# Experiences with incomplete block designs in Denmark

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- Introduction
  - Official variety testing
  - Heterogeneity of fields
- Used incomplete block designs
  - Types of trials
  - Types of designs
  - Layout in the field
  - No. of varieties
- Efficiency of the designs
  - Analyses
  - Relative efficiencies
- Discussion
  - Benefits
  - Drawbacks

# Introduction

- Official variety testing
  - Two types of trials in Denmark
    - DUS trials (one trial per crop per year)
      - On one experimental station
    - Performance trials (4-6 trials per crop per year)
      - On experimental stations and private farms
  - Increasing number of varieties to be tested
  - The number of varieties in the trials cannot be determined by the experimenter
- Other trials for different types of research

# Introduction

- Heterogeneity of fields
  - Size of experiment
    - Plot size most typical 1.5 m by 10-12 m
    - Size of complete blocks e.g. 150 m by 15 m or 75 m by 30 m or 50 m by 45 m (100 varieties)
  - Previous experiments on the land (crop rotation)
  - Soil heterogeneity
  - Heterogeneous application of e.g. fertiliser

# Used incomplete block designs

- Types of trials
  - Distinctness Uniformity and Stability trials
    - Winter Rape, Spring Rape, Yellow Mustard, Sugar Beets, Winter Wheat, Spring Wheat, Winter Barley, Spring Barley, Oat, Grassland Crops
  - Performance trials
    - Winter Rape, Spring Rape, Yellow Mustard, Sugar Beets, Winter Wheat, Spring Wheat, Winter Barley, Spring Barley, Oat, Grassland Crops, Rye, Triticale, Maize and Potatoes
  - BAR-OF (Barley for organic farming)
    - Spring Barley

# Used incomplete block designs

- Types of designs
  - $\alpha$-designs
  - Lattice designs
  - Row-column designs based on $\alpha$-designs
  - $\alpha$-designs in split-plots
  - Ad. hoc. designs in a few cases

# Used incomplete block designs

- Lay out in the field (principles)
  - Number of plots per incomplete block usually slightly less than $v^{0.5}$
  - Incomplete blocks should cover only one row of plots in the field
  - It should be possible to stop harvesting (and other operations in the field) at the border between two complete replicates

# Used incomplete block designs

- Number of varieties in some crops in spring 2003
  - Spring barley: 101
  - Peas: 34
  - Maize: 74
- Since 1979 the number of varieties in the incomplete block designs has ranged from about 12 and up to more than 300

# Used incomplete block designs

- Example 1 ($\alpha$-design)
  - 119 varieties
  - 2 complete replicates
  - 15 incompletes blocks per replicate
  - 8 (7) plots per incomplete block
  - Laid out in 4 rows of plots with up to 63 plots in each

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 30 | | 77 | 102 | 63 | 24 | 32 | 19 |
| 105 | | 62 | 41 | 9 | 95 | 51 | 48 |
| 4 | | 12 | 80 | 61 | 108 | 13 | 116 |
| 51 | | 26 | 7 | 117 | 106 | 111 | 45 |
| 32 | | 78 | 107 | 53 | 72 | 14 | 16 |
| 94 | | 31 | 88 | 14 | 64 | 24 | 118 |
| 115 | | 69 | 98 | 26 | 88 | 91 | 1 |
| 101 | 59 | 76 | 29 | 109 | 38 | 89 | 71 |
| 91 | 68 | 50 | 100 | 92 | 37 | 74 | 97 |
| 98 | 81 | 108 | 115 | 69 | 79 | 35 | 8 |
| 90 | 50 | 119 | 83 | 42 | 17 | 34 | 3 |
| 65 | 96 | 43 | 53 | 44 | 16 | 93 | 28 |
| 1 | 58 | 94 | 22 | 86 | 78 | 20 | 46 |
| 3 | 114 | 5 | 36 | 7 | 119 | 17 | 63 |
| 52 | 76 | 21 | 49 | 110 | 60 | 67 | 109 |
| 43 | 15 | 54 | 27 | 13 | 8 | 112 | 30 |
| 18 | 33 | 84 | 25 | 35 | 49 | 38 | 2 |
| 67 | 41 | 81 | 106 | 5 | 77 | 92 | 55 |
| 97 | 113 | 52 | 103 | 31 | 34 | 86 | 114 |
| 2 | 22 | 9 | 70 | 85 | 28 | 101 | 73 |
| 116 | 56 | 33 | 105 | 83 | 80 | 72 | 87 |
| 75 | 70 | 95 | 59 | 102 | 21 | 37 | 42 |
| 57 | 118 | 99 | 18 | 40 | 104 | 57 | 65 |
| 39 | 54 | 60 | 6 | 48 | 103 | 15 | 4 |
| 107 | 66 | 56 | 47 | 55 | 12 | 40 | 10 |
| 89 | 19 | 79 | 117 | 73 | 36 | | 90 |
| 47 | 100 | 82 | 85 | 84 | 74 | | 61 |
| 82 | 10 | 44 | 23 | 11 | 87 | | 113 |
| 62 | 6 | 66 | 68 | 112 | 45 | | 104 |
| 71 | 93 | 11 | 75 | 23 | 25 | | 110 |
| 27 | 111 | 58 | 64 | 29 | 99 | | 96 |
| 63 | 24 | 32 | 19 | 46 | 20 | | 39 |

# Used incomplete block designs

- Example 2 (Row column based on $\alpha$-design)
  - 123 varieties
  - 3 complete replicates
  - 16 incompletes blocks per replicate
  - 8 (7 + ’guards’) plots per incomplete block
  - Laid out as row-column design with 24 rows of 16 plots

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 116 | 60 | 101 | 38 | 109 | 21 | 81 | 36 | 28 | 108 | 97 | 11 | 62 | 89 | 55 |
| 56 | 63 | 115 | 47 | 59 | 93 | 29 | 121 | 104 | 61 | 39 | 79 | 103 | 75 | 90 | 51 |
| 1 | 15 | 65 | 82 | 35 | 91 | 110 | 100 | 71 | 84 | 42 | 74 | 18 | 123 | . | 12 |
| 17 | 14 | 50 | 24 | 67 | 87 | 57 | 102 | 37 | 99 | 72 | 23 | 112 | 118 | 86 | 119 |
| 30 | 107 | 34 | 44 | 6 | 16 | 19 | 92 | 94 | 83 | 26 | 106 | 46 | . | 48 | 52 |
| 120 | 49 | 69 | 88 | 4 | 25 | 10 | 27 | 53 | 70 | 64 | 96 | 78 | 76 | 45 | 58 |
| 68 | 95 | 117 | 7 | 111 | 77 | 32 | 80 | 41 | 20 | 5 | 40 | 98 | 43 | 54 | 13 |
| . | 73 | 66 | 85 | 105 | 114 | 22 | 2 | 33 | 8 | . | . | 3 | 122 | 113 | 9 |
| 25 | 13 | 88 | 28 | 16 | 93 | 46 | 11 | 17 | 22 | 77 | 110 | 74 | 121 | 2 | 102 |
| 101 | 73 | 37 | 122 | 12 | 27 | 39 | 112 | 18 | 7 | 56 | 60 | 49 | 48 | 106 | 5 |
| 95 | 41 | 66 | 85 | 55 | 62 | 107 | 69 | 92 | 100 | 63 | 57 | 42 | 50 | 51 | 64 |
| 87 | 47 | . | 6 | 120 | 90 | . | 78 | 123 | 20 | 54 | 36 | . | 113 | 119 | 89 |
| 79 | 71 | 97 | 8 | 38 | 4 | 98 | 24 | 58 | 86 | 1 | 83 | 94 | 75 | 32 | 114 |
| 30 | 91 | 118 | 19 | 68 | 59 | 72 | 104 | 80 | 33 | 81 | 76 | 15 | 45 | 109 | . |
| 10 | 117 | 23 | 44 | 82 | 29 | 9 | 26 | 108 | 3 | 99 | 96 | 115 | 84 | 40 | 21 |
| 103 | 53 | . | 14 | 105 | 70 | 31 | 43 | 52 | 111 | 35 | 67 | 65 | 34 | 61 | 116 |
| 72 | 14 | 12 | 107 | 26 | 79 | 36 | 96 | 104 | 13 | 110 | 62 | 114 | . | 7 | 53 |
| 54 | 70 | 2 | 95 | 28 | 38 | 61 | 118 | 15 | 29 | 10 | 122 | 37 | 42 | . | 94 |
| 9 | 85 | 59 | 4 | 120 | 5 | 92 | 91 | 77 | 24 | 56 | 44 | 89 | 31 | 102 | 65 |
| 27 | 76 | 66 | 32 | 20 | 81 | 75 | 87 | 101 | 34 | 3 | 121 | 35 | 84 | 16 | 50 |
| 82 | 100 | 11 | 17 | 86 | 30 | 43 | 113 | 48 | 78 | 97 | 80 | 103 | 115 | 69 | 73 |
| 111 | 58 | 33 | 68 | 55 | 21 | 51 | 23 | 1 | 47 | 88 | . | 112 | . | 106 | 46 |
| 52 | 57 | 74 | 19 | 90 | 63 | 108 | 49 | 22 | 116 | 119 | 18 | 45 | 8 | 98 | 117 |
| 105 | 93 | 6 | . | 64 | 25 | 67 | 60 | 40 | 99 | 39 | 83 | 109 | 41 | 123 | 71 |

# Analyses of α-designs

(1) $Y_{vb} = \mu + \alpha_v + \gamma_b + E_{vb}$

(2) $Y_{vrb} = \mu + \alpha_v + \beta_r + \gamma_{rb} + E_{vrb}$ Blocks within reps

(3) $Y_{vrb} = \mu + \alpha_v + \beta_r + C_{rb} + E_{vrb}$ Blocks effects random

$E_{vb}$, $E_{vrb}$ and $C_{rb}$ asumed independent and normal distributed with constant varians, $\sigma_E^2$ og $\sigma_C^2$

# Analyses of Row column based on α-designs

(1) $Y_{vsc} = \mu + \alpha_v + \gamma_s + \delta_c + E_{vsc}$

(2) $Y_{vrsc} = \mu + \alpha_v + \beta_r + \gamma_{rs} + \delta_{rc} + E_{vrsc}$ s and c within replicate

(3) $Y_{vrb} = \mu + \alpha_v + \beta_r + C_{rs} + D_{rc} + E_{vrsc}$ s and c effects random

$E_{vsc}$, $E_{vrsc}$, $C_{rs}$ and $D_{rc}$ assumed independent and normal distributed with constant varians, $\sigma_E^2$, $\sigma_C^2$ and $\sigma_{\mathrm{D}}^2$

# Relative efficiencies

- Sugar beets
  - 13 to 30 varieties
  - 4 to 6 plots per block
    - Root dry matter 1.4 1.0-2.0
    - Top dry matter 1.8 1.0-3.1
    - Sugar weight 1.4 1.0-2.1

# Relative efficiencies

- Barley
  - 100 to 123 varieties
  - 8 to 10 plots per block

| | | |
|---|---|---|
| • Yield (grain) | 1.4 | 1.0-2.5 |
| • Relative dry matter in grains | 1.4 | 1.0-1.7 |
| • RVI | 1.9 | 1.4-2.4 |
| • Weed coverage | 1.4 | 1.0-2.0 |
| • Weed counted | 1.1 | 1.0-1.2 |
| • Disease coverage | 1.0 | 1.0-1.1 |

# Discussion

- Benefits
  - Increased prediction of parameters for variables that seem dependent on soil fertility?
  - More equal variances from trial to trial, as the increase in prediction was greatest in trials with high variability
  - Possible to decrease number of replicates
  - More easy to layout reasonable in field

# Discussion

- Drawbacks
  - More complicated design layout
  - Slightly more sensitive to missing observations
  - More complicated analysis
  - No simple connection between registrations and published results