A “Sudoku” design for field experiments

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Organic Flax Industry in Saskatchewan

- 28,500 ha of organic flax in 2005 (Macey, 2006)
- Long term price ~$25.00/bu (~$1/kg) but goes as high as ~$40.00/bu (University of Saskatchewan, 2006)
- $15 million/year worth of primary production
  - value added in processing
- Most organic production goes into nutraceutical market
Flax nutraceutical products

15 mg Lignans,
54% Omega-3 alpha-linolenic acid (ALA)
16% Omega-9 oleic acid (OA)
14% Omega-6 linoleic acid (LA)

Fuller taste due to more naturally occurring nutrients than other brands.

Quality control from soil to oil. Our involvement begins in the fields and continues through harvesting, seed selection, oil pressing and purity testing.

Superior freshness with FreshGuard™ antioxidants, light protective bottles and nitrogen-flushed packaging.

Cold Pressed, Unrefined & Hexane-Free. No chemical solvents, sugars, starch, artificial colors, flavors or preservatives.

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Nature's Way® EFAGold® is the highest quality flax seed oil, and one of nature's richest botanical sources of healthy Omega-3 essential fatty acids.
Weed competition in flax

- Weeds are a huge problem in organic farming
  - no herbicides allowed
- Flax least competitive of crops commonly grown in Western Canada (Dew, 1972)
- Delayed planting can reduce populations of early emerging weeds (Sexsmith, 1955)
Weed competition in flax

- Dr. G Rowland developed early flowering flax genotypes
- Wanted to test if they yielded proportionally higher at later seeding dates
- Test with a “simple” seeding date by genotype experiment
Issues with seeding date trials

- requirement that they be seeded at the same time
- using a factorial randomized block design doesn’t work great
  - trouble of getting machinery to the randomized plots
  - border effects from crops at different stages
- often use split plot designs
  - seeding date main plot
  - “other” effect in the sub plots
Seeding rate trial design: Two factor RCB Seeding date and other treatment

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Seed Date 1 Four treatments
Seed Date 2 A,B,C,D
Seed Date 3
Seeding rate trial design: Two factor Split plot Seeding date (main plot) and other treatment

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Seed Date 1: Four treatments
Seed Date 2: A, B, C, D
Seed Date 3
Seeding rate trial design: Two factor “Herb design” Seeding date (main plot) and other treatment

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Seed Date 1: Four treatments
Seed Date 2: A, B, C, D
Seed Date 3
Seeding rate trial design: Two factor “Sideways” Split plot Seeding date (main plot) and other treatment

Block 1
A B B
B D D
D A C
C C A

Block 2
B C A
C D B
D A C
A B D

Block 3
B D C
A B A
D A B
C C D

Block 4
A C A
D D C
C A D
B B B

Seed Date 1
Four treatments
A,B,C,D

Seed Date 2

Seed Date 3
Seeding rate trial design: Two factor “Suduko” Split plot Seeding date (main plot) and other treatment

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Seed Date 1: Four treatments A,B,C,D
Seed Date 2: Four treatments A,B,C,D
Seed Date 3: Four treatments A,B,C,D
One seeding date of the experimental design

Seed Date 1

A B D C
B D C A
D C A B
C A B D
Potential of this design

- Also the potential to use multiples of the number of reps for the subplots
- \( r^n \)
  - where \( r \) is rep and \( n \) is an integer
- thus number of subplot treatments for different reps
- 3 reps – 3, 6, 9... treatments
- 4 reps – 4, 8, 12... treatments
- 5 reps – 5, 10, 15... treatments
- 3, 4, 5, 6, 8, 9, 10, 12 subplot treatments possible
12 flax genotypes
- 9 advanced breeding lines selected for early flowering
- 3 registered varieties
  - CDC Bethune, CDC Normandy, and Vimy
- 3 seeding dates
  - May 15
  - June 1
  - June 15
Random Effects

- Experiment was ran at two sites for three years
  - 6 site-years
- Total of 432 observations
  - $12 \times 3 \times 4 \times 6$
**Experimental design**

- **Row and Column design**
- **Used to facilitate different seeding dates**

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**Seed Date**

- Seed Date 1
- Seed Date 2
- Seed Date 3

**Replication**

- Rep 1
- Rep 2
- Rep 3
- Rep 4

**Seeding Dates**

- Seed Date 1
- Seed Date 2
- Seed Date 3
Experimental design

- Row and Column design
- 4 rows and 4 columns

Split plot, partially Latinized, row and column design
Model statement (Proc mixed)

Single location RCBD analyzed as a split plot (columns are blocks)

model Yield = sd cult sd*cult;
random column sd*column;
Single location RCBD analyzed as a split plot (columns are blocks) with rows added

```
model Yield = sd cult sd*cult;
random row column sd*column;
```
Model statement

Multi location RCBD analyzed as a split plot (columns are blocks) with rows added

model Yield = sd cult sd*cult;
random siteyr row(siteyr) sd*column(siteyr) siteyr*sd siteyr*cult siteyr*sd*cult;
Effect of seeding date and genotype on flax yield. Average of six site years.
Relationship between time to flowering and yield. Average of six site years.

\[ y = -27.647x + 2340.8 \]
\[ R^2 = 0.4849 \]

\[ y = -22.088x + 2781.7 \]
\[ R^2 = 0.0656 \]

\[ y = 26.796x - 292.88 \]
\[ R^2 = 0.0861 \]
Effect of genotype on days to 10% flowering. Average of six site-years.
Effect of genotype on days to 10% flowering. Average of six site-years.
Conclusions

- It seemed to work???
  - still an analysis in progress
  - efficiency?

- design was effective in removing spatial variability in two directions

- may have applicability in other agronomic field trials
  - factorial design, two factors
  - where treatments can only be applied in strips
  - seeding date trials, irrigation trials, field scale “sprayer” trials
  - greater than 3 subtratments
Those who paid for this:

Saskatchewan Agriculture, Food and Rural Revitalization
Questions?
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Seeding date and other treatment

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Seeding date (main plot) and other treatment

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Seed Date 1: Two treatments
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