regression model:

$$\overline{Y}_{ij.} = \beta 0_i + \beta 1_i \tau_j + \beta 2_i \tau_j Z_j + \beta 3_j Z_j\, \delta_{ij} + \varepsilon_{ij}$$

Here: $\hat{\tau}_j = \tau_j + \upsilon_j$

$\hat{\tau}_j Z_j = \tau_j Z_j + \upsilon_j Z_j$

$Z_j = 1$, if $\hat{\tau}_j > 0$

0, if $\hat{\tau}_j \leq 0$, and

$\overline{Y}_{ij.}$ is the mean of the ith cultivar at the jth locality, with the random component averaged over blocks ε_{ij} such that **E** $(\varepsilon_{ij}) = 0$ and **E** $(\varepsilon_{ij}^2) = \sigma_\varepsilon^2 = (1/K)(\sigma^2 + \sigma_b^2)$ (block σ_b^2 and error σ^2 variances). For cultivar i: $\beta 0_i$ is a constant; $\beta 1_i$ measures the slope of the first regression segment; $\beta 2_i$ is the difference in slope between the second and the first regression segments; and, $\beta 3_i$ measures the discontinuity between both linear regression segments. For the ijth combination, δ_{ij} is a measure of deviation from the model, with **E** $(\delta_{ij}) = 0$, **E** $(\delta_{ij}^2) = \sigma_{\delta i}^2$ and is independent from ε_{ij}; τ_j is the (not observable) random effect of environment j, estimable through $\hat{\tau}_j = \overline{Y}_{.j.} - \overline{Y}_{...}$ but associated to a measurement error υ_j such that $\mathrm{Var}(\upsilon_j) = \sigma_\upsilon^2 = (J-1)(\sigma^2 + I\,\sigma_b^2)/IK$ and $\mathrm{Cov}(\varepsilon_{ij}; \upsilon_j) = \sigma_{\varepsilon\upsilon} = \sigma_\upsilon^2$. Since σ_ε^2 and σ_υ^2 are estimable from the joint analysis, the method of moments was applied for estimation of all parameters of this model, as given below.

To evaluate the effect of type υ_j errors, associated with the independent variables on parameters estimation and for hypothesis testing, the analysis was performed (a) with corrections (wc) to compensate for the existence of such errors, as shown by Storck (1989) and (b) without corrections (wo) in which we ignore υ_j, such that $\tau_j = \hat{\tau}_j$ and consequently $\sigma_\upsilon^2 = \sigma_{\varepsilon\upsilon} = 0$. Ratios, in percentage, between estimates obtained (wc and wo) were taken to evaluate differences between the corrected and uncorrected stability analyses.

For the corrected procedure, estimation of parameters required solving the following equations (Storck, 1989):

$$\underset{\sim}{\hat{\beta}}_i = \left\{ \hat{\beta} 1_i\ \hat{\beta} 2_i\ \hat{\beta} 3_i \right\} = \left[Mxx - S(\upsilon\upsilon)\right]^{-1} \left[Mxy_i - S(\varepsilon\upsilon)\right]$$

$$\hat{\beta}o_i = \overline{Y}_{i..} - \hat{\beta}2_i\,\overline{\tau z} - p\,\hat{\beta}3_i$$

$$\hat{\sigma}^2_{\delta i} = Svv_i - \underset{\sim}{\hat{\beta}i}'\,S(\upsilon\upsilon)\,\underset{\sim}{\hat{\beta}i} + 2\,S(\upsilon\varepsilon)\,\underset{\sim}{\hat{\beta}i} - \hat{\sigma}^2_{\varepsilon}$$

with $p = (\sum_{j=1}^{J} Z_j)/J$; $\overline{\tau z} = (\Sigma_j \hat{\tau}_j Z_j)/J$;

$$Mxx = \begin{bmatrix} S^2(\hat{\tau}) & S(\hat{\tau},\hat{\tau}Z) & S(\hat{\tau},Z) \\ & S^2(\hat{\tau}Z) & S(\hat{\tau}Z,Z) \\ \text{(simmetric)} & & S^2(Z) \end{bmatrix}; \quad S(\upsilon\upsilon) = \begin{bmatrix} \hat{\sigma}^2_{\upsilon} & p\hat{\sigma}^2_{\upsilon} & 0 \\ p\hat{\sigma}^2_{\upsilon} & p\hat{\sigma}^2_{\upsilon} & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$M'xyi = \left[S(\overline{Y}i,\hat{\tau}) \quad S(\overline{Y}i,\hat{\tau}Z) \quad S(\overline{Y}i,Z)\right];$$

$$S'(\varepsilon\upsilon) = S(\upsilon\varepsilon) = \left[\hat{\sigma}^2_{\upsilon} \quad p\hat{\sigma}^2_{\upsilon} \quad 0\right];$$

$$Svv_i = \sum_{j=1}^{J} \left\{\overline{Y}_{ij.} - \hat{\beta}0_i - \hat{\beta}1_i\,\hat{\tau}_j - \hat{\beta}2_i\,\hat{\tau}_j\,Z_j - \hat{\beta}3_i\,Z_j\right\}^2/(J-4),$$

S^2 and S, standing for variance and covariance, respectively.

The usual least squares method was applied for the uncorrected estimation of parameters.

RESULTS AND DISCUSSION

Table II shows quantities pertinent to each locality or environment. The hypothesis of homogeneity of error variance was accepted on the basis of Cochran's F* criterion; here F* = 3.62 < 7.00. In spite of the non significance of F*, Cochran's procedure was also applied for correcting degrees of freedom of the cultivars x environments (CxE) and pooled error mean squares. The joint analysis, given in Table III, shows significant F statistics ($\alpha \leq 1\%$) for the CxE effects, with corrected degrees of freedom $g_1 = 531$ and $g_2 = 1{,}683$, correspondingly. High significance was also found for variations among environments within all cultivars ($\alpha \leq 1\%$). Here F was taken with $g_1 = 15$ and $g_2 = 97$ degrees of freedom. These results indicated that a subsequent stability analysis is recommendable.

Table II - Error (EMS) and blocks (BMS) mean square, coefficients of variation (CV%) and independent variables ($\hat{\tau}$, $\hat{\tau}z$ and z) for the 16 environments. Maize grain yield, t/ha.

Envir.	EMS	BMS	Mean	CV%	$\hat{\tau}$	$\hat{\tau}z$	z
1	0.19507	1.62378	6.1378	7.20	1.1082	1.1082	1
2	0.24952	2.14828	2.4056	20.77	-2.6240	0.0000	0
3	0.22449	0.22347	3.7661	12.58	-1.2635	0.0000	0
4	0.30937	3.65387	3.1383	17.72	-1.8913	0.0000	0
5	0.23620	0.42510	7.1643	6.78	2.1347	2.1347	1
6	0.55380	1.07390	5.9546	12.50	0.9250	0.9250	1
7	0.26300	0.86228	4.7851	10.72	-0.2445	0.0000	0
8	0.43205	8.15047	5.3305	12.33	0.3009	0.3009	1
9	0.41080	1.19500	3.3011	19.42	-1.7285	0.0000	0
10	0.25718	14.23578	8.2258	6.17	3.1962	3.1962	1
11	0.59137	2.47235	6.6520	11.56	1.6225	1.6225	1
12	0.21010	1.07320	5.7088	8.03	0.6792	0.6792	1
13	0.26058	1.91569	4.9604	10.29	-0.0692	0.0000	0
14	0.16334	2.09207	2.2268	18.15	-2.8028	0.0000	0
15	0.21807	0.43445	5.9472	7.85	0.9176	0.9176	1
16	0.23500	6.01720	4.7689	10.17	-0.2607	0.0000	0
Mean	0.30062	2.97480	5.0296	12.02	0.0000	0.68027	0.5

Table III - Joint analysis of variance with partioning of the interaction sum of squares. Maize grain yield, t/ha.

Variations	DF	SS	MS	F(Under Ho)
Cultivar (C)	41	627.36876	15.30168	11.973*
Environment (E)	15	7378.13718	491.87581	115.729*
Int. C x E	615	785.97921	1.27802	4.251*
Block/Envir.	48		2.97481	9.895*
Error	1968		0.30062	
		Partition of interaction and environments		
Env./Cult.	630	8164.11639	12.95891	
Env./Cult. 1	15	196.27847	13.08523	35.919*
Env./Cult. 2	15	238.66985	15.91132	43.677*

Continued

Table III - Continued.

Variations	DF	SS	MS	F(Under Ho)
Env./Cult. 3	15	218.77743	14.58516	40.036*
Env./Cult. 4	15	236.78257	15.78551	43.331*
Env./Cult. 5	15	249.19965	16.61331	45.604*
Env./Cult. 6	15	183.83616	12.25574	33.642*
Env./Cult. 7	15	264.78972	17.65265	48.457*
Env./Cult. 8	15	174.11579	11.60772	31.863*
Env./Cult. 9	15	215.82334	14.38822	39.496*
Env./Cult. 10	15	220.43286	14.69552	40.339*
Env./Cult. 11	15	215.10689	14.34046	39.365*
Env./Cult. 12	15	184.51919	12.30128	33.767*
Env./Cult. 13	15	248.61763	16.57451	45.497*
Env./Cult. 14	15	163.05252	10.87017	29.839*
Env./Cult. 15	15	168.87529	11.25835	30.904*
Env./Cult. 16	15	223.17028	14.87802	40.840*
Env./Cult. 17	15	149.54091	9.96939	27.366*
Env./Cult. 18	15	173.50170	11.56678	31.751*
Env./Cult. 19	15	150.39836	10.02656	27.523*
Env./Cult. 20	15	158.20622	10.54708	28.952*
Env./Cult. 21	15	186.21185	12.41412	34.077*
Env./Cult. 22	15	153.15290	10.21019	28.027*
Env./Cult. 23	15	183.96664	12.26444	33.666*
Env./Cult. 24	15	184.05681	12.27045	33.682*
Env./Cult. 25	15	244.02691	16.26846	44.657*
Env./Cult. 26	15	223.01605	14.86774	40.812*
Env./Cult. 27	15	206.20657	13.74710	37.736*
Env./Cult. 28	15	176.46135	11.76409	32.292*
Env./Cult. 29	15	188.05271	12.53685	34.414*
Env./Cult. 30	15	152.04454	10.13630	27.824*
Env./Cult. 31	15	165.34346	11.02290	30.258*
Env./Cult. 32	15	137.89561	9.19304	25.235*
Env./Cult. 33	15	190.80043	12.72003	34.917*
Env./Cult. 34	15	208.62043	13.90803	38.178*
Env./Cult. 35	15	235.96641	15.73109	43.182*
Env./Cult. 36	15	264.11421	17.60761	48.333*
Env./Cult. 37	15	229.55205	15.30347	42.008*
Env./Cult. 38	15	188.72478	12.58165	34.537*
Env./Cult. 39	15	171.84399	11.45627	31.448*
Env./Cult. 40	15	104.08043	6.93869	19.047*
Env./Cult. 41	15	185.27033	12.35135	33.905*
Env./Cult. 42	15	151.01314	10.06754	27.635*

* - Significant at $\alpha \leq 1\%$.

The last three columns of Table II give values of the independent variables ($\hat{\tau}_j$; $\hat{\tau}_j Z_j$; Z_j), required for the bi-segmented model addopted. Environmental indices ($\hat{\tau}_j$) were found to be approximately equidistant and evenly distributed around zero, with an adequate range of 5.999 t/ha.

The variance-covariance matrix of estimates of the independent variables and the corresponding inverse, with and without correction due to error, are shown in Table IV. The error variance of the independent variable $\hat{\tau}$ was estimated by $\hat{\sigma}^2_\upsilon$ = (16-1) (2.97481)/(42 x 16 x 4) = 0.01660 (t/ha)^2 with n_υ = 48 degrees of freedom. This corresponds to only 0.57% of the total variance of $\hat{\tau}$, $S^2(\hat{\tau})$ = 2.92783 {element (1;1) of the first matrix of Table IV}. Thus, $\hat{\sigma}^2_\tau = S^2(\hat{\tau}) - \hat{\sigma}^2_\upsilon = 2.91123$ is the estimated variance of τ (non observable index). Relative to $S^2(\hat{\tau}_Z)$ and to the covariance $S(\hat{\tau}; \hat{\tau}_Z)$, corrections elements were also very small (0.92% and 0.60% respectively). The magnitude of $\hat{\sigma}^2_\upsilon$ can be verified if we consider that $\hat{\sigma}^2_\upsilon = \frac{1}{IK}\left(\frac{J-1}{J}\right)(\hat{\sigma}^2 + I\hat{\sigma}^2_b)$ (Storck, 1989). With I = 42

Table IV - Variance-covariance matrices of independent variables and corresponding inverses.

Without correction due to error

2.92783	1.39220	0.72563
1.39220	0.89858	0.36281
0.72563	0.36281	0.26667

Previous matrix inverse

1.82356	-1.82356	-2.48105
-1.82356	4.29297	-0.87871
-2.48105	-0.87871	11.69670

With correction due to error

2.91123	1.38390	0.72563
1.38390	0.89028	0.36281
0.72563	0.36281	0.26667

Previous matrix inverse

1.85159	-1.85159	-2.51918
-1.85159	4.37267	-0.91088
-2.51918	-0.91088	11.84423

cultivars, K = 4 replications and J = 16 environments, we understand why $\hat{\sigma}_\upsilon^2$ was small in our case, despite the significance of F for the blocks within environments means square (BMS/E; with σ_b^2 as the block component). It is apparent that a large number of cultivars and replications will tend to reduce the error variance of the independent variable and hence the corresponding need for corrections, as shown.

Random element ε_{ij} of the linear model for $\overline{Y}_{ij.}$ includes experimental error plus random block effects, averaged over environments. For our data $\hat{\sigma}_\varepsilon^2 = (1/K)\,(\hat{\sigma}^2 + \hat{\sigma}_b^2) = 0.0911$, with $n_\varepsilon = 895$ degrees of freedom; elements of $\hat{\sigma}_\varepsilon^2$ being (from Table III) $\hat{\sigma}^2 = 0.3006$ and $\hat{\sigma}_b^2 = (1/42)\,(2.9748 - 0.3006) = 0.0637$. In computing the error variance of $\overline{Y}_{ij.}$ one should not ignore contribution of variance due to block effects, as usually done (Eberhart and Russell, 1966).

Estimates of $\beta 0$, $\beta 1$, $\beta 2$ and $\beta 3$ for all cultivars, without correction for error υ_j of the independent variable, are given in Table V. We observe that average values of $\hat{\beta}1$, $\hat{\beta}2$ and $\hat{\beta}3$ are 1.0, 0.0 and 0.0, respectively. Hypothesis $H1{:}\beta 1_i = 1$ was rejected in favor of the alternative $H1{:}\beta 1_i > 1$ for cultivars 2 and 4 and of the alternative $H1{:}\beta 1_i < 1$ for cultivars 17, 21, 22 and 38. Relative to $\beta 2_i$, $H1{:}\beta 2_i = 0$ was rejected for cultivar 38 (with $H1{:}\beta 2_i > 0$). For $\beta 3_i$, the alternative hypothesis was accepted for cultivar 9. No cultivars with $\beta 2$ and $\beta 3$ smaller than zero were observed. Corresponding *t* statistics are given in Table VI. Incorporating corrections for error of the independent variable in estimation of β's and *t* we obtained the results shown in Tables VII and VIII. As can be seen, corrected computations did not change major conclusions drawn on hypothesis testing without corrections. Adequacy of the model is given by R^2 (%) values in both Tables.

Table V - Estimates of parameters without correction for error of independent variables. Discontinuous bi-segmented model. Maize grain yield, t/ha.

Cultivar	$\hat{\beta}0$	$\hat{\beta}1$	$\hat{\beta}2$	$\hat{\beta}3$
1	5.721	1.164	-0.547	0.389
2	5.731	1.399*	-0.190	-0.775
3	5.175	1.179	0.059	-0.446
4	5.791	1.275*	-0.061	-0.434
5	5.401	1.087	-0.138	0.561
6	5.192	0.824	0.382	-0.041
7	5.498	1.232	-0.057	-0.012
8	4.903	0.986	0.053	-0.120
9	4.505	0.964	-0.196	0.858*

Continued

Table V - Continued.

Cultivar	$\hat{\beta}0$	$\hat{\beta}1$	$\hat{\beta}2$	$\hat{\beta}3$
10	5.737	1.167	-0.300	-0.017
11	5.983	1.239	-0.085	-0.502
12	5.470	0.972	-0.062	0.138
13	5.398	1.210	-0.016	-0.180
14	4.321	0.869	-0.061	0.296
15	5.324	1.070	-0.267	0.070
16	4.243	0.746	0.377	0.418
17	3.998	0.761*	0.067	0.423
18	3.903	0.785	0.423	-0.280
19	4.041	0.807	0.289	-0.253
20	4.034	0.891	-0.026	0.166
21	4.004	0.671*	0.414	0.475
22	3.707	0.683*	0.287	0.295
23	5.023	1.091	-0.190	0.029
24	4.836	1.073	-0.323	0.250
25	5.741	1.267	-0.412	0.265
26	5.950	1.344	-0.127	-0.875
27	5.006	0.807	0.437	0.049
28	5.306	1.084	-0.333	-0.110
29	5.448	1.053	0.027	-0.331
30	4.294	0.979	-0.265	-0.069
31	5.892	1.306	-0.770	-0.533
32	4.722	0.779	0.106	0.067
33	5.506	1.102	-0.060	-0.463
34	5.123	1.123	0.025	-0.297
35	4.847	1.030	0.302	-0.168
36	5.074	1.008	0.166	0.470
37	5.107	0.826	0.339	0.509
38	5.142	0.756*	0.424*	0.213
39	4.995	0.923	0.020	-0.024
40	5.386	0.772	0.131	-0.444
41	4.692	0.880	0.269	-0.089
42	5.072	0.811	-0.112	0.522
Mean	5.030	1.000	0.000	0.000
St. Dev.	0.622	0.196	0.280	0.385

* - Significant at $\alpha \leq 5\%$ (unilateral).

Table VI - *t* statistics for tests of hypothesis on parameters of the discontinuous bi-segmented model: coefficient of determination in %. Uncorrected analysis.

Cultivar	$t_{\beta 1}$	$t_{\beta 2}$	$t_{\beta 3}$	R^2(%)
1	0.820	-1.779	0.766	91.93
2	2.012*	-0.624	-1.541	93.48
3	1.381	0.296	-1.360	96.97
4	1.965*	-0.282	-1.222	96.72
5	0.520	-0.540	1.326	95.58
6	-1.256	1.775	-0.116	95.77
7	1.384	-0.222	-0.029	95.82
8	-0.127	0.314	-0.430	97.26
9	-0.303	-1.081	2.870*	97.45
10	0.550	-0.644	-0.022	83.53
11	1.452	-0.335	-1.201	95.01
12	-0.135	-0.196	0.265	90.96
13	1.161	-0.058	-0.392	94.80
14	-0.648	-0.198	0.578	90.09
15	0.562	-1.406	0.222	96.42
16	-0.868	0.842	0.566	84.93
17	-1.790*	0.326	1.248	95.28
18	-0.888	1.139	-0.457	86.67
19	-1.093	1.072	-0.569	91.87
20	-0.702	-0.110	0.421	93.97
21	-1.935*	1.590	1.104	93.89
22	-1.867*	1.101	0.687	92.56
23	0.803	-1.094	0.101	97.25
24	0.397	-1.148	0.540	92.81
25	1.410	-1.416	0.553	94.17
26	1.582	-0.380	-1.589	91.64
27	-0.901	1.334	0.091	91.27
28	0.290	-0.751	-0.151	81.29
29	0.250	0.084	-0.620	90.68
30	-0.076	-0.648	-0.102	81.49
31	0.965	-1.580	-0.663	75.90
32	-1.273	0.398	0.152	91.41

Continued

Table VI - Continued.

Cultivar	$t_{\beta 1}$	$t_{\beta 2}$	$t_{\beta 3}$	R^2(%)
33	0.382	-0.146	-0.686	85.27
34	0.776	0.104	-0.736	95.20
35	0.198	1.285	-0.432	96.06
36	0.055	0.756	1.299	96.95
37	-1.194	1.518	1.380	96.35
38	-1.932*	2.190*	0.668	96.67
39	-0.333	0.056	-0.042	87.76
40	-1.381	0.517	-1.063	89.69
41	-0.650	0.950	-0.189	92.72
42	-1.115	-0.430	1.215	92.47
Mean	-0.037	0.061	0.058	92.10

* - Significant at $\alpha \leq 5\%$ (unilateral).

Table VII - Estimates of parameters with correction for error of independent variables. Discontinuous bi-segmented model. Maize grain yield, t/ha.

Cultivar	$\hat{\beta}0$	$\hat{\beta}1$	$\hat{\beta}2$	$\hat{\beta}3$
1	5.724	1.167	-0.557	0.396
2	5.739	1.405*	-0.192	-0.789
3	5.179	1.182	0.061	-0.457
4	5.797	1.280*	-0.061	-0.446
5	5.402	1.088	-0.141	0.561
6	5.188	0.821	0.389	-0.043
7	5.503	1.235	-0.057	-0.022
8	4.903	0.986	0.054	-0.121
9	4.504	0.964	-0.200	0.865*
10	5.740	1.169	-0.305	-0.017
11	5.988	1.243	-0.085	-0.511
12	5.469	0.972	-0.063	0.141

Continued

Table VII - Continued.

Cultivar	$\hat{\beta}0$	$\hat{\beta}1$	$\hat{\beta}2$	$\hat{\beta}3$
13	5.402	1.213	-0.015	-0.190
14	4.319	0.867	-0.063	0.304
15	5.326	1.071	-0.272	0.074
16	4.238	0.743	0.384	0.420
17	3.993	0.757*	0.067	0.433
18	3.899	0.782	0.431	-0.282
19	4.037	0.805	0.294	-0.252
20	4.031	0.889	-0.027	0.172
21	3.997	0.666*	0.421	0.479
22	3.700	0.678*	0.291	0.303
23	5.024	1.092	-0.193	0.030
24	4.838	1.074	-0.329	0.256
25	5.746	1.272	-0.419	0.264
26	5.958	1.349	-0.128	-0.888
27	5.002	0.805	0.445	0.046
28	5.307	1.085	-0.340	-0.105
29	5.449	1.053	0.028	-0.334
30	4.294	0.979	-0.271	-0.061
31	5.898	1.311	-0.785	-0.526
32	4.717	0.776	0.107	0.074
33	5.508	1.103	-0.060	-0.467
34	5.125	1.125	0.027	-0.304
35	4.847	1.031	0.309	-0.178
36	5.074	1.008	0.169	0.465
37	5.103	0.823	0.345	0.508
38	5.137	0.752*	0.432*	0.213
39	4.993	0.922	0.020	-0.021
40	5.382	0.769	0.132	-0.436
41	4.690	0.878	0.274	-0.090
42	5.068	0.808	-0.115	0.535
Mean	5.030	1.000	0.000	0.000
St. Dev.	0.625	0.199	0.285	0.389

* - Significant at $\alpha \leq 5\%$ (unilateral).

Table VIII - *t* statistics for tests of the hypothesis on parameters of the discontinuous bi-segmented model; coefficient of determination in %. Corrected analysis.

Cultivar	$t_{\beta 1}$	$t_{\beta 2}$	$t_{\beta 3}$	R^2(%)
1	0.820	-1.780	0.771	91.93
2	2.011*	-0.618	-1.550	93.48
3	1.381	0.301	-1.375	96.97
4	1.965*	-0.276	-1.240	96.72
5	0.520	-0.539	1.308	95.58
6	-1.256	1.774	-0.120	95.77
7	1.384	-0.218	-0.052	95.82
8	-0.127	0.314	-0.427	97.26
9	-0.303	-1.085	2.858*	97.45
10	0.550	-0.644	-0.021	83.53
11	1.451	-0.331	-1.209	95.01
12	-0.135	-0.197	0.268	90.96
13	1.161	-0.054	-0.408	94.80
14	-0.648	-0.201	0.587	90.09
15	0.562	-1.407	0.232	96.42
16	-0.868	0.841	0.561	84.93
17	-1.790*	0.321	1.261	95.28
18	-0.888	1.139	-0.454	86.67
19	-1.093	1.071	-0.559	91.87
20	-0.702	-0.113	0.431	93.97
21	-1.935*	1.587	1.100	93.89
22	-1.866*	1.097	0.695	92.56
23	0.803	-1.094	0.103	97.25
24	0.397	-1.150	0.545	92.81
25	1.410	-1.414	0.542	94.17
26	1.582	-0.376	-1.593	91.64
27	-0.901	1.334	0.084	91.27
28	0.290	-0.752	-0.142	81.29
29	0.250	0.085	-0.618	90.68
30	-0.076	-0.650	-0.089	81.49
31	0.965	-1.580	-0.646	75.90
32	-1.273	0.395	0.168	91.41

Continued

Table VIII - Continued.

Cultivar	$t_{\beta 1}$	$t_{\beta 2}$	$t_{\beta 3}$	$R^2(\%)$
33	0.382	-0.145	-0.682	85.27
34	0.776	0.107	-0.744	95.20
35	0.198	1.288	-0.452	96.06
36	0.055	0.758	1.269	96.94
37	-1.194	1.517	1.359	96.35
38	-1.932*	2.188*	0.659	96.67
39	-0.333	0.055	-0.036	87.76
40	-1.381	0.513	-1.032	89.69
41	-0.650	0.949	-0.191	92.72
42	-1.115	-0.435	1.228	92.47
Mean	-0.037	0.061	0.057	92.10

* - Significant at $\alpha \leq 5\%$ (unilateral).

Parameter $\beta 0_i$ of our model does not correspond to the overall mean of cultivar i, $\overline{Y}_{i..}$. However, average $\beta 0_i$ or $\overline{\beta 0}$ is equal to the grand mean $\overline{Y}_{...}$ (Tables II, V and VII). Hence as criteria for selecting or discarding cultivars we should take the set of estimates $\overline{Y}_{i..}$, $\hat{\beta}1_i$, $\hat{\beta}2_i$, $\hat{\beta}3_i$ and deviations from regression $\hat{\sigma}^2_{\delta i}$.

Corrected and uncorrected values of $\beta 1$, $\beta 2$ and $\beta 3$ estimates have the same overall mean, relative to cultivars. Dispersion of β estimates among cultivars, however, was slightly greater with correction, as shown by corresponding standard deviations (St. Dev.) at the bottom of Tables V and VII. This will tend to facilitate discrimination among cultivars.

Ratios between estimates of parameters obtained without (Table V) and with corrections (Table VII) are given in Table X as percentages. On the average, no bias was observed for $\hat{\beta}0$ and $\hat{\beta}1$. Only $\hat{\beta}2$ and $\hat{\beta}3$ were slightly underestimated without corrections (1.58% and 1.76%, respectively). Ranges and standard deviations of these ratios indicate high consistence of $\beta 1$ and $\beta 2$ estimates but a relative instability of $\hat{\beta}3$ (range 54.5% to 114.3% and St. Dev. = 8.1%).

Ratios in percentage of *t* statistics involving parameter estimates $\hat{\beta}1$, $\hat{\beta}2$ and $\hat{\beta}3$ (Tables VI and VIII) are summarized in Table XI. As can be seen, computations with or without corrections lead to similar conclusions, showing indirectly that variances of these estimates were also not strongly affected by the correcting procedure. This is reinforced through the magnitude of the coefficient of determination obtained (Tables VI and VIII), their corresponding ratios (Table XI) in percentage, and the average values of R^2 = 92.10% for both cases.

Table IX - Overall mean and means for negative (NM) and positive (PM) environments. Maize grain yield, t/ha.

Cultivar	Ov. Mean	NM	PM
1	5.543	4.137	6.949
2	5.214	3.827	6.601
3	4.992	3.571	6.412
4	5.533	4.056	7.010
5	5.587	3.922	7.252
6	5.432	4.071	6.792
7	5.453	3.822	7.084
8	4.880	3.562	6.197
9	4.801	3.193	6.408
10	5.524	4.149	6.899
11	5.675	4.297	7.053
12	5.497	4.147	6.847
13	5.297	3.752	6.843
14	4.428	3.139	5.716
15	5.177	3.869	6.486
16	4.709	3.228	6.191
17	4.255	2.963	5.547
18	4.051	2.835	5.267
19	4.112	2.943	5.281
20	4.099	2.821	5.376
21	4.523	3.090	5.955
22	4.049	2.777	5.321
23	4.908	3.538	6.277
24	4.742	3.377	6.107
25	5.593	4.016	7.170
26	5.427	4.122	6.732
27	5.328	3.907	6.748

Continued

Table IX - Continued.

Cultivar	Ov. Mean	NM	PM
28	5.024	3.831	6.217
29	5.301	4.015	6.586
30	4.079	2.961	5.196
31	5.101	4.114	6.088
32	4.827	3.661	5.993
33	5.234	4.007	6.461
34	4.991	3.594	6.389
35	4.969	3.445	6.492
36	5.422	3.703	7.141
37	5.592	3.983	7.201
38	5.537	4.113	6.961
39	4.996	3.739	6.253
40	5.253	4.336	6.171
41	4.831	3.495	6.167
42	5.257	3.969	6.545
Mean	5.030	3.669	6.390

Table X - Ratios in % between uncorrected and corrected estimates of parameters of the discontinuous bi-segmented model.

Cultivar	$\hat{\beta}0$	$\hat{\beta}1$	$\hat{\beta}2$	$\hat{\beta}3$
1	99.95	99.74	98.20	98.23
2	99.86	99.57	98.96	98.23
3	99.92	99.75	96.72	97.59
4	99.90	99.61	100.00	97.31
5	99.98	99.91	97.87	100.00
6	100.08	100.36	98.20	95.35
7	99.91	99.76	100.00	54.54
8	100.00	100.00	98.15	99.17
9	100.02	100.00	98.00	99.19
10	99.95	99.83	98.36	100.00

Continued

Table X - Continued.

Cultivar	$\hat{\beta}0$	$\hat{\beta}1$	$\hat{\beta}2$	$\hat{\beta}3$
11	99.92	99.68	100.00	98.24
12	100.02	100.00	98.41	97.87
13	99.93	99.75	106.67	94.74
14	100.05	100.23	96.82	97.37
15	99.96	99.91	98.16	94.59
16	100.12	100.40	98.18	99.52
17	100.12	100.53	100.00	97.69
18	100.10	100.38	98.14	99.29
19	100.10	100.25	98.30	100.40
20	100.07	100.22	96.29	96.51
21	100.17	100.75	98.34	99.16
22	100.19	100.74	98.62	97.36
23	99.98	99.91	98.45	96.67
24	99.96	99.91	98.17	97.65
25	99.91	99.61	98.33	100.38
26	99.87	99.63	99.22	98.53
27	100.08	100.25	98.20	106.52
28	99.98	99.91	97.94	104.76
29	99.98	100.00	96.43	99.10
30	100.00	100.00	97.79	113.11
31	99.90	99.62	98.09	101.33
32	100.11	100.39	99.06	90.54
33	99.96	99.91	100.00	99.14
34	99.96	99.82	92.59	97.69
35	100.00	99.90	97.73	94.38
36	100.00	100.00	98.22	101.07
37	100.08	100.36	98.26	100.20
38	100.10	100.53	98.15	100.00
39	100.04	100.11	100.00	114.29
40	100.07	100.39	99.24	101.83
41	100.04	100.23	98.17	98.89
42	100.08	100.37	97.39	97.57
Mean	100.01	100.05	98.42	98.24
St. Dev.	0.08	0.32	1.82	8.08

Table XI - Ratios in % between *t* statistics and R^2 values, (uncorrected)/(corrected) values.

Cultivar	$t_{\beta 1}$	$t_{\beta 2}$	$t_{\beta 3}$	R^2(%)
1	100.00	99.94	99.35	100.00
2	100.05	100.97	99.42	100.00
3	100.00	98.34	98.91	100.00
4	100.00	102.17	98.55	100.00
5	100.00	100.18	101.37	100.00
6	100.00	100.06	96.67	100.00
7	100.00	101.83	55.77	100.00
8	100.00	100.00	100.70	100.00
9	100.00	99.63	100.42	100.00
10	100.00	100.00	104.76	100.00
11	100.07	101.21	99.34	100.00
12	100.00	99.49	98.88	100.00
13	100.00	107.41	96.08	100.00
14	100.00	98.51	98.47	100.00
15	100.00	99.93	95.69	100.00
16	100.00	100.12	100.89	100.00
17	100.00	101.56	98.97	100.00
18	100.00	100.00	100.66	100.00
19	100.00	100.09	101.79	100.00
20	100.00	97.34	97.68	100.00
21	100.00	100.19	100.36	100.00
22	100.05	100.36	98.85	100.00
23	100.00	100.00	98.06	100.00
24	100.00	99.83	99.08	100.00
25	100.00	100.14	102.03	100.00
26	100.00	101.06	99.75	100.00
27	100.00	100.00	108.33	100.00
28	100.00	99.87	106.34	100.00
29	100.00	98.82	100.32	100.00
30	100.00	99.69	114.61	100.00
31	100.00	100.00	102.63	100.00
32	100.00	100.76	90.47	100.00
33	100.00	100.69	100.59	100.00

Continued

Table XI - Continued.

Cultivar	$t_{\beta 1}$	$t_{\beta 2}$	$t_{\beta 3}$	R^2(%)
34	100.00	97.20	98.92	100.00
35	100.00	99.77	95.57	100.00
36	100.00	99.74	102.36	100.01
37	100.00	100.07	101.54	100.00
38	100.00	100.09	101.36	100.00
39	100.00	101.82	116.67	100.00
40	100.00	100.78	103.00	100.00
41	100.00	100.10	98.95	100.00
42	100.00	98.85	98.94	100.00
Mean	100.00	100.21	99.60	100.00
St. Dev.	0.015	1.53	8.25	0.002

The discontinuous bi-segmented model adopted here (BSD) efficiently explained most yield variation of the cultivars. For comparison we obtained the following R^2 values with Eberhard and Russell's (1966) (ER) and Cruz *et al.* (1989) (CTV) models

	R^2 (%), models		
	ER	CTV	BSD
Average	91.12%	91.52%	92.10%
Standard deviation	5.59%	5.48%	5.03%
Maximum	97.20%	97.25%	97.45%
	(cult. 8)	(cult. 8)	(cult. 3)
Minimum	69.38%	70.64%	75.90%
	(cult. 31)	(cult. 31)	(cult. 31)

Average R^2 and the corresponding standard deviation suggest a slight advantage of the BSD model over the other two. This advantage was more evident for cultivars with less predictable yield variation (such as cultivar 31).

Estimates of variances of deviations from the model ($\hat{\sigma}^2_{\delta i}$), and related quantities without (Table XII) and with correction (Table XIII) and corresponding ratios in percentage (Table XIV), clearly show that the uncorrected analysis underestimated this variance ($\hat{\sigma}^2_{\delta i}$), the number of degrees of freedom of the estimate (*f*o) and *F* statistics under Ho: $\sigma^2_{\delta i} = 0$.

Table XII - Estimates of $\hat{\sigma}^2_{\delta i}$, corresponding standard deviation (SD), number of degrees of freedom (*f*o), 95% confidence interval (CI), and *F* statistics under Ho:$\sigma^2_{\delta i}$ = 0. Uncorrected analysis.

Cult.	$\hat{\sigma}^2_{\delta i}$	SD	*f*o	CI	gl	F(gl;n5)#
1	0.2391	0.1348	75	0.1778 ; 0.3387	129	$4.18^{(0)}$
2	0.2332	0.1325	74	0.1731 ; 0.3318	129	$4.10^{(0)}$
3	0.0470	0.0565	16	0.0261 ; 0.1088	106	$1.63^{(0)}$
4	0.0705	0.0661	27	0.0441 ; 0.1307	113	$1.94^{(0)}$
5	0.1386	0.0939	52	0.0977 ; 0.2127	123	$2.84^{(0)}$
6	0.0710	0.0663	27	0.0444 ; 0.1316	113	$1.94^{(0)}$
7	0.1397	0.0943	52	0.0984 ; 0.2144	122	$2.86^{(0)}$
8	0.0084	0.0408	1	0.0017 ; 0.8400	95	$1.11^{(22)}$
9	0.0235	0.0470	6	0.0098 ; 0.1138	103	$1.31^{(2)}$
10	0.6655	0.3089	111	0.5200 ; 0.8822	137	$9.85^{(0)}$
11	0.1324	0.0913	50	0.0927 ; 0.2046	122	$2.76^{(0)}$
12	0.2565	0.1420	78	0.1918 ; 0.3602	130	$4.41^{(0)}$
13	0.1782	0.1100	62	0.1290 ; 0.2623	125	$3.37^{(0)}$
14	0.2455	0.1375	76	0.1829 ; 0.3470	129	$4.27^{(0)}$
15	0.0350	0.0517	11	0.0176 ; 0.1009	106	$1.47^{(0)}$
16	0.6097	0.2861	109	0.4793 ; 0.8106	137	$9.11^{(0)}$
17	0.0560	0.0602	21	0.0331 ; 0.1143	113	$1.74^{(0)}$
18	0.3907	0.1967	94	0.2993 ; 0.5318	133	$6.20^{(0)}$
19	0.1635	0.1040	59	0.1175 ; 0.2433	125	$3.18^{(0)}$
20	0.1076	0.0812	42	0.0732 ; 0.1739	120	$2.43^{(0)}$
21	0.1461	0.0969	54	0.1036 ; 0.2218	123	$2.94^{(0)}$
22	0.1462	0.0970	54	0.1036 ; 0.2220	123	$2.95^{(0)}$
23	0.0144	0.0433	3	0.0046 ; 0.1968	111	$1.19^{(0)}$
24	0.1846	0.1126	64	0.1342 ; 0.2699	126	$3.46^{(0)}$
25	0.2054	0.1211	69	0.1510 ; 0.2952	128	$3.73^{(0)}$

Continued

Table XII - Continued.

Cult.	$\hat{\sigma}^2_{\delta i}$	SD	*f*o	CI	g1	F(g1;n5)#
26	0.2973	0.1586	84	0.2245 ; 0.4126	131	4.96(0)
27	0.2838	0.1531	82	0.2136 ; 0.3955	131	4.78(0)
28	0.5967	0.2808	108	0.4648 ; 0.7942	137	8.94(0)
29	0.2740	0.1491	81	0.2059 ; 0.3826	131	4.64(0)
30	0.4953	0.2394	102	0.3832 ; 0.6654	135	7.59(0)
31	0.7390	0.3389	114	0.5792 ; 0.9757	138	10.83(0)
32	0.1556	0.1008	57	0.1112 ; 0.2332	125	3.07(0)
33	0.4943	0.2390	102	0.3824 ; 0.6640	135	7.58(0)
34	0.1175	0.0853	45	0.0809 ; 0.1865	120	2.56(0)
35	0.1025	0.0792	40	0.0691 ; 0.1679	119	2.36(0)
36	0.0770	0.0688	30	0.0492 ; 0.1376	115	2.02(0)
37	0.0835	0.0714	32	0.0540 ; 0.1461	114	2.11(0)
38	0.0399	0.0537	13	0.0210 ; 0.1036	105	1.53(0)
39	0.3471	0.1790	90	0.2645 ; 0.4759	133	5.62(0)
40	0.1325	0.0914	50	0.0928 ; 0.2048	122	2.76(0)
41	0.1899	0.1148	65	0.1384 ; 0.2769	126	3.53(0)
42	0.1459	0.0968	54	0.1034 ; 0.2214	123	2.94(0)
Mean	0.2162	0.1255	58		123	3.88

- Significant at (%) level with g1 and n5 = 1968 degrees of freedom.

Table XIII - Estimates of $\sigma^2_{\delta i}$, corresponding standard deviation (SD), number of degrees of freedom (*f*o), 95% confidence interval (CI), and *F* statistics under Ho:$\sigma^2_{\delta i}$ = 0. Corrected analysis.

Cult.	$\hat{\sigma}^2_{\delta i}$	SD	*f*o	CI	g1	F(g1; n5)#
1	0.2542	0.1350	84	0.1919 ; 0.3527	140	4.38(0)
2	0.2481	0.1327	83	0.1871 ; 0.3450	140	4.30(0)
3	0.0628	0.0568	29	0.0399 ; 0.1136	137	1.84(0)
4	0.0861	0.0664	40	0.0580 ; 0.1410	138	2.15(0)
5	0.1551	0.0940	64	0.1128 ; 0.2268	140	3.06(0)
6	0.0870	0.0664	40	0.0586 ; 0.1424	137	2.16(0)
7	0.1556	0.0945	64	0.1132 ; 0.2275	140	3.07(0)

Continued

Table XIII - Continued.

Cult.	$\hat{\sigma}^2_{\delta i}$	SD	*fo*	C1	g1	F(g1; n5)#
8	0.0250	0.0410	9	0.0118 ; 0.0833	139	$1.33^{(1)}$
9	0.0396	0.0471	16	0.0220 ; 0.0918	130	$1.53^{(0)}$
10	0.6817	0.3089	116	0.5354 ; 0.8977	143	$10.07^{(0)}$
11	0.1484	0.0915	62	0.1074 ; 0.2184	140	$2.97^{(0)}$
12	0.2730	0.1420	88	0.2074 ; 0.3757	143	$4.63^{(0)}$
13	0.1941	0.1101	74	0.1441 ; 0.2758	142	$3.58^{(0)}$
14	0.2616	0.1375	86	0.1982 ; 0.3616	142	$4.48^{(0)}$
15	0.0513	0.0519	23	0.0310 ; 0.1009	136	$1.68^{(0)}$
16	0.6256	0.2861	114	0.4904 ; 0.8260	143	$9.32^{(0)}$
17	0.0718	0.0602	33	0.0467 ; 0.1245	136	$1.96^{(0)}$
18	0.4065	0.1967	102	0.3145 ; 0.5461	143	$6.41^{(0)}$
19	0.1797	0.1041	71	0.1327 ; 0.2574	142	$3.39^{(0)}$
20	0.1240	0.0813	55	0.0881 ; 0.1874	140	$2.65^{(0)}$
21	0.1618	0.0970	66	0.1182 ; 0.2351	141	$3.15^{(0)}$
22	0.1620	0.0970	66	0.1183 ; 0.2354	140	$3.15^{(0)}$
23	0.0309	0.0435	12	0.0159 ; 0.0842	137	$1.41^{(0)}$
24	0.2006	0.1127	75	0.1492 ; 0.2842	141	$3.67^{(0)}$
25	0.2212	0.1213	79	0.1657 ; 0.3103	141	$3.94^{(0)}$
26	0.3126	0.1588	92	0.2388 ; 0.4269	141	$5.16^{(0)}$
27	0.2996	0.1531	91	0.2285 ; 0.4099	142	$4.99^{(0)}$
28	0.6127	0.2809	113	0.4798 ; 0.8102	142	$9.15^{(0)}$
29	0.2905	0.1491	90	0.2213 ; 0.3982	142	$4.86^{(0)}$
30	0.5112	0.2395	108	0.3982 ; 0.6805	142	$7.80^{(0)}$
31	0.7530	0.3390	117	0.5939 ; 0.9904	141	$11.02^{(0)}$
32	0.1716	0.1008	68	0.1259 ; 0.2478	140	$3.28^{(0)}$
33	0.5108	0.2391	109	0.3983 ; 0.6791	143	$7.80^{(0)}$
34	0.1338	0.0854	58	0.0959 ; 0.1999	140	$2.78^{(0)}$
35	0.1182	0.0793	52	0.0833 ; 0.1814	138	$2.57^{(0)}$
36	0.0934	0.0689	43	0.0637 ; 0.1498	138	$2.24^{(0)}$
37	0.0996	0.0715	46	0.0688 ; 0.1572	140	$2.33^{(0)}$
38	0.0558	0.0537	25	0.0343 ; 0.1063	135	$1.74^{(0)}$
39	0.3637	0.1790	98	0.2800 ; 0.4915	142	$5.84^{(0)}$
40	0.1486	0.0914	62	0.1076 ; 0.2187	139	$2.98^{(0)}$
41	0.2062	0.1148	76	0.1537 ; 0.2915	141	$3.74^{(0)}$
42	0.1614	0.0969	65	0.1176 ; 0.2353	139	$3.15^{(0)}$
Mean	0.2322	0.1256	68		140	4.09

- Significant at (%) level with g1 and n5 = 1968 degrees of freedom.

Table XIV - Ratios in % between uncorrected and corrected estimates of $\sigma^2_{\delta i}$, corresponding standard deviation (SD) number of degrees of freedom (*fo*) and *F* statistics under Ho: $\sigma^2_{\delta i} = 0$.

Cultivar	$\hat{\sigma}^2_{\delta i}$	SD	*fo*	*F*
1	94.06	99.85	89.28	95.43
2	93.99	99.85	89.16	95.35
3	74.84	99.47	55.17	88.59
4	81.88	99.55	67.50	90.23
5	89.36	99.89	81.25	92.81
6	81.61	99.85	67.50	89.81
7	89.78	99.79	81.25	93.16
8	33.60	99.51	11.11	83.46
9	59.34	99.79	37.50	85.62
10	97.62	100.00	95.69	97.81
11	89.22	99.78	80.64	92.93
12	93.96	100.00	88.64	95.25
13	91.81	99.91	83.78	94.13
14	93.84	100.00	88.37	95.31
15	68.23	99.61	47.83	87.50
16	97.46	100.00	95.61	97.75
17	77.99	100.00	63.64	88.77
18	96.11	100.00	92.16	96.72
19	90.98	99.90	83.10	93.80
20	86.77	99.88	76.36	91.70
21	90.30	99.89	81.82	93.33
22	90.25	100.00	81.82	93.65
23	46.60	99.54	25.00	84.39
24	92.02	99.91	85.33	94.28
25	92.86	99.83	87.34	94.67
26	95.11	99.87	91.30	96.12
27	94.73	100.00	90.11	95.79
28	97.39	99.96	95.57	97.70
29	94.32	100.00	90.00	95.47
30	96.89	99.95	94.44	97.31
31	98.14	99.97	97.44	98.28

Continued

Table XIV - Continued.

Cultivar	$\hat{\sigma}^2_{\delta i}$	SD	*fo*	*F*
32	90.68	100.00	83.82	93.59
33	96.77	99.96	93.58	97.18
34	87.82	99.88	77.58	92.09
35	86.72	99.87	76.92	91.83
36	82.44	99.85	69.77	90.18
37	83.83	99.86	69.56	90.56
38	71.51	100.00	52.00	87.93
39	95.44	100.00	91.84	96.23
40	89.16	100.00	80.64	92.62
41	92.09	100.00	85.53	94.38
42	90.39	99.90	83.08	93.33
Mean	86.62	99.88	77.62	93.03
St. Dev.	13.54	0.14	19.20	3.69

In the special case of cultivar 8 the corrected procedure led to a change in decision about Ho: $\sigma^2_{\delta i} = 0$, with $\alpha \leq 1\%$ against the uncorrected $\alpha \leq 22\%$ level. We have rejected this hypothesis for cultivars 8 and 9, despite their high R^2 values (97%). This sensitivity derives from the fact that estimator

$$\hat{\sigma}^2_{\delta i} = (TSS - MSS)/(J - 4) - \underset{\sim}{\hat{\beta}}i' \, S(\upsilon\upsilon) \, \underset{\sim}{\hat{\beta}}i + 2 \, S(\upsilon\varepsilon) \, \underset{\sim}{\hat{\beta}}i - \hat{\sigma}^2_{\varepsilon}$$

(total TSS and regression MSS sum squares) is corrected for error on the dependent (σ^2_ε) and independent (σ^2_υ) variables and its covariances. On the other hand, for R^2 = MSS/TSS, the sum of squares due to parameters (MSS) is corrected while the total (TSS) is not. In the usual analytical procedure, both MSS and TSS are uncorrected.

For selecting among cultivars, when all F values for testing Ho: $\sigma^2_{\delta i} = 0$ are significant, as in this example, an alternative procedure is to consider those with the smallest value of the upper limit of the confidence interval for $\sigma^2_{\delta i}$.

Storck's approach (1989) for identifications of agronomically desirable cultivars could be applied with additional information given by Table IX. The following cultivars and corresponding classes were identified: cultivar 4 of the class S5 ($Y_{i..} > Y_{...}$

and $\hat{\sigma}^2_{\delta i} < \hat{\sigma}^2_{\delta .}$); 9 of class S3 ($\overline{Y}^+_{i..} > \overline{Y}^+_{...}$ and $\hat{\sigma}^2_{\delta i} < \hat{\sigma}^2_{\delta .}$) and 38 of class S4 ($\overline{Y}^-_{i..} > \overline{Y}^-_{...}$ and $\hat{\sigma}^2_{\delta i} < \hat{\sigma}^2_{\delta .}$). With the same approach for discarding cultivars, we identify cultivars 17, 21 and 22, all belonging to class D6 ($\overline{Y}_{i..} < \overline{Y}_{...}$ and any $\hat{\sigma}^2_{\delta i}$).

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RESUMO

Um grupo de 42 cultivares de milho foi avaliado em 16 locais do Estado do Rio Grande do Sul. Dados de rendimento de grãos foram submetidos a uma análise da variância conjunta e uma análise de estabilidade segundo o modelo de regressão bi-segmentado descontínuo, com e sem o uso das correções para compensar os erros das variáveis independentes e da covariância entre os erros das variáveis independentes e dependentes. Resultados indicaram que o efeito da correção sobre as estimativas dos parâmetros angulares e de descontinuidades são desprezíveis. Ignorando-se a correção, no entanto, resultou em uma razoável subestimação (média de 14%) sobre a variância dos desvios do modelo. A importância do procedimento de correção na análise de estabilidade aumenta com a redução do número de tratamentos ou de repetições.

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