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EFFICIENCY OF INCOMPLETE BLOCK DESIGNS IN SPRING RAPE
AND YELLOW MUSTARD

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Efficiency of incomplete block designs in Spring Rape and Yellow Mustard

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Introduction

Spring Rape, Winter Rape and Yellow Mustard are some of the major crops for DUS-testing in Denmark, i.e. there are many candidate and reference varieties grown each year. At the same time some difficulties have been encountered in the establishment of distinctness of new candidates. Since spring 1997 the DUS trials with those crops have been laid out as resolvable incomplete block designs. Previous calculations using rape trials from Denmark and United Kingdom with complete blocks have shown that there could be some benefit from using incomplete blocks in rape trials (Kristensen and Jensen, 1998).

The present paper describes the efficiency of 4 Danish trials with incomplete blocks, from which we at present have all results for two years.

DATA

Results from 2 trials (1997 and 1998) with Spring Rape and 2 trials (1997 and 1998) with Yellow Mustard have been used. All trials were laid out as α-designs with 3 replicates. The actual dimensions of the designs used are shown in table 1.

Table 1. Design parameters

Crop	Year	Number of			
		Entries	Plots	Reps.	Plots/block
Spring rape	97	114	342	3	9-10
	98	131	393	3	11-12
Yellow mustard	97	55	165	3	11
	98	66	198	3	11

All UPOV characters, that were based on field assessments and for which it could be assumed that the data could be analysed by linear mixed models were used. A list of those characters is given in table 2. Twenty plants were planed to be recorded in all plots. However, because of loss of plants, a few records were missing in some of the plots, and - for some of the recorded characters - some plots were not recorded at all (see table 2).

Table 2. List of characters and number of recorded plots for each trial

Character identification	Character name	Number of recorded plots in trial			
		SR97	SR98	YM97	YM98
UPOV 6	Leaf : Number of lobes	309	367	165	198
UPOV 8	Leaf : Length	309	366	165	198
UPOV 9	Leaf : Width	309	367	165	198
UPOV 10	Leaf: Length of petiole	309	367	165	198
UPOV 13	Flower: Length of petals	309	368	165	198
UPOV 14	Flower: Width of petals	309	368	165	198
UPOV 16	Plant: Height (at full flowering)	309	369	165	193
UPOV 17	Plant: Total length incl. side branches	309	368	165	198
UPOV 18	Siliqua: Length	309	368	165	198
UPOV 19	Siliqua: Length of beak	309	368	165	198
UPOV 20	Siliqua: Length of peduncle	309	368	165	198

Method

The data from each trial were analysed by three models: A, B, and C. All models were general linear models or general linear mixed models (see e.g. Searle, 1971 and Searle et al., 1992) and are shown here:

$$\text{A}: Y_{vr} = \mu + \alpha_v + \beta_r + E_{vr}$$
$$\text{B}: Y_{vrb} = \mu + \alpha_v + \beta_r + \gamma_{rb} + E_{vrb}$$
$$\text{C}: Y_{vrb} = \mu + \alpha_v + B_r + C_{rb} + E_{vrb}$$

where

Y_{vr} and Y_{vrb} = recorded value in the plot with variet v in block b of replicate r

α_v = variety effect

β_r = fixed replicate effect

B_r = random replicate effect, $B_r \sim i.i.d.\ N(0, \sigma_B^2)$

γ_{rb} = fixed block effect

C_{rb} = random block effect, $C_{rb} \sim i.i.d.\ N(0, \sigma_C^2)$

E_{vr} and E_{vrb} = random plot effect, E_{vr} and $E_{vrb} \sim i.i.d.\ N(0, \sigma^2)$

The parameters of the models were estimated using the method of Residual Maximum Likelihood (REML).

Based on model C and the pooled within plot (plant to plant) variation the variance components for replicates, incomplete blocks, plots and within plots were estimated. The variance component for plot were calculated as the estimate of σ^2 minus $s_p^2/20$, where s_p^2 is the within plot variation (on plant basis). The variance components for within plot variation are reported as $s_p^2/20$.

For the character with UPOV number 10 the logarithm of the character were analysed in stead of the character itself. The reported variance components and LSD values for this character are reported on log scale.

Based on each of these models for each individual trial, estimates of variety effects were calculated as $\mu+\alpha_v$. The estimates from each model and each of the two crops were then submitted to a COY-D analysis. The model for the COY-D analysis were:

$$Y_{vy} = \mu + \tau_v + \delta_y + E_{vy}$$

where

Y_{vy} = the calculated estimate of variety v in year y

τ_v = the COY - D variety effect of variety v

δ_y = the effect of year y

E_{vy} = random effect, $E_{vy} \sim i.i.d\ N(0, \sigma_E^2)$

For each of the 3 models (for individual trials) the LSD-value for comparing to varieties in the COY-D analysis were calculated using the formula:

$$LSD = t_{.995,\upsilon}\sqrt{\frac{2}{2}\sigma_E^2}$$

where

$t_{.995,\upsilon}$ = 0.995 fraktilen in a t – distribution with ν degrees of freedom

Results

The effect of using incomplete blocks varied from character to character and from year to year as well as from crop to crop (table 3). The recordings of height (character no.16 and 17) seemed to be the only one where there always were a significant effect of incomplete blocks (using model B). For Spring Rape 1997 most characters showed a significant effect of incomplete blocks. On average 52% of the trial/character combinations showed significant effects of incomplete blocks on the 5% level of significance.

Table 3 Test of significance for effect of incomplete blocks. Values are percent probability of rejecting the hypothesis that there are no fixed block effects.

Trial	UPOV Character number										
	6	8	9	10	13	14	16	17	18	19	20
Spring Rape 1997	19.8	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Spring Rape 1998	30.8	16.5	0.5	21.4	12.4	1.4	0.0	0.0	26.5	11.6	12.0
Yellow Mustard 97	0.7	20.8	7.6	0.0	34.3	33.1	0.0	0.0	0.5	1.8	20.3
Yellow Mustard 98	36.2	61.1	49.9	10.7	25.9	17.0	0.0	0.0	0.9	0.8	41.5

The estimated variance components are shown in table 4 and 5. The tables show that for many cases the variance component for incomplete blocks are of the same magnitude as the variance component for replicates. The variance components for plots had in most cases the largest contribution to the total variance (when reported on plot level). In all cases the variance component for between plots were larger than the variance within plots. This indicates that most of the residual variance were caused by plot to plot variation and not by plant to plant variation. In some characters the variance within plots were considerable smaller than the variance between plots – e.g. for character 16 the contribution from between plots were between 34 and 169 times larger than the contribution from within plots.

Table 4 Estimated variance components in Spring Rape based on the model with random block effects.

Year and component	UPOV Character number										
	6	8	9	10	13	14	16	17	18	19	20
97 Replicate	.0112	29.2	1.2	.0014	.0735	.0557	9.46	20.46	13.42	0.307	1.421
97 Incompl. blocks	.0102	103.8	12.2	.0036	.0614	.0166	10.87	7.71	13.51	0.331	1.099
97 Plots	.1732	252.2	47.1	.0112	.2018	.1084	46.10	23.90	4.53	0.296	1.319
97 Plants/20	.0627	12.4	4.6	.0009	.0300	.0183	1.35	4.74	2.42	0.149	0.522
97 Total	.2574	397.7	65.1	.0170	.3668	.1990	67.78	56.82	33.89	1.084	4.361
98 Replicates	.0228	20.9	5.6	.0006	.0162	.0236	0.85	0.00	0.00	0.007	0.000
98 Incompl. blocks	.0052	25.9	14.3	.0004	.0130	.0145	6.13	4.50	0.20	0.023	0.084
98 Plots	.3367	901.1	113.4	.0207	.2744	.1225	20.61	20.60	9.23	0.392	1.909
98 Plants/20	.0611	15.8	6.5	.0009	.0344	.0214	0.41	3.67	1.72	0.106	0.342
98 Total	.4258	963.8	139.9	.0225	.3380	.1820	28.01	28.77	11.16	0.528	2.334

Table 5 Estimated variance components in Yellow Mustard based on the model with random block effects.

Year and component	UPOV Character number										
	6	8	9	10	13	14	16	17	18	19	20
97 Replicate	.0297	2.9	0.00	.0006	.0514	.0035	0.00	12.1	1.80	0.63	.0000
97 Incompl. blocks	.0147	4.8	1.84	.0020	.0091	.0028	9.55	30.9	0.41	0.16	.0258
97 Plots	.0412	94.6	19.21	.0056	.3144	.1173	26.28	19.5	1.03	0.56	.3506
97 Plants/20	.0305	7.3	5.15	.0006	.0305	.0206	0.74	5.4	0.86	0.46	.1740
97 Total	.1161	109.7	26.21	.0088	.4054	.1443	36.58	67.8	4.10	1.81	.5504
98 Replicates	.0000	.8.2	2.32	.0002	.0098	.0078	12.65	0.8	0.00	0.00	.0000
98 Incompl. blocks	.0003	0.0	0.00	.0007	.0052	.0048	16.99	38.2	0.24	0.11	.0000
98 Plots	.0662	320.7	72.96	.0083	.1586	.0797	48.92	29.1	1.26	0.49	.4154
98 Plants/20	.0319	8.7	7.35	.0006	.0280	.0184	0.29	8.0	0.52	0.25	.1732
98 Total	.0983	337.6	82.63	.0098	.2016	.1107	78.84	76.1	2.02	0.85	.5886

The results from the COY-D analysis are reported as LSD-values for comparing two varieties. The LSD-values are shown in table 6 and the values show that estimates based on model A (Complete block design) in a few cases (5 out of 22 cases) yields the smallest LSD value (using plenty of decimals). In most cases the difference is small (less than 5%). Character 13 of Yellow Mustard shows the largest difference (The LSD-value of Method A is 7% smaller than the LSD-value of method B, but only slightly smaller than the LSD-value of method C). Method B and or C yielded the smallest LSD-value in most cases (14 and 3 out of 22 cases, respectively). Also here the differences are in general small, but some examples of large differences can be found – the two largest are character 17 of Yellow Mustard and character 18 of Spring Rape where the reduction by using method B or C is 23% and 13%, respectively.

Comment [UD1]: The actual figures for the 2 crops are:

Method	Spring Rape	Yellow Mustard	Total
A	3	2	5
B	8	6	14
C	0	3	3
I alt	11	11	22

Table 6 LSD values from COY-D analysis based on each of the 3 models used for calculating the variety effect in a single trial.

Crop and method	UPOV Character number										
	6	8	9	10	13	14	16	17	18	19	20
Spring Rape A	0.927	58.9	22.1	0.325	1.25	1.072	23.7	17.6	7.79	1.68	2.86
Spring Rape B	0.967	58.8	22.1	0.327	1.32	1.070	23.5	17.5	6.83	1.59	2.65
Spring Rape C	0.967	58.8	22.1	0.327	1.32	1.070	23.5	17.5	6.83	1.59	2.65
Yellow Mustard A	0.591	27.2	11.4	0.141	1.13	0.838	16.9	17.6	2.99	2.20	1.61
Yellow Mustard B	0.574	27.4	11.4	0.145	1.21	0.858	15.6	13.6	2.80	2.13	1.78
Yellow Mustard C	0.588	27.1	11.4	0.138	1.14	0.838	15.7	13.8	2.81	2.13	1.62

Discussions and conclusions

Previous calculations (Kristensen and Jensen, 1998) showed that incomplete blocks in most cases would be expected to improve the individual trial results. This is in agreement with the present calculations that show that the incomplete block in 52% of the character/trial combinations had fixed block effects that were significant at the 5% level of significance.

The calculations based on Spring Rape and Yellow Mustard show that the use of incomplete blocks for most characters yielded lower COY-D LSD values than complete blocks. Only in a few cases did the COY-D based on randomised complete blocks yield slightly better results than COY-D based on incomplete blocks. The differences between the different methods were in general not large. Only in a few cases did the use of incomplete blocks decrease the LSD-value by more than 10%.

In the data used there are some trials where some of the characters were not recorded in all plots. This lowers the efficiency of the used designs which means that the incomplete blocks are not optimal. This may be a reason why the complete block model showed to have the lowest COY-D LSD-value for some of the character/trial combination.

The results indicates that the use of incomplete blocks may yield better separations than complete blocks for most characters (using COY-D) although the benefit may be small for most characters. In cases where the complete blocks did best the difference was in all cases small.

References

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