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EFFICIENCY OF DIFFERENT DESIGNS IN SPRING RAPE

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Efficiency of different designs in Spring Rape

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Introduction

In the DUS testing spring rape is one of the major crops in Denmark, i.e. there are many reference varieties grown each year. At the same time some difficulties have been encountered in the establishment of distinctness of new candidates. An investigation was therefore started in order to examine whether the designs could be improved in order to lower the critical differences necessary to distinct new candidates from established varieties.

The investigation consists of two parts: In the first part some existing trials laid out as complete block designs with many entries (varieties) were analysed in order to access the possibly effect if the trials had actually been laid out using an incomplete block design. This was done by imposing incomplete blocks on the actual designs. In the second part a single resolvable incomplete block design was analysed using the incomplete block structure and compared with the result when the trial were analysed as a randomised complete block design.

Post-blocking on complete randomised block designs

Data
Four years of trials from Tystofte in Denmark and two years of trials from Cambridge in United Kingdom were collected. The years and the parameters of the used designs are shown in table 1.

Table **Error! Unknown switch argument.** Design parameters

Locality	Year	Number of			
		Entries	Plots	Rows	Plots/-row
Cambridge	96	187	667	4	210
	97	231	806	6	147
Tystofte	93	76	152	2	76
	94	90	180	2	90
	95	110	220	3	82
	96	123	246	2	123

An entry is a combination of source and variety

From those 6 trials all available measured UPOV-character and two common national characters were used. The characters, their character number and the experiments from which they were available are shown in table 2.

Table **Error! Unknown switch argument.** Overview of characters

Character identification	Character name	Cambridge		Tystofte			
		1996	1997	1993	1994	1995	1996
NATI 1	Pod: Width	x	x	x	x	x	x
NATI 2	Pod: Number of seeds	x	x	x	x	x	x
UPOV 2	Cotyledon: Length			x	x	x	x
UPOV 3	Cotyledon: Width			x	x	x	x
UPOV 6	Leaf : Number of lobes			x	x	x	x
UPOV 8	Leaf : Length			x	x	x	x
UPOV 9	Leaf : Width			x	x	x	x
UPOV 10	Leaf: Length of petiole			x	x	x	x
UPOV 13	Flower: Length of petals	x	x	x	x	x	x
UPOV 14	Flower: Width of petals	x	x	x	x	x	x
UPOV 16	Plant: Height (at full flowering)	x	x	x	x	x	x
UPOV 17	Plant: Total length incl. side branches			x	x	x	x
UPOV 18	Siliqua: Length	x	x	x	x	x	x
UPOV 19	Siliqua: Length of beak	x	x	x	x	x	x
UPOV 20	Siliqua: Length of peduncle	x	x	x	x	x	x

Method

Incomplete blocks were post-constructed on the actually used designs. The incomplete blocks were constructed in different ways with blocks in the range between 2 and 20. For most block sizes the incomplete blocks were formed in two ways: 1) The incomplete blocks were formed as a continuos number of plots within a row. 2) The incomplete blocks were formed from two rows of plots with half the number of plots in each row, i.e. an incomplete block with k plots were formed from ½k by 2 plots. The data from each trial were analysed in the following model (see e.g. Searle, 1971):

$$Y_{vrb} = \mu + \alpha_v + B_r + C_b + D_{rb} + E_{vrb}$$

where

v = entry no

r = row no

b = block no within row

B_r, C_b, D_{rb} *and* E_{vrb} *are random row, block, row * block and plot effects which are assumed be i.i.d. normal destributed vith variances* σ^{2r}, σ^{2b}, σ^{2rb} *and* σ^{2vrb}, *respectively*

From this model the variance of E_{vb} was estimated by the method of least square. Based on the estimated residual variances the variances on a difference between two varieties in a single year was estimated for different optimal (or near optimal) α-designs assuming 120 varieties and 3 replicates. For comparison these variances on a difference between two varieties were also calculated for the present randomised block design. Based on the variances on differences between two varieties the LSD-values at the 95% level of significance were calculated. The plot size was assumed to be as in the present RBD design.

The LSD-value for comparing two varieties in a single years analysis was estimated by:

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$$s_d^2 = \begin{cases} 2[\hat{\sigma}_i^2 / 60 + \hat{\sigma}_{vrb}^2 / n] / E_\alpha & for \quad \alpha - design \\ 2[\hat{\sigma}_i^2 / 60 + (\hat{\sigma}_{rb}^2 + \hat{\sigma}_{vrb}^2) / n] / E_{rc} & for \quad bar - design \\ 2[\hat{\sigma}_i^2 / 60 + (\hat{\sigma}_b^2 + \hat{\sigma}_{rb}^2 + \hat{\sigma}_{vrb}^2) / n] & for \quad rb - design \end{cases}$$

where n = number of replicates
E_α= efficiency factor of the α-design

The degree of freedoms in the error variance and the used efficiency factors were as shown in the following table:

Block size	2	3	4	5	6	8	10	12	20	120
ν	61	121	151	169	181	196	205	211	223	238
E_α	.24	.53	.65	.73	.78	.84	.88	.90	.94	1.00

Comment [kk1]:

Results

For each of the 76 possible combinations of trials and characters the design with the smallest LSD-value were found. This showed that designs with blocks restricted to plots in just one row were smallest in 49 out of 76 cases. In table 3 this is elucidated further showing that block restricted to be in just one row was preferable for all examined block sizes except blocks of size 120 (complete blocks). Here blocks of 120 plots divided over two rows were preferable to blocks of 120 continuos plots in 52 out of 60 (8 + 52) examined cases. The average relative LSD-values (column 5 of table 3) also showed that dividing the blocks over two rows resulted in average relative LSD-values greater than 100 for all block sizes.

When the block were formed by plots in just one row the results indicates that a block size of 10-12 seemed to be preferable The average relative LSD-values were smallest for block size 12. The block sizes 10, 12 and 20 were the block sizes which most frequently were the best block size.

Very small block sizes (less than 5) were very rare among the best block sizes. Complete blocks were also rarely the best design.

Table **Error! Unknown switch argument.** Frequency of best blocksizes and relative LSD-values

Block size	Number of best in		Relative LSD-value		Number of best block size
	Number of rows		Number of rows		
	1	2	1	2	
2	46	30	183	256	2
3	.	.	117	.	2
4	56	20	106	124	1
5	.	.	100	.	8
6	60	16	96	111	5
8	49	27	97	108	3
10	68	18	94	105	13
12	64	22	93	103	20
20	48	28	95	102	20
120	8	52	**100**	.	2

The measurements on the whole plant, leafs and pods were those which on average seemed to benefit most from using incomplete block designs whereas the two count characters and measurements on cotyledons and flowers seemed to be less influenced by using incomplete blocks.

Figure 1 shows the relative LSD profile for each combination of trial and character when the blocks were formed by plots from just 1 row of plots. From this it is seen that a few characters had a very low relative LSD-value when the block size was 6. Many characters showed a minimum value at a block size of 10.

Figure 1. Relative LSD-profiles

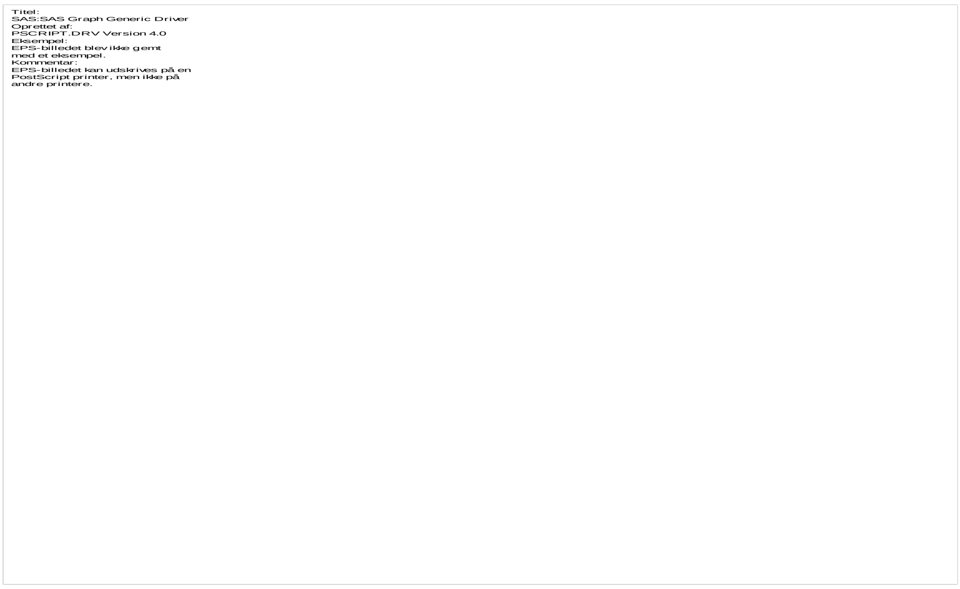

Table **Error! Unknown switch argument.** Average relative LSD-values for each character and all characters

Block size in 1 row	Character															
	LOCAL 1	LOCAL 2	UPOV 2	UPOV 3	UPOV 6	UPOV 8	UPOV 9	UPOV 10	UPOV 13	UPOV 14	UPOV 16	UPOV 17	UPOV 18	UPOV 19	UPOV 20	ALL
2	183	194	192	226	193	167	190	148	176	158	159	189	171	208	193	183
3	111	123	110	138	120	116	122	106	125	116	93	93	127	125	123	117
4	103	118	101	115	111	108	112	102	112	103	86	88	109	104	116	106
5	101	106	100	108	110	97	105	93	111	107	78	81	101	99	106	100
6	98	103	102	105	105	97	105	91	99	100	74	74	97	94	104	96
8	99	102	104	100	107	97	106	95	102	99	81	79	98	92	105	97
10	95	99	99	96	104	92	98	91	96	98	75	76	93	91	99	94
12	98	98	100	96	98	95	100	92	96	96	78	75	91	87	97	93
20	94	101	100	96	102	99	103	97	98	97	84	85	92	89	97	95
120	103	102	103	104	103	102	102	103	99	101	103	104	103	102	103	103

Incomplete block designs

Data

The trial with spring rape in Denmark was in 1997 laid out with incomplete blocks, and the 13 UPOV characters mentioned for the analyses on post-constructed block were available. In the trial there were 114 entries in 342 plots. The trial were laid out as an α-design with 3 replicates with a block size of 10 or 9 plots. Physically the trial were placed in 4 rows with 76, 76, 95 and 95 plots, respectively. All blocks were continuos, i.e. a block were never divided over two rows.

Methods

The trial were analysed in three different ways. First the trial were analysed using the actual design using both a combined intra/inter block analysis (i.e. the block effects were assumed to be random) and an intra block analysis (i.e. assuming fixed block effects). Next the trial were analysed as a randomised block design (i.e. ignoring the incomplete blocks).

The mean value of the characters for each plot were analysed in the following linear model:

$$Y_{vrb} = \mu + \alpha_v + B_r + C_b + D_{rb} + E_{vrb}$$

where

v = *entry no*

r = *row no*

b = *block no within row*

B_r, C_b, D_{rb} *and* E_{vrb} *are random row, block, row * block and plot effects*

which are assumed be i.i.d. normal destributed vith variances

σ^{2r}, σ^{2b}, σ^{2rb} *and* σ^{2vrb}, *respectively*

This model gives the combined intra/inter block analysis. The variance components were estimated by the method of restricted maximum likelihood (REML), (Patterson & Thompson, 1971, see also Searle et.al., 1992).

By assuming that the γ_{rb}-terms (block within replicate effects) were fixed the combined intra/inter block analysis were carried out. In the intra block analyses an efficiency factors of 0.88 were used for an α-designs with 3 replicates.

The analysis for a randomised block design were obtained by leaving out the D_{rb} –terms.

Based on each analysis an estimate of the LSD-value were calculated. In all cases the LSD-values were calculated at the 95% level of significance.

Results

The LSD-values of the randomised block design (at the 5% level of significance) and the relative LSD-values of the actually used α-design are shown in table 5.

Table **Error! Unknown switch argument.** LSD-values for characters in 1997

Char.	Randomised block design	% α-design	% combined α-design
UPOV 2	1.72	106	100
UPOV 3	2.88	104	99
UPOV 6	0.79	104	100
UPOV 8	30.48	93	91
UPOV 9	12.75	99	96
UPOV 10	23.25	94	92
UPOV 13	0.86	96	95
UPOV 14	0.60	99	98
UPOV 16	12.62	100	98
UPOV 17	9.63	96	95
UPOV 18	7.10	66	66
UPOV 19	1.38	82	82
UPOV 20	2.73	88	87

For most characters the LSD-value for the α-design was smaller than the LSD-value for a randomised block design. The gain by using an α-design was very large for characters with UPOV numbers 18, 19 and 20. The reduction for character 18 was equivalent to increasing the number of replicates (and plants) to 7 replicates (with 140 plants). The characters with UPOV numbers 2, 3 and 6 showed only a small increase when using an α-design in stead of a randomised block design.

Discussion and conclusion

The effect of using incomplete block design in 1997 reduced the LSD-values by -6% to 34% when using 3 replicates and an intra block analysis. If also the inter block information was used in the analysis the LSD-values was further reduced by 0%-6%. Using the combined intra/inter block analysis the α-design was always as good as the randomised complete block analysis (as expected, Yates, 1940).

Acknowledgement

The data used here were provided by National Institute of Agricultural Botany, Cambridge and Department of Variety Testing, Danish Institute of Agricultural Sciences.

Concluding remark

The calculations showed that the use of incomplete block designs in DUS trials may reduce the LSD-value in a single experiments considerably in some cases. The effect seemed to be most pronounced on plant height and some other length measurements whereas the effect on characters which were counts and which were measured very early (on cotyledons) were less effected by the use of incomplete blocks

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