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REVISED DOCUMENT ON ANALYZING VISUALLY OBSERVED DATA IN TWO GRASS SPECIES

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Analysing visually observed data in Dactylus and Festuca

1. Introduction

At the XIV-th meeting of the TWC in Hannover threshold models were introduced as a means to analyse visually observed data. In TWC/14/12 a brief exposition of theory was given together with two examples. Those examples did not cover routine application of threshold models to assess distinctness and uniformity. In this paper experiences with threshold models are reported for the analysis of the character which is called alternativité in French for the grasses cocksfoot (Dactylus) and tall fescue (Festuca élevé). Special attention is given to checking the assumption of uni-modality for the threshold model. To comply with this assumption observed categories may have to be combined. An alternative to the threshold model that is close to a standard COY-D is presented, and was found to be useful as a conservative, i.e., less powerful, approximation.

2. Summary of theory and assumptions

As explained in TWC/14/12 the key idea of a threshold model is that the observed category scores, y_i, for a treatment (variety) i are the expression of a continuous underlying variable, U_i, that cannot be observed and that follows a certain distribution like the normal or the logistic. The underlying variable U_i determines the category in which observations on the treatment can lie. The categories 1 to C are separated by so-called cut points or thresholds: θ_1 to θ_{C-1}. If the underlying variable lies in the interval before the first threshold, θ_1, the observation belongs to the lowest category 1, if the underlying variable lies in the interval θ_{c-1} till θ_c, the observation belongs to category c (c = 2...C-1), and finally above the last threshold, θ_{C-1}, the observation belongs to the highest category C. The underlying variable U_i is a theoretical construct that allows us to model the observed category scores. A popular type of threshold model is the so-called proportional odds model. This model has the form $\log(\gamma_{ic} / (1-\gamma_{ic})) = \theta_c - \sum \beta_j x_{ij}$, where γ_{ic} is the probability that the observation lies in one of the categories 1 to c. The distribution of γ_{ic} can be obtained from the multinomial. The parameter β_j stands for the regression coefficient to the explanatory variable x_j (varieties in our case). An important assumption to be fullfilled for threshold models is that the underlying variable is uni-modal. Roughly said this means that a histogram of the numbers of observations in the different categories (for a particular variety) should have more observations in the middle categories than in the extreme categories. When this is not the case categories may be combined to see whether this solves the problem of multi-modality. For the application of the proportional odds form of the threshold model it is also necessary that the difference between treatments (varieties) on the log-odds scale, $\log(\gamma_{ic}/(1-\gamma_{ic}))$, is independent of the category c.

3. Dactylus and Festuca data description and rearrangement

Analysed were data from Dactylus and Festuca, covering the years 1995 to 1997. Per year a trial in three replicates was done, where each replicate contained 20 individual plants. Category scores were given to individual plants. The totals of observed category scores over years and replicates per variety are given for Dactylis in Table 1 and for Festuca in Table 7. Looking at these tables clearly the assumption of uni-modality is not fulfilled for neither of both species. For Dactylis most observations occurred in the extreme categories of 2 and 8, with some observations in between. For Festuca most observations occurred in the categories 2 and 6 with a dip in the categories 3 and 4. For both sets of data rearrangement of categories was a prerequisite for application of a threshold model.

For Dactylis category 2 became one category and all other categories were combined to form a second category (Table 2). Effectively, the character alternativité becomes a binary trait, either category 2 is observed or a higher category. After this rearrangement a threshold model would again be feasible. The threshold model gets a very simple structure with only two categories. The unique threshold $\square$ is automatically fixed at 0 and does not need to be estimated. The proportional odds model becomes a standard general linear model with logit link and binomial distribution, a form known under the name of logistic regression: $\log(\gamma_{ic} / (1 - \gamma_{ic})) = \sum \beta_j x_{ij}$ (McCullagh and Nelder, 1989).

For Festuca three categories could be formed by combining categories 1 and 2 to a new category 1, fusing 3, 4 and 6 to a new category 2, while category 8 became the new category 3 (Table 8). Because after rearrangement so few categories remained, the possibility for testing simultaneously distinctness and uniformity was discarded. Testing of differences in uniformity, differences in width of the underlying dsitributions, makes only sense when more than 3 categories are retained.

4. Analysis of variance and threshold model

As discussed in TWC/14/12, for the analysis of visually observed data threshold models would be the most appropriate models. Thus, the Dactylis and Festuca data were analysed with threshold models. After presentation of TWC/14/12 questions arose to simpler alternatives to the threshold model. One alternative to the application of threshold models was investigated. First acknowledge that the proportional odds model can be interpreted as a series of logistic regressions for the cumulative category probabilities, γ_{ic}, for c=1...C-1. As there were only two categories for Dactylis, the threshold model was equivalent to a logistic regression. For Festuca the proportional odds model could be approximated by logistic regressions for γ_{i1} and γ_{i2}. Next, an approximation to a logistic regression is ordinary regression on the logit transformed cumulative category counts, $\log(y_{ic} / (\square y_{ic} - y_{ic})$, which is equivalent to an analysis of variance for our type of data. The residuals of the logistic regressions for γ_{i1} and γ_{i2} , and to a lesser degree the residuals of the corresponding regressions on the logit transforms, can be used as checks for the threshold model.

Thus results obtained by applying threshold models may be compared to those of analysis of variance on logit transformed cumulative category counts. For calculating pairwise differences following standard COY-D practices, the Variety by Year interaction mean square serves as the basis for the calculation of a standard error of difference between varieties. For generalized linear models, including threshold models, the equivalents of mean squares and sums of squares are so-called mean deviances and deviances. The latter may be treated as if they were mean squares and sums of squares. Therefore, for assessing distinctness in threshold models, the Variety by Year mean deviance was used to calculate the standard errors of differences. In contrast to the standard COY-D, in threshold models every comparison has its own standard error.

For Dactylis distinctness was assessed by a logistic regression model, after which all pairwise differences were calculated. For comparison a classical COY-D procedure was followed for transformed category counts. Both types of comparison were done at $p<0.01$.

For Festuca various threshold models were fitted and pairwise comparisons were made. For comparison COY-D was applied to the logits of the cumulative category counts for the classes 1 and 2.

5. Results Dactylis

In Table 3 it is shown how many times distinctness was assessed for each variety using the different methods. As can be seen the results of COY-D (AOV) and the threshold model were in good agreement. Every variety could be identified as being distinct from at least 6 others by COY-D. For the threshold model this figure was 8. The analyses of variance and deviance are given in Tables 4 and 5. As can be seen both types of analysis indicate the presence of Variety by Year interaction. This interaction may be tried to be reduced by Modified Joint Regression to achieve a more powerful test on distinctness. The analysis of deviance table for the threshold model allows the same kind of inference as the analysis of variance table in the application of COY-D. Table 6 shows in detail all incidences of distinctness as assessed by the threshold model.

6. Results Festuca

A first threshold model was fitted to the Variety by Year table of category counts (Table 9). The Variety by Year interaction mean deviance then was used to calculate standard errors of differences at $p<0.01$. Results per variety for the threshold model can be found in Table 10 (TM), at least 7 varieties were found to be distinct from each individual variety. The results of the COY-D procedures on the cumulative logit transforms can be seen in Table 10 in the columns AOV1, AOV2 and AOV1-2. The last column is of special interest as its shows the consistency of the two COY-D’s, only distinctnesses which were distinct for both cumulative logits at $p<0.001$ are present in the counts of the column AOV1-2. The disctinctnesses of the simultaneous COY-D at $p<0.001$ were almost completely contained in those of the threshold model at $p<0.01$ (AOV-TM, Table 10). The simultaneous COY-D behaved like a conservative approximation to the threshold model, because the threshold model allowed 802 pairwise comparisons to be distinct against 476 for the simultaneous COY-D. Nevertheless, the behaviour of the simultaneous COY-D shows that it might be an alternative in cases where software for threshold models is less accessible. Increasing the COY-D p-value led to both more distinctnesses which were shared with the threshold model as to distinctnesses that were only found distinct by the COY-D procedure and not by the threshold model. These latter distinctnesses do not seem to be very trustworthy.

In addition to the use of the logit transforms for the COY-D procedure, these transforms can also be used to check the assumption of constant differences between varieties, i.e., the difference should be independent of the category. To check the assumption one can regress one logit on the other. If the slope does not deviate from 1, the assumption is fulfilled. For the Festuca data the slope measured 1.16 with an 95% confidence interval of +/- 0.19, while the fit was good, $r^2 = 0.64$. Figure 1 shows a graph of the cumulative logit for category 2 against that for 1.

The residuals from the analyses of variance on the cumulative logits are useful to check for anomalies in the data. Suspect observations are likely to cause problems also in the threshold model. Figures 2a and 2b contain half-normal plots of the residuals for the cumulative logits of category 1 and 2. There is one clearly deviating observation in Figure 2a. It was identified as being due to the remarkable behaviour of variety 416530 in 1996 (Table 9). For the remainder, the half-normal plots gave no reason for concern as the residuals behaved as they should for normally distributed observations, namely to lie on a straight line through the origin.

For determining whether Variety by Year interaction was present a threshold model was fitted containing a so-called mixed model for the underlying variable U_i, with as fixed terms Variety, Year and Variety by Year interaction, and as random terms Replicates within Years and Plants within Replicates within Years. The most important result from this exercise was that there appeared to be substantial interaction. To investigate whether the Variety by Year mean deviance might be reduced by modified joint regression the estimated Variety by Year means for the underlying variable U were regressed by ordinary regression on the estimated Variety main effects for each of the years 1995, 1996 and 1997. Results are shown in Figures 3a, b and c and Table 11. There were clear differences between the years, with 1995 reducing differences (slope 0.73), 1996 increasing differences (slope 1.34), and 1997 being more or less average (slope 0.93). Extending threshold models by a formulation for modified joint regression thus seems worthwhile.

7. Conclusions

The application of threshold models to assess distinctness in grasses led to encouraging results. Using a threshold model all varieties of Dactylis and Festuca could be distinguished on the basis of the visually assessed character alternativité. Before application of threshold models the assumption of uni-modality of the underlying response should be checked. It wil often be necessary to combine observation categories to comply with this requirement. Another assumption to be checked for the proportional odds model is whether the difference between varieties is constant over the categories. As an alternative to the threshold model COY-D like procedures can be used on the logits of the cumulative category counts. For this alternative to work, p-values should be smaller than the standard UPOV values and only consistent distinctnesses over the various categories should be taken into account.

Acknowledgement

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Reference

McCullagh, P. & J.A. Nelder (1989) Generalized linear models, 2nd. edn., Chapman and Hall.

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Table 1. Observed category scores for *alternativit* in Dactylis (Cocksfoot).

Number	2	4	6	7	8	Total
423320	157	1	2	0	20	180
426850	147	2	8	0	23	180
508850	173	1	1	0	5	180
516690	170	1	5	0	4	180
517770	123	15	15	0	27	180
520070	135	4	7	0	34	180
520080	159	2	11	0	8	180
521780	165	6	7	0	2	180
530200	125	7	15	0	33	180
559770	153	2	7	0	18	180
566170	132	4	12	0	32	180
581380	161	1	7	0	11	180
599260	132	2	13	0	33	180
609050	148	4	7	0	21	180
620150	170	1	2	0	7	180
620730	171	0	3	0	6	180
655360	1	2	35	0	142	180
655650	162	5	3	0	10	180
655870	168	2	3	0	7	180
655880	151	5	4	0	20	180
667410	174	3	0	0	3	180
678290	167	2	4	0	7	180
678430	117	4	11	1	47	180
678580	150	0	7	0	23	180
678920	117	24	27	0	12	180
903120	140	3	13	0	24	180
903150	143	10	8	0	19	180
1127680	118	5	18	0	39	180
1348090	73	14	22	0	71	180
1371510	148	6	9	0	17	180
Total	4250	138	286	1	725	5400

Table 2. Rearranged category scores for Dactylis.

1	423320	DP 6502	157	23
2	426850	AND 687	147	33
3	508850	LUCYLE	173	7
4	516690	LULLY	170	10
5	517770	DORISE	123	57
6	520070	LUDE	135	45
7	520080	LUTETIA	159	21
8	521780	MODAC	165	15
9	530200	CAMBRIA	125	55
10	559770	ARLY	153	27
11	566170	AMPLY	132	48
12	581380	FURLY	161	19
13	599260	ATHOS	132	48
14	609050	PORTHOS	148	32
15	620150	KID	170	10
16	620730	LUPRE	171	9
17	655360	MATOP	1	179
18	655650	SABORTO	162	18
19	655870	STARLY	168	12
20	655880	ACCORD	151	29
21	667410	BAR DGL 38	174	6
22	678290	MOM DAC 17	167	13
23	678430	87-2	117	63
24	678580	L-DGL 258	150	30
25	678920	K 2 M	117	63
26	903120	FLOREAL	140	40
27	903150	PRAIRIAL	143	37
28	1127680	BARAULA	118	62
29	1348090	MOBITE	73	107
30	1371510	AS 26	148	32

Table 3. Number of Dactylis varieties that were found distinct at p<0.01 from a specific variety by an analysis of variance on logits (AOV) and by a generalized linear model with logit link and binomial distribution (GLM), plus the number of coincidences on distinctness. (* Total is sum column divided by 2).

number	AOV	GLM	Coinc.
423320	10	9	9
426850	6	10	6
508850	17	18	17
516690	14	15	14
517770	14	17	14
520070	13	12	11
520080	15	9	9
521780	10	11	10
530200	14	15	14
559770	7	9	7
566170	13	14	13
581380	12	10	10
599260	14	14	14
609050	8	10	7
620150	15	15	14
620730	14	16	14
655360	29	29	29
655650	8	10	8
655870	12	12	12
655880	6	8	4
667410	17	18	17
678290	11	12	11
678430	15	20	15
678580	6	9	6
678920	16	20	16
903120	11	10	9
903150	10	9	8
1127680	16	20	16
1348090	25	29	25
1371510	8	10	7
Total*	193	210	183

Table 4. Analysis of variance for logit transformed Dactlyis data.

Variate: Alternativit

Source of variation	d.f.	s.s.	m.s.	v.r.
Year.Rep stratum				
Year	2	92.1832	46.0916	36.00
Residual	6	7.6822	1.2804	3.27
year.rep.*Units* stratum				
Cult	29	466.0963	16.0723	41.06
Cult.Year	58	45.5479	0.7853	2.01
Residual	174	68.1044	0.3914	
Total	269	679.6141		

Table 5. Analysis of deviance for generalized linear model with logit link and binomial distribution for Dactlyis data.

*** Accumulated analysis of deviance ***

	d.f.	deviance	mean deviance	deviance ratio
Year	2	195.4658	97.7329	65.65
Year.Rep	6	22.0972	3.6829	2.48
Cult	29	1154.2227	39.8008	26.74
Cult.Year	58	113.1846	1.9515	1.95
Cult.Year.Rep	174	191.7480	1.1020	0.75
Residual	5130	3916.1265	0.7634	
Total	5399	5592.8447	1.0359	

Table 6. Distinctness at p<0.01 for Dactylis. 1 = row number had significantly higher alternativit□than column number, -1 = vice versa, 0 = no significant difference found.

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
423320	*	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0
426850	0	*	-1	-1	0	0	0	0	0	0	0	0	0	0	-1	-1	1	0	0	0	-1	0	1	0	1	0	0	1	1	0
508850	0	1	*	0	1	1	0	0	1	1	1	0	1	1	0	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1
516690	0	1	0	*	1	1	0	0	1	0	1	0	1	1	0	0	1	0	0	0	0	0	1	0	1	1	1	1	1	1
517770	-1	0	-1	-1	*	0	-1	-1	0	-1	0	-1	0	0	-1	-1	1	-1	-1	-1	-1	-1	0	-1	0	0	0	0	1	0
520070	0	0	-1	-1	0	*	0	-1	0	0	0	-1	0	0	-1	-1	1	-1	-1	0	-1	-1	0	0	0	0	0	0	1	0
520080	0	0	0	0	1	0	*	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0
521780	0	0	0	0	1	1	0	*	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	1	0	1	1	0
530200	-1	0	-1	-1	0	0	-1	-1	*	-1	0	-1	0	0	-1	-1	1	-1	-1	0	-1	-1	0	0	0	0	0	0	1	0
559770	0	0	-1	0	1	0	0	0	1	*	0	0	0	0	0	0	1	0	0	0	-1	0	1	0	1	0	0	1	1	0
566170	-1	0	-1	-1	0	0	-1	-1	0	0	*	-1	0	0	-1	-1	1	-1	-1	0	-1	-1	0	0	0	0	0	0	1	0
581380	0	0	0	0	1	1	0	0	1	0	1	*	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0
599260	-1	0	-1	-1	0	0	-1	-1	0	0	0	-1	*	0	-1	-1	1	-1	-1	0	-1	-1	0	0	0	0	0	0	1	0
609050	0	0	-1	-1	0	0	0	0	0	0	0	0	0	*	-1	-1	1	0	0	0	-1	0	1	0	1	0	0	1	1	0
620150	0	1	0	0	1	1	0	0	1	0	1	0	1	1	*	0	1	0	0	0	0	0	1	0	1	1	1	1	1	1
620730	0	1	0	0	1	1	0	0	1	0	1	0	1	1	0	*	1	0	0	0	0	0	1	1	1	1	1	1	1	1
655360	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	*	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
655650	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	1	*	0	0	0	0	1	0	1	0	0	1	1	0
655870	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	1	0	*	0	0	0	1	0	1	1	1	1	1	0
655880	0	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	*	-1	0	1	0	1	0	0	1	1	0
667410	0	1	0	0	1	1	0	0	1	1	1	0	1	1	0	0	1	0	0	1	*	0	1	1	1	1	1	1	1	1
678290	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	*	1	0	1	1	1	1	1	0
678430	-1	-1	-1	-1	0	0	-1	-1	0	-1	0	-1	0	-1	-1	-1	1	-1	-1	-1	-1	-1	*	-1	0	0	0	0	1	-1
678580	0	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	-1	1	0	0	0	-1	0	1	*	1	0	0	1	1	0
678920	-1	-1	-1	-1	0	0	-1	-1	0	-1	0	-1	0	-1	-1	-1	1	-1	-1	-1	-1	-1	0	-1	*	0	0	0	1	-1
903120	0	0	-1	-1	0	0	0	-1	0	0	0	0	0	0	-1	-1	1	0	-1	0	-1	-1	0	0	0	*	0	0	1	0
903150	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	-1	-1	1	0	-1	0	-1	-1	0	0	0	0	*	0	1	0
1127680	-1	-1	-1	-1	0	0	-1	-1	0	-1	0	-1	0	-1	-1	-1	1	-1	-1	-1	-1	-1	0	-1	0	0	0	*	1	-1
1348090	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	*	-1
1371510	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	-1	-1	1	0	0	0	-1	0	1	0	1	0	0	1	1	*

Table 7. Observed category scores for alternativit□ in Festuca.

Number	0	2	3	4	6	8	Total
			Category				
407030	0	55	0	19	65	41	180
411190	0	52	0	16	71	41	180
416520	0	79	0	15	74	12	180
416530	0	61	1	9	83	26	180
416800	0	56	0	9	77	38	180
419770	0	77	0	15	76	12	180
423710	0	54	0	12	70	44	180
423810	0	86	0	16	69	9	180
426950	0	141	0	15	20	4	180
426960	0	113	0	9	47	11	180
512670	0	102	0	12	57	9	180
525950	0	88	0	14	72	6	180
526540	0	130	0	6	37	7	180
533760	0	113	0	16	47	4	180
533940	0	117	0	17	41	5	180
534010	0	47	0	19	84	30	180
538910	0	35	0	10	77	58	180
539130	0	101	0	14	55	10	180
539310	0	20	0	13	88	59	180
548500	0	83	0	17	74	6	180
552610	0	47	0	24	69	40	180
553110	0	73	0	10	92	5	180
559300	0	54	0	9	94	23	180
559340	0	36	0	11	102	31	180
559780	0	104	0	15	55	6	180
560280	0	33	0	14	83	50	180
566010	0	51	0	18	83	28	180
566270	0	46	0	17	100	17	180
566440	0	92	0	14	58	16	180
572470	0	43	0	13	75	49	180
572550	0	45	0	17	96	22	180
572590	0	48	0	9	85	38	180
580680	0	34	0	14	86	46	180
580770	0	85	0	15	63	17	180
581530	0	84	0	6	34	56	180
589890	0	33	0	14	92	41	180
589970	0	13	0	0	37	130	180
590060	0	54	0	14	82	30	180
598740	0	13	0	6	103	58	180
599220	0	51	0	23	81	25	180

Table 7. Continued.

599590	0	44	0	11	78	47	180
609060	0	49	0	11	83	37	180
609300	0	137	0	8	30	5	180
609310	0	72	0	18	76	14	180
609720	0	137	0	12	30	1	180
609790	0	40	0	19	59	62	180
609830	0	43	0	13	94	30	180
620160	0	22	0	19	88	51	180
620520	0	65	0	22	59	34	180
630260	0	64	0	16	81	19	180
631000	0	56	0	9	92	23	180
631740	0	32	0	10	56	82	180
631960	0	38	0	19	90	33	180
632220	0	98	0	15	64	3	180
632390	0	119	0	15	38	8	180
642980	1	49	0	20	84	26	180
643490	0	62	0	11	60	47	180
644110	0	54	0	22	82	22	180
644320	0	49	0	8	83	40	180
644480	0	51	0	11	101	17	180
644640	0	53	0	18	87	22	180
654990	0	70	0	17	78	15	180
655570	0	70	0	8	59	43	180
655580	0	54	0	6	73	47	180
655960	0	47	0	12	85	36	180
655970	0	39	0	15	61	65	180
666980	0	124	0	8	44	4	180
667090	0	50	0	10	75	45	180
667370	0	63	0	21	71	25	180
667390	0	51	0	8	78	43	180
667420	0	48	0	16	94	22	180
667530	0	54	0	21	69	36	180
667660	0	43	0	7	99	31	180
677930	0	72	0	3	87	18	180
677940	0	65	0	27	87	1	180
677950	0	49	0	9	91	31	180
678130	0	43	0	11	63	63	180
678140	0	73	0	19	71	17	180
678680	0	75	0	11	85	9	180
678710	0	96	0	9	56	19	180
678940	0	41	0	7	30	102	180
679570	0	36	0	10	101	33	180
901770	0	71	0	15	63	31	180
903170	0	52	0	22	57	49	180
915550	0	54	0	15	90	21	180
Nobservd	1	5423	1	1150	6136	2589	15300

Table 8. Rearranged category scores for Festuca.

			Category 1	2	3
1	407030	PAULINO	55	84	41
2	411190	MUSTANG	52	87	41
3	416520	FA 402	79	89	12
4	416530	BONAPARTE	61	93	26
5	416800	ISS-0	56	86	38
6	419770	BAR FA 209	77	91	12
7	423710	BAR RZ 315	54	82	44
8	423810	Hykor	86	85	9
9	426950	Kora	141	35	4
10	426960	G 48	113	56	11
11	512670	KASBA	102	69	9
12	525950	PASTELLE	88	86	6
13	526540	CLARINE	130	43	7
14	533760	BARCEL	113	63	4
15	533940	LUBRETTE	117	58	5
16	534010	ONDINE	47	103	30
17	538910	BARTES	35	87	58
18	539130	SOPLINE	101	69	10
19	539310	DOVEY	20	101	59
20	548500	BUFFALO	83	91	6
21	552610	OLGA	47	93	40
22	553110	CIGALE	73	102	5
23	559300	FUEGO	54	103	23
24	559340	FESTORINA	36	113	31
25	559780	RIVIERA	104	70	6
26	560280	HOUNDOG	33	97	50
27	566010	ADVENTURE	51	101	28
28	566270	FLORINE	46	117	17
29	566440	ARIANE	92	72	16
30	572470	NUBA	43	88	49
31	572550	APACHE	45	113	22
32	572590	FATIMA	48	94	38
33	580680	CLEMFINE	34	100	46
34	580770	DARCY	85	78	17
35	581530	NOVO	84	40	56
36	589890	JAGUAR	33	106	41
37	589970	NORIA	13	37	130
38	590060	SINFONIA	54	96	30
39	598740	SEINE	13	109	58
40	599220	AMELIE	51	104	25

Table 8. Continued.

41	599590	VILLAGEOIS	44	89	47
42	609060	FELINE	49	94	37
43	609300	GARDIAN	137	38	5
44	609310	IBIS	72	94	14
45	609720	LUTINE	137	42	1
46	609790	MAX	40	78	62
47	609830	WRANGLER	43	107	30
48	620160	MADRA	22	107	51
49	620520	MIRO	65	81	34
50	630260	SILVERADO	64	97	19
51	631000	MURRAY	56	101	23
52	631740	ELDORADO	32	66	82
53	631960	DYNOS	38	109	33
54	632220	MYLENA	98	79	3
55	632390	LUNIBELLE	119	53	8
56	642980	BORNEO	50	104	26
57	643490	ASTERIX	62	71	47
58	644110	COCHISE	54	104	22
59	644320	CARMINE	49	91	40
60	644480	EMPEROR	51	112	17
61	644640	TOMAHAWK	53	105	22
62	654990	ELFINA	70	95	15
63	655570	BARFELIX	70	67	43
64	655580	BARBIZON	54	79	47
65	655960	LEPRECHAUN	47	97	36
66	655970	SAVOY	39	76	65
67	666980	NOBEL	124	52	4
68	667090	PST-RDG	50	85	45
69	667370	VEGAS	63	92	25
70	667390	BARLEDUC	51	86	43
71	667420	BARDOUX	48	110	22
72	667530	DP PL 7901	54	90	36
73	667660	ZPS J3	43	106	31
74	677930	BAR RZ 480	72	90	18
75	677940	BAR FA 411	65	114	1
76	677950	DTF	49	100	31
77	678130	SG P145	43	74	63
78	678140	SG P146	73	90	17
79	678680	FE P174	75	96	9
80	678710	FE GP30	96	65	19
81	678940	L.G.M.	41	37	102
82	679570	SFL	36	111	33
83	901770	RABA	71	78	31
84	903170	MANADE	52	79	49
85	915550	LUDION	54	105	21
			5424	7287	2589

Table 9. Rearranged category scores for Festuca, per year.

		95			96			97		
	Number	1	2	3	1	2	3	1	2	3
1	407030	6	47	7	37	6	17	12	31	17
2	411190	11	40	9	34	14	12	7	33	20
3	416520	17	43	0	45	10	5	17	36	7
4	416530	1	49	10	57	2	1	3	42	15
5	416800	1	40	19	48	8	4	7	38	15
6	419770	15	43	2	38	14	8	24	34	2
7	423710	7	41	12	29	11	20	18	30	12
8	423810	19	39	2	44	11	5	23	35	2
9	426950	41	19	0	53	5	2	47	11	2
10	426960	33	25	2	50	7	3	30	24	6
11	512670	16	43	1	52	6	2	34	20	6
12	525950	12	45	3	51	7	2	25	34	1
13	526540	31	28	1	58	1	1	41	14	5
14	533760	28	32	0	49	9	2	36	22	2
15	533940	34	26	0	49	8	3	34	24	2
16	534010	6	49	5	29	18	13	12	36	12
17	538910	3	29	28	21	19	20	11	39	10
18	539130	24	34	2	48	8	4	29	27	4
19	539310	1	46	13	14	21	25	5	34	21
20	548500	10	50	0	51	6	3	22	35	3
21	552610	11	38	11	29	12	19	7	43	10
22	553110	8	52	0	44	13	3	21	37	2
23	559300	11	48	1	37	12	11	6	43	11
24	559340	3	53	4	27	19	14	6	41	13
25	559780	29	31	0	47	11	2	28	28	4
26	560280	8	41	11	19	19	22	6	37	17
27	566010	12	44	4	34	13	13	5	44	11
28	566270	3	55	2	34	17	9	9	45	6
29	566440	22	32	6	46	10	4	24	30	6
30	572470	8	43	9	26	15	19	9	30	21
31	572550	6	52	2	34	15	11	5	46	9
32	572590	0	50	10	28	14	18	20	30	10
33	580680	1	45	14	27	16	17	6	39	15
34	580770	17	42	1	51	4	5	17	32	11
35	581530	10	30	20	47	0	13	27	10	23
36	589890	5	52	3	19	18	23	9	36	15
37	589970	0	24	36	13	4	43	0	9	51
38	590060	6	48	6	36	11	13	12	37	11
39	598740	1	47	12	11	19	30	1	43	16
40	599220	11	44	5	30	15	15	10	45	5

Table 9. Continued.

41	599590	0	44	16	31	9	20	13	36	11
42	609060	5	52	3	32	10	18	12	32	16
43	609300	40	20	0	59	1	0	38	17	5
44	609310	11	49	0	44	12	4	17	33	10
45	609720	33	27	0	59	0	1	45	15	0
46	609790	7	37	16	22	14	24	11	27	22
47	609830	4	49	7	27	21	12	12	37	11
48	620160	1	46	13	16	22	22	5	39	16
49	620520	18	32	10	34	12	14	13	37	10
50	630260	16	38	6	42	9	9	6	50	4
51	631000	1	57	2	48	7	5	7	37	16
52	631740	2	32	26	28	16	16	2	18	40
53	631960	6	52	2	24	18	18	8	39	13
54	632220	19	40	1	51	8	1	28	31	1
55	632390	25	32	3	52	4	4	42	17	1
56	642980	3	46	11	40	11	9	7	47	6
57	643490	2	41	17	50	5	5	10	25	25
58	644110	3	51	6	46	5	9	5	48	7
59	644320	5	43	12	29	13	18	15	35	10
60	644480	2	55	3	42	9	9	7	48	5
61	644640	12	43	5	39	12	9	2	50	8
62	654990	9	45	6	39	18	3	22	32	6
63	655570	3	47	10	51	1	8	16	19	25
64	655580	2	35	23	46	4	10	6	40	14
65	655960	3	42	15	39	10	11	5	45	10
66	655970	7	37	16	30	9	21	2	30	28
67	666980	25	33	2	58	1	1	41	18	1
68	667090	6	40	14	37	9	14	7	36	17
69	667370	13	40	7	42	8	10	8	44	8
70	667390	16	41	3	32	15	13	3	30	27
71	667420	8	48	4	31	21	8	9	41	10
72	667530	13	43	4	31	13	16	10	34	16
73	667660	7	45	8	35	12	13	1	49	10
74	677930	17	43	0	45	5	10	10	42	8
75	677940	5	55	0	49	10	1	11	49	0
76	677950	4	48	8	40	8	12	5	44	11
77	678130	6	35	19	35	7	18	2	32	26
78	678140	9	44	7	46	9	5	18	37	5
79	678680	7	52	1	43	11	6	25	33	2
80	678710	18	41	1	55	2	3	23	22	15
81	678940	3	14	43	21	8	31	17	15	28
82	679570	7	48	5	27	13	20	2	50	8
83	901770	11	37	12	45	13	2	15	28	17
84	903170	9	34	17	33	13	14	10	32	18
85	915550	9	48	3	33	19	8	12	38	10

Table 10. Numbers of Festuca varieties that were distinct from a particular variety at p<0.001 in an analysis of variance on the cumulative logits for the categories 1 and 2 (AOV1 and AOV2), the coincidence between both analyses of variance (AOV1-2), the numbers found distinct at p<0.01 by a threshold model (TM), and the coincidence between consistent analyses of variance differences (AOV1-2) and threshold model differences (AOV-TM). (* Total is sum of column divided by 2).

	Number	AOV1	AOV2	AOV1-2	TM	AOV-TM
1	407030	7	17	6	11	6
2	411190	7	17	6	12	6
3	416520	7	20	5	10	5
4	416530	10	5	2	8	2
5	416800	13	14	9	11	8
6	419770	7	14	5	9	5
7	423710	7	20	6	12	6
8	423810	6	20	6	12	6
9	426950	56	48	46	62	46
10	426960	32	13	11	37	11
11	512670	19	26	12	23	11
12	525950	7	36	7	14	6
13	526540	57	39	38	57	38
14	533760	32	48	27	42	25
15	533940	34	44	27	45	27
16	534010	8	14	6	11	6
17	538910	14	26	14	24	14
18	539130	15	14	8	21	8
19	539310	30	25	24	29	24
20	548500	7	40	6	12	6
21	552610	8	17	7	12	7
22	553110	6	44	4	9	4
23	559300	7	5	2	9	2
24	559340	14	13	8	14	8
25	559780	19	40	18	29	16
26	560280	13	23	12	20	12
27	566010	8	11	5	10	5
28	566270	10	6	2	9	2
29	566440	10	5	2	12	2
30	572470	8	22	8	16	8
31	572550	10	6	2	10	2
32	572590	15	17	11	12	9
33	580680	20	20	14	19	14
34	580770	7	12	4	11	4
35	581530	8	26	3	8	3
36	589890	14	14	9	16	9
37	589970	71	78	69	82	69
38	590060	7	14	6	10	6
39	598740	52	26	25	30	25
40	599220	7	9	5	9	5

41	599590	17
42	609060	8
43	609300	66
44	609310	6
45	609720	67
46	609790	10
47	609830	10
48	620160	29
49	620520	7
50	630260	7
51	631000	13
52	631740	22
53	631960	10
54	632220	14
55	632390	41
56	642980	10
57	643490	7
58	644110	10
59	644320	8
60	644480	10
61	644640	10
62	654990	7
63	655570	7
64	655580	10
65	655960	13
66	655970	14
67	666980	55
68	667090	8
69	667370	7
70	667390	9
71	667420	8
72	667530	7
73	667660	15
74	677930	6
75	677940	7
76	677950	10
77	678130	14
78	678140	6
79	678680	6
80	678710	19
81	678940	10
82	679570	15
83	901770	6
84	903170	7
85	915550	7
	Total*	672

Table 11. Modified joint regressions of estimated Variety by Year means in threshold model on Variety main effects.

Response variate: x95

	d.f.	s.s.	m.s.	v.r.
Regression	1	40.11	40.1094	279.03
Residual	83	11.93	0.1437	
Total	84	52.04	0.6195	

Percentage variance accounted for 76.8

	estimate	s.e.	t(83)
Constant	0.7321	0.0505	14.50
main	0.7277	0.0436	16.70

Response variate: x96

	d.f.	s.s.	m.s.	v.r.
Regression	1	136.27	136.2693	441.22
Residual	83	25.63	0.3088	
Total	84	161.90	1.9274	

Percentage variance accounted for 84.0

	estimate	s.e.	t(83)
Constant	-1.3115	0.0740	-17.72
main	1.3413	0.0639	21.01

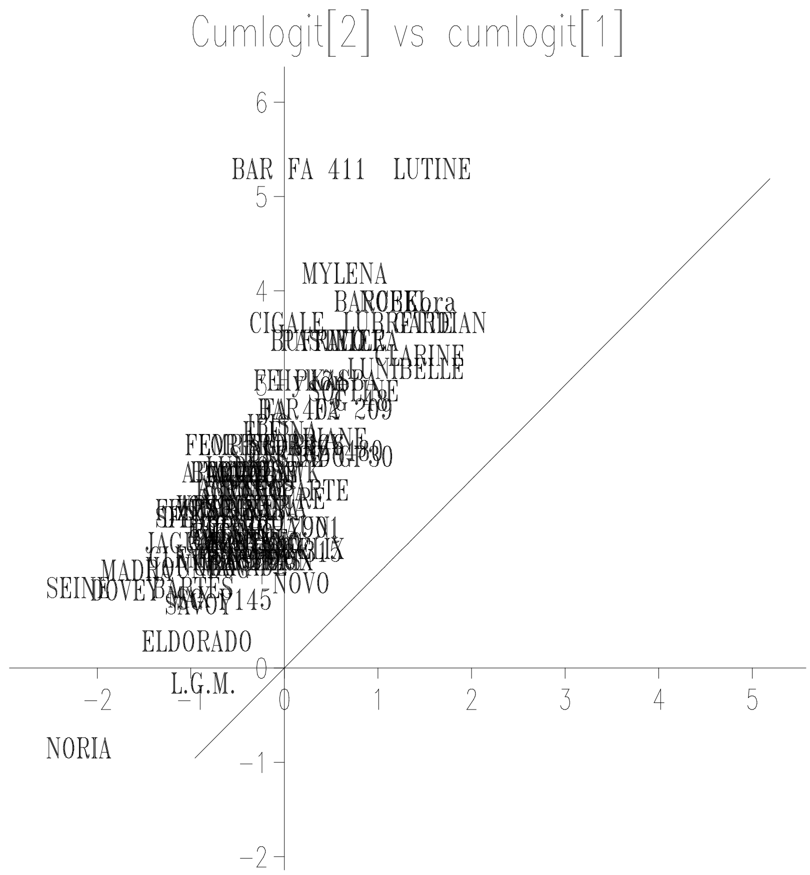
Response variate: x97

	d.f.	s.s.	m.s.	v.r.
Regression	1	65.64	65.6414	398.58
Residual	83	13.67	0.1647	
Total	84	79.31	0.9442	

Percentage variance accounted for 82.6

	estimate	s.e.	t(83)
Constant	0.5795	0.0541	10.72
main	0.9310	0.0466	19.96

Figure 1.
Cumulative lo
for category
of category 2
against those
category 1.



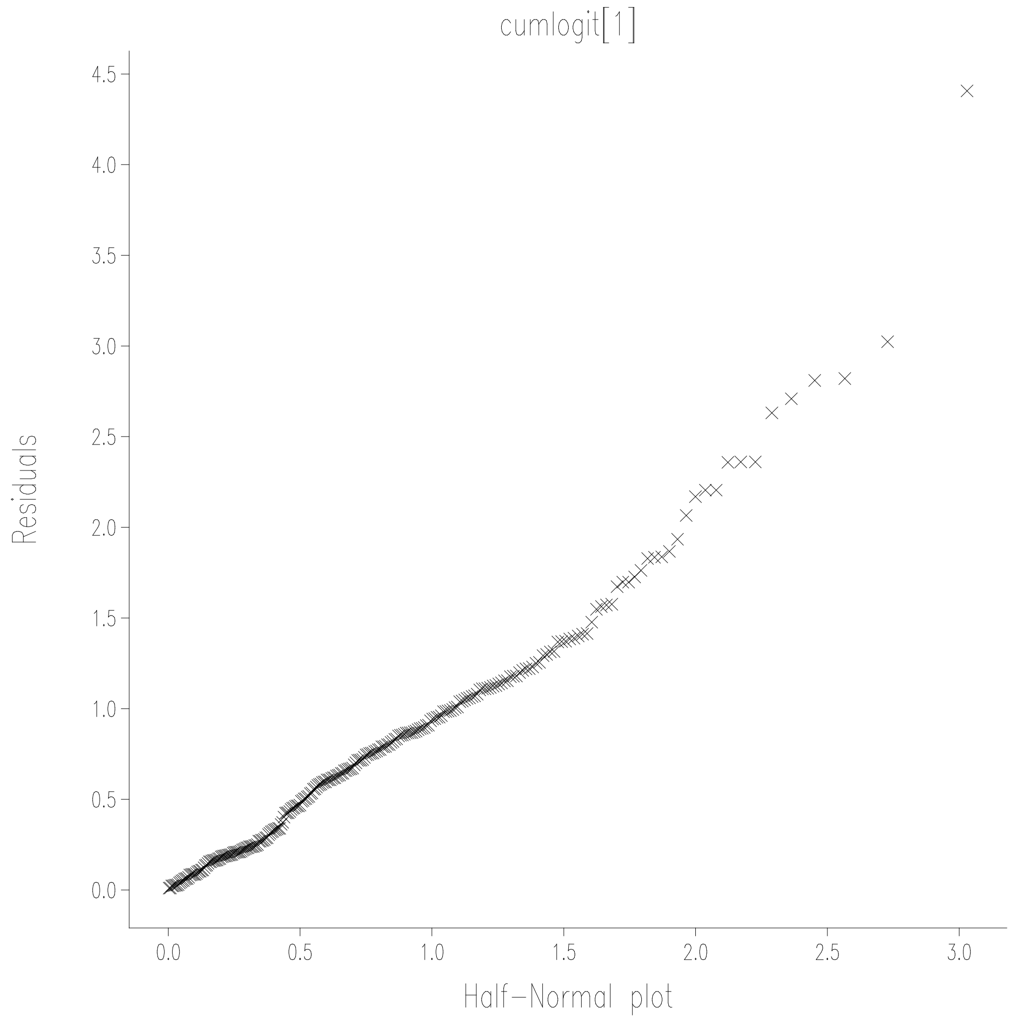


Figure 2a. Half-Normal plot for residuals from analysis of variance for cumulative logits of category 1.

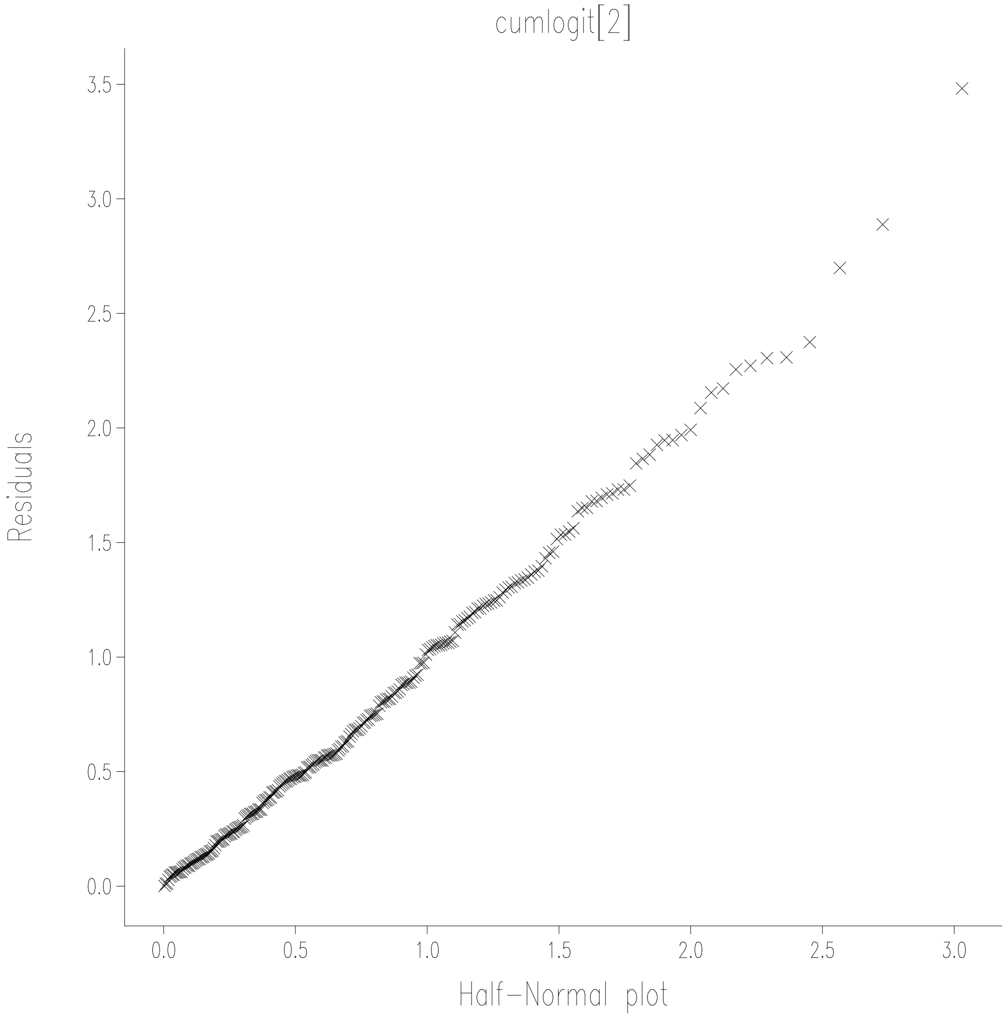


Figure 2b. Half-Normal plot for residuals from analysis of variance for cumulative logits of category 2.

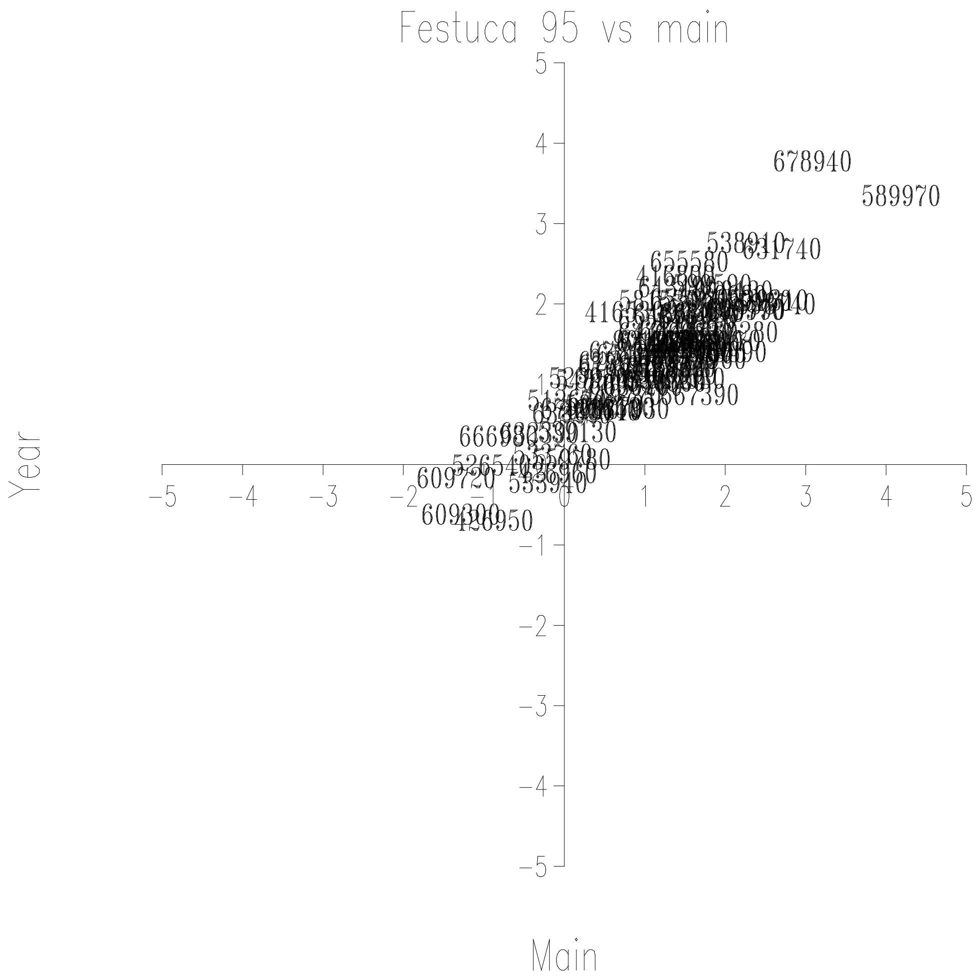


Figure 3a. Variety means for 1995 against variety means over full period 1995-1997.

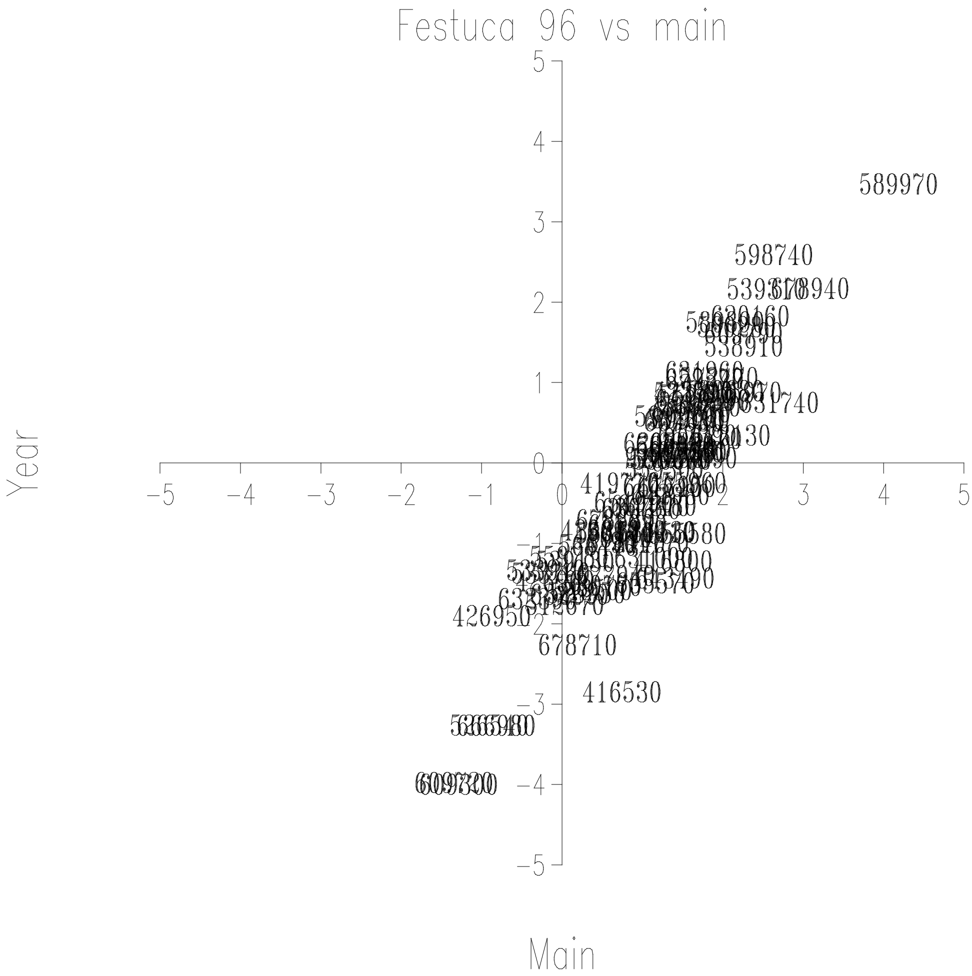


Figure 3b. Variety means for 1996 against variety means over full period 1995-1997.

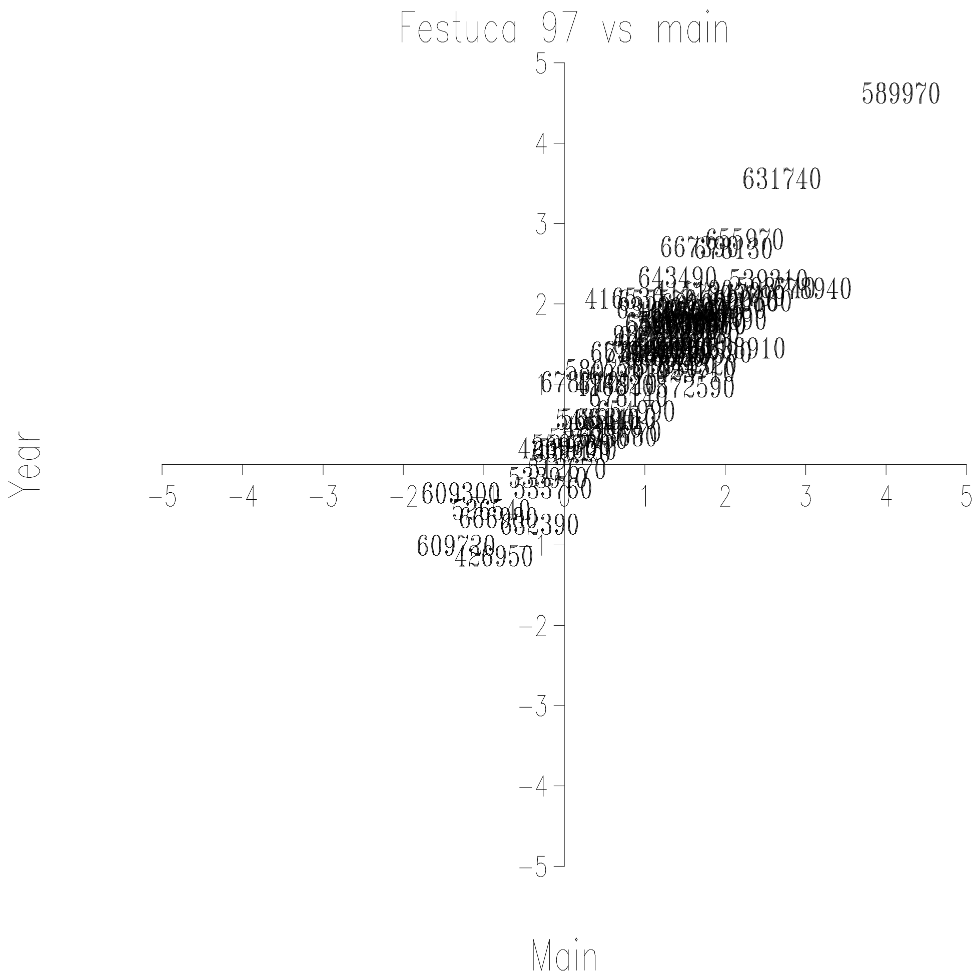


Figure 3c. Variety for 1997 against variety means over full period 1995-1997.

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