Experimental designs for winter oilseed rape variety tests in consideration of interplot interference

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Summary

In the majority of cases variety trials are carried out in a randomized complete block-design (RCB) or in lattice-designs. Complete or incomplete blocks should have approximately a quadratic shape to reduce soil heterogeneity and minimize experimental error. Furthermore it can be shown that many small plots give more exact results than a small number of large plots. In consideration of a minimum plot size to accomodate the machinery needed to seed, fertilize, cultivate, and harvest the plot, plot sizes of 10 m² and a rectangular, long and narrow shape will be the best choice.

Several experiments with different species showed that the performance of a variety in a trial with narrow plots is affected by interplot interference. Statistical analysis of official oilseed rape variety trials in Germany showed a bias up to 5% of yield when results are compared with the performance in pure stand. Possible reasons are differences in plant height (competition for light), differences in lodging or a generally stronger habit of hybrid varieties.

To minimize or overcome effects of interplot interference several alternative ways are possible:

1. To sow wider plots, harvest only the centre part of the plot and discard the border rows
2. To sow wider plots and harvest the whole plot
3. Partition in different groups of varieties according to the type of breeding technique (hybrid, non-hybrid) or plant height
4. Adjustment of performance with analysis of covariance (i.e. covariate plant height of neighbours)
5. Adjustment of performance with estimation of neighbourhood effects and estimation of predicted yield for pure stand (Maximum Likelihood, General linear model)

The different possibilities will be discussed. The author recommends a partition in 4 groups (long hybrids, short hybrids, long OP-varieties, short OP-varieties) with different competitiveness. Plot width should be doubled. The lower error variance because of greater plot area allows to reduce the number of replicates. The experiment can be carried out and analysed as a split-plot-design.

Versuchsanlagen für Winterraps-Sortenprüfungen unter Berücksichtigung von Nachbarschaftseffekten

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Zusammenfassung

Sortenversuche werden meist in Blockanlage oder Gitteranlage durchgeführt. Die vollständigen oder unvollständigen Blöcke sollen dabei eine möglichst quadratische Form haben, um Bodenunterschiede und damit den Versuchsfehler zu minimieren. Weiterhin lässt sich zeigen, dass die Anlage von vielen kleinen Parzellen, d.h. vielen Wiederholungen, günstiger ist, als den Versuch mit wenigen großen Parzellen durchzuführen. Unter Berücksichtigung einer durch technisches Versuchsgerät vorgegebenen Mindestgröße, führen diese Überlegungen zu optimalen Parzellengrößen von ca. 10 m² und einer langgestreckt rechteckigen Parzellenform.

Aus verschiedenen Untersuchungen bei unterschiedlichen Fruchtarten ist bekannt, dass die Leistung einer Sorte in einem Versuch mit schmalen Parzellen durch die benachbarten Parzellen beeinflusst werden kann. In neueren Untersuchungen bei Winterraps konnten Beeinflussungen der Sortenleistung von bis zu 5% des Kornertrages gezeigt werden. Als Ursachen konnten Unterschiede in der Pflanzenlänge und damit Konkurrenz um Licht, unterschiedliche Lagerneigung sowie die allgemein größere Wüchsigkeit von Hybridsorten herausgearbeitet werden.

Zur Vermeidung bzw. Verringerung der Nachbarschaftseffekte sind verschiedene Alternativen möglich.

1. Verbreiterung der Parzellen und Kerndrusch
2. Verbreiterung der Parzellen und Drusch der gesamten Parzelle
3. Teilung des Sortimentes nach Sortentyp (Hybride/Nichthybride) und/oder Pflanzenlänge
4. Adjustierung der Ertragsleistung über eine Kovarianzanalyse (z.B. über Kovariable Pflanzenlänge der Nachbarparzelle)
5. Adjustierung der Ertragsleistung über die Schätzung von Nachbarschaftseffekten und Erwartungswerten für den Reinbestand in einem Allgemeinen linearen Modell (über Maximum Likelihood)

Die verschiedenen Alternativen werden im Vortrag dargestellt und mit ihren Vor- und Nachteilen diskutiert. Der Autor empfiehlt eine Teilung des Sortiments in vier Teilsortimente mit unterschiedlicher Konkurrenzkraft (lange Hybriden, kurze Hybriden, lange OP-Sorten, kurze OP-Sorten), bei gleichzeitiger Verdoppelung der Parzellenbreite. Der geringere Versuchsfehler bei Ernte der größeren Parzellenfläche erlaubt eine Reduzierung der Anzahl Wiederholungen. Als Versuchsdesign bietet sich eine Spaltanlage an.

1. Introduction

The objective of a variety trial is the comparison of different genotypes. The trial should show low experimental error and close correlation to results under practical conditions. Experimental conditions and methods are chosen to reduce error variance and minimize systematic bias.

In the majority of cases variety trials are carried out in a randomized complete block-design (RCB) or in lattice-designs. Complete or incomplete blocks should have approximately a quadratic shape to reduce soil heterogeneity and minimize experimental error. Furthermore it can be shown that many small plots give more exact results than a small number of large plots. In consideration of a minimum plot size to accomodate the machinery needed to seed, fertilize, cultivate, and harvest the plot, plot sizes of 10 m^2 and a rectangular, long and narrow shape will be the best choice.

Several experiments with different species showed that the performance of a variety in a trial with narrow plots is affected by interplot interference. This work shows some aspects of interplot interference between winter oilseed rape varieties and possibilities to reduce these effects.

2. Results of "Federal variety trial winter oilseed rape" in Germany 1997-1999

Winter oilseed rape varieties in Germany are tested three years to become approval for national list. Before they go in regional trials for recommended list, one year a nationwide series "Federal variety trial" (german: "Bundessortenversuch") is carried out at different sites all over Germany. Because of interplot interference in last years the varieties have been tested in two different groups. In 1999 first time varieties have been grouped by plant height into a "short" and a "tall" group. At some locations plot widht has been doubled. Although this changes in trial technique reduced interplot interference, interference effects are significant in the results. In the "tall" group theoretical a bias up to 5% of grain yield occurred (Fig. 1). All hybrid-varieties (marked with "H") showed a higher yield under competition in the trial than in monoculture. Figure 2 shows the plant height of the varieties. Hybrides are almost the tallest genotypes. This may cause high competitiveness when competition for light is of importance.

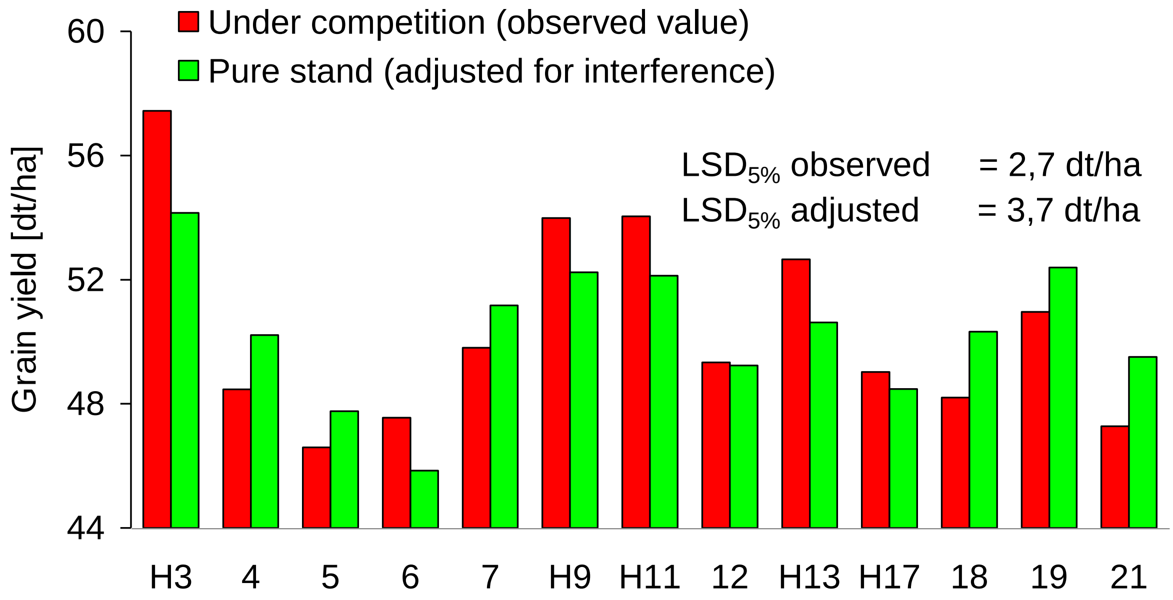


Fig. 1: Performance of varieties under competition and calculated performance in monoculture (pure stand), Federal variety trials for winter oilseed rape, Germany 1999

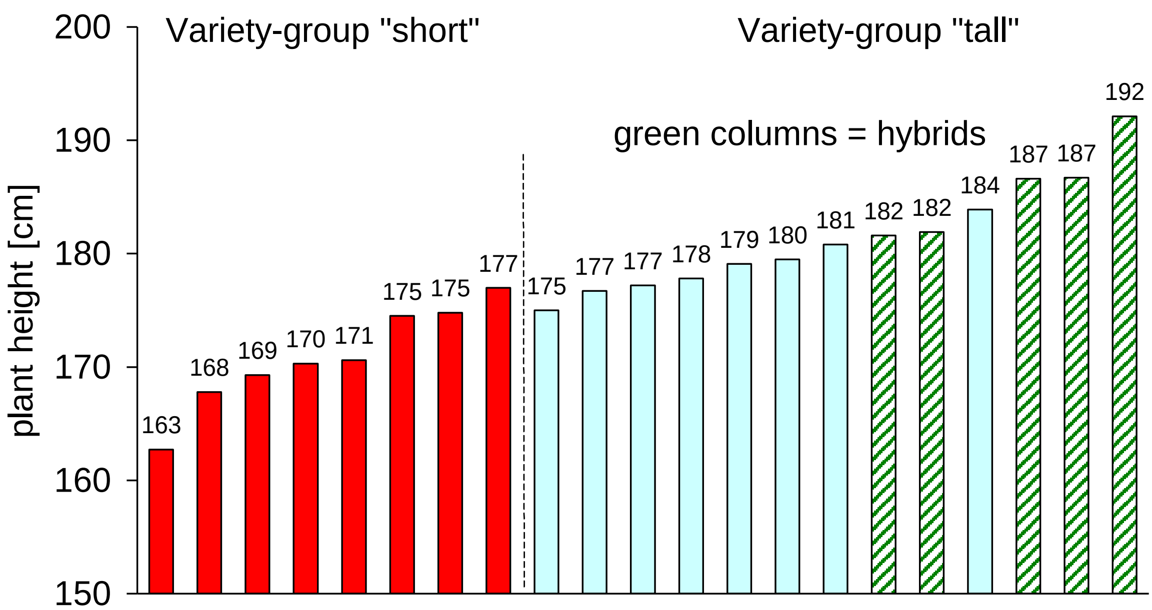


Fig. 2: Plant heights and partition into short and tall varieties, Federal variety trials for winter oilseed rape, Germany 1999

The correlation between plant height and competitiveness is shown in figure 3. In both groups one cm of plant height causes more than 0,1 dt/ha effect on grain yield of a neighboured plot. When a multiple regression is calculated and plant height, lodging and breeding system (hybrid/non-hybrid) are taken into one equation, all three parameters showed influence on competitiveness (Tab. 1). If a non-hybrid-variety is neighboured on both sides by a hybrid-variety that is 10 cm taller and has 1.0 greater susceptibility to lodging then yield will be 2 x (0,662 + 10 x 0,051 + 0,507) = 3,358 dt/ha lower than if the variety is neighboured by itself.

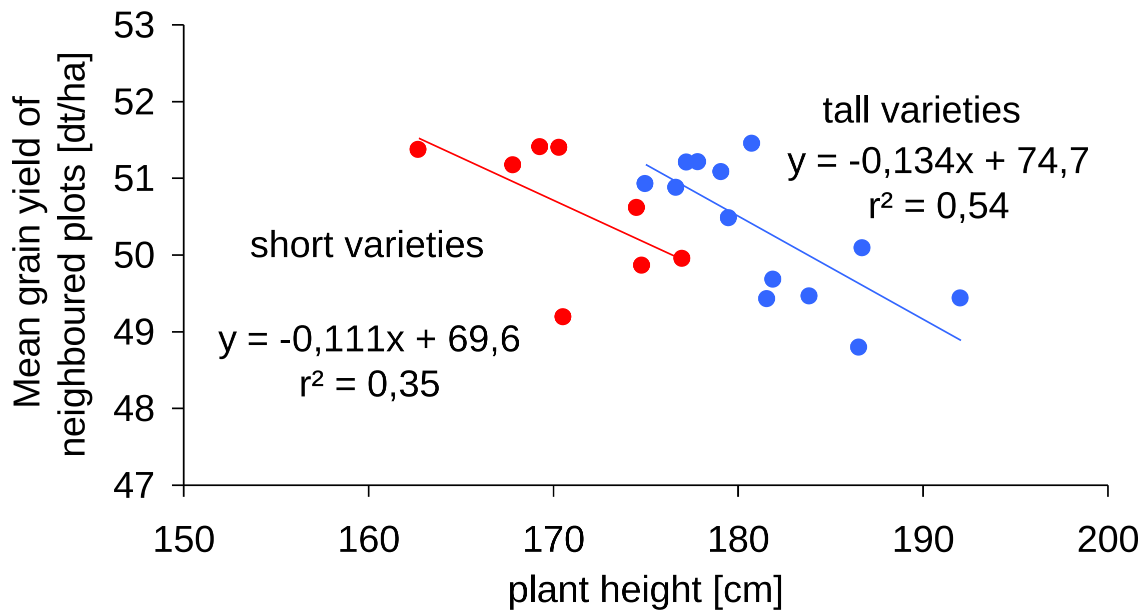


Fig. 3: Plant heights and competitiveness of different varieties, Federal variety trials for winter oilseed rape, Germany 1999

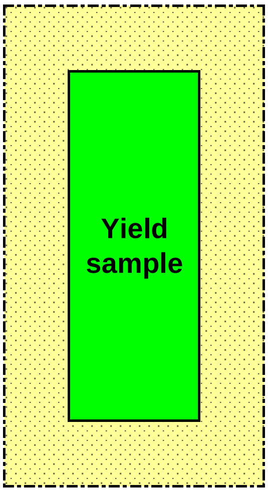
Tab. 1: Parameters of multiple regression between varietal characteristics and competitiveness[1)]

Year	Mean [dt/ha]	Interception [dt/ha]	OP/hybrid 0 / 1	plant height [cm]	lodging [1-9]	r^2	F-value (model)
1997	46,57	55,57	-0,722	-0,045	-0,502	0,50	4,4*
1998	45,57	54,95	-0,488	-0,047	-0,572	0,76	11,6***
1999	50,31	63,24	-0,775	-0,061	-0,448	0,77	10,3**
Mean			-0,662	-0,051	-0,507		

*1) Neighbourhood on one side; *, **, *** significant F-Value with α = 5%, 1%, 0.1%*

3. Possibilities to reduce interplot interference

There are different possibilities to reduce interference effects. The first and most powerful is to sow wider plots and to harvest only the core of the plot. The border rows have to be discarded in this case. Bias will be reduced to a minimum but costs will increase because of difficulties at harvest and an increase of total plot area.



Plot size
3,00 x 9,50 m = 28,5 m²

Size of the yield sample
1,50 x 8,00 m = 12,0 m²

Fig. 4: „Optimum“ plot size: Discard of border rows

Tab. 2: Experimental error (coefficient of variation [%]) in oilseed rape variety trials with different plot sizes (UFOP 1992-94)

Year	Experimental site	Plot width		
		Double (3,0 m)	Core / discard of border rows (1,5 m out of 3 m)	Single (1,5 m)
1992	Futterkamp	2,7	3,2	4,1
	Hohenlieth	3,0	2,6	4,4
	Teendorf	4,6	8,1	6,9
	Dornburg	5,6	5,7	6,7
1993	Futterkamp	3,3	4,1	4,8
	Hohenlieth	2,4	2,8	4,4
	Teendorf	4,0	4,2	5,4
	Freising	4,7	5,5	5,0
1994	Futterkamp	4,2	6,0	6,0

Hohenlieth	4,8	7,1	6,8
Poppenburg	4,1	5,1	6,3
Thuele	10,0	8,5	10,9
arithmetic mean	**4,5**	**5,2**	**6,0**
Tukey-grouping (α = 5%)	b	a	a

A second way is to sow wider plots and harvest all rows. When plot width is doubled interference effects should be halved. In a trial series 1992-1994 the doubled plot width showed significant lower error variances (Tab. 2). Because of increase in plot area, experimental error decreases. This allows reducing the number of replications (Tab. 3).

Tab. 3: Calculated LSD (t-Test, α = 5%) at different combinations of plot type and number of replications

number of replications	error variance (coefficient of variation %)		
	5,0 (double width)	5,5 (core)	6,0 (single width)
2	10,0	11,0	12,0
3	8,2	9,0	9,8
4	7,1	7,8	8,5

Third possibility is to separate varieties from each other that have different competitiveness. A partition into four groups (short hybrids, tall hybrids, short op-varieties, tall op-varieties) like shown in Fig. 5 may be a good choice. Such a trial can be carried out and analysed as a type of split-plot-design. Comparisons between varieties of the same group have lower LSD than comparisons between varieties of different groups.

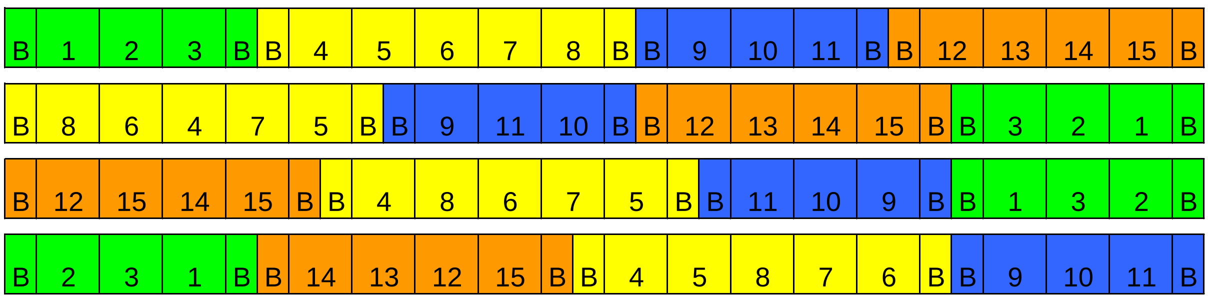


Fig. 5: Design of a variety trial with four competition groups

It is also possible to test the different groups in totally separated trials, but in this case comparisons between varieties of different groups are not possible at a single location and have high LSD when analysed over several locations.

A fourth possibility to overcome interference effects is a mathematical adjustment. Two different models are possible: Analysis of covariance (ANCOVA) or Analysis of variance (ANOVA). The equations to calculate the monocultural effect for one variety are shown below. For an exakt estimation of interference effects and yields in monoculture a neighbour-balanced randomization is necessary. Totally balanced designs need n-1 replications when n is the number of varieties. So this mathematical approach is only a good alternative when the number of varieties is not to high.

a) **Analysis of covariance**

$$x_{ijklm} = \mu + b_m(s_l) + v_i^* + s_l + vs_{il} + ß\,(h_j - 1/2(h_{j-1} + h_{j+1}) + e$$

	x_{ijklm}	= the observed value
	μ	= grand mean
fix effects	v_i *	= the monoculture effect of the i-th variety
	h_j	= the plant height in a plot
	h_{j-1}	= the plant height of the left neighbour
	h_{j+1}	= the plant height of the right neighbour
	ß	= the covariate regression coefficient
random effects	s_l	= the l-th site
	vs_{il}	= the interaction of i-th variety with l-th site
	$b_m(s_l)$	= the m-th block (in l-th site)
	e	= error

b) Analysis of variance or Maximum-Likelihood

$$x_{ijklm} = \mu + b_m(s_l) + v_i + s_l + vs_{il} + n_j + m_k + e$$

	x_{ijklm}	= the observed value
	μ	= grand mean
fix effects	v_i	= the i-th variety
	n_j	= the j-th left neighbour
	m_k	= the k-th right neigbour

random effects s_l = the l-th site

vs_{il} = the interaction of i-th variety with l-th site

$b_m(s_l)$ = the m-th block (in l-th site)

e = error

the monoculture effect: $v_i^* = v_i + n_i + m_i$

4. Summary

In the majority of cases variety trials are carried out in a randomized complete block-design (RCB) or in lattice-designs. Complete or incomplete blocks should have approximately a quadratic shape to reduce soil heterogeneity and minimize experimental error. Furthermore it can be shown that many small plots give more exact results than a small number of large plots. In consideration of a minimum plot size to accomodate the machinery needed to seed, fertilize, cultivate, and harvest the plot, plot sizes of 10 m² and a rectangular, long and narrow shape will be the best choice.

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To minimize or overcome effects of interplot interference several alternative ways are possible:

6. To sow wider plots, harvest only the core of the plot and discard the border rows (Fig. 4)
7. To sow wider plots and harvest the whole plot (Tab. 2 and 3)
8. Partition in different groups of varieties according to the type of breeding technique (hybrid, non-hybrid) or plant height (Fig. 5)
9. Adjustment of performance with analysis of covariance (i.e. covariate plant height of neighbours) or estimation of predicted yield for monoculture (Maximum Likelihood, General linear model)

The author recommends a partition in 4 groups (long hybrids, short hybrids, long OP-varieties, short OP-varieties) with different competitiveness. Plot width should be doubled. The lower error variance because of greater plot area allows reducing the number of replicates. The experiment can be carried out and analysed as a split-plot-design.

The project has been financielly supported bei German plant breeders association (SFG) and UFOP e.V.

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