A “Suduko” design for field experiments

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UNIVERSITY OF SASKATCHEWAN

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

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.

15 mg Lignans.
54% Omega-3 alpha-linolenic acid (ALA)
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Flax Oil

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NEW! Drip-Free Flip-Top

ORGANIC

15 MG LIGNANS

Cold Pressed / Zero Trans Fat

DIETARY SUPPLEMENT **24 FL. OZ. (710 ml)**

dation: Shake well before al settling may occur. Take (15 ml) 1 to 3 times daily. used in salad dressings, eads; on bread, rice and ed into yogurt, cottage or cold beverages. **after opening.**

ement Facts

Serving Size 1 Tbsp (15 ml)
Servings Per Container 48

Amount Per Serving		% Daily Value
Calories	130	
Calories from Fat	130	
Total Fat	14 g	22%†
Saturated Fat	1.5 g	7%†
Polyunsaturated Fat	10 g	**
Monounsaturated Fat	2.5 g	**
Omega-3 Fatty Acids as Alpha-Linolenic Acid (ALA)	7.5 g (7,490 mg)	**
Lignan-Rich Flax (providing 15 mg Lignans)	2.8 g (2,800 mg)	**
Omega-9 Fatty Acids as Oleic Acid (OA)	2.2 g (2,230 mg)	**
Omega-6 Fatty Acids as Linoleic Acid (LA)	2.0 g (1,970 mg)	**

†Percent Daily Values based on a 2,000 calorie diet.
****Daily Value not established.**

Ingredients: Organic Flax Oil (seed), Organic Lignan-Rich Flax Oil (seed), Antioxidant Blend (Rosemary, Mixed Tocopherols, Ascorbyl Palmitate, Citric Acid)

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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

Block 1	A	B	B	B	C	A	D	D	C	A	C	D
Block 2	B	D	D	C	D	B	A	B	A	A	C	C
Block 3	D	A	C	D	B	C	D	A	B	C	A	B
Block 4	C	C	A	A	B	D	D	C	D	B	A	B

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

Block 1	A	B	D	C	C	A	B	D	C	A	B	D
Block 2	B	D	A	C	D	B	A	C	A	B	C	D
Block 3	B	A	C	D	B	C	D	A	D	C	A	B
Block 4	C	D	B	A	B	D	A	C	D	B	A	C

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

Block 1	A	B	D	C	C	A	B	D	C	A	B	D
Block 2	B	D	A	C	D	B	A	C	A	B	C	D
Block 3	B	A	C	D	B	C	D	A	D	C	A	B
Block 4	C	D	B	A	B	D	A	C	D	B	A	C

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			Block 2			Block 3			Block 4		
A	B	B	B	C	A	B	D	C	A	C	A
B	D	D	C	D	B	A	B	A	D	D	C
D	A	C	D	A	C	D	A	B	C	A	D
C	C	A	A	B	D	C	C	D	B	B	B

Seed Date 1
Seed Date 2
Seed Date 3

Four treatments
A,B,C,D

Seeding rate trial design: Two factor "Suduko" Split plot Seeding date (main plot) and other treatment

Block 1			Block 2			Block 3			Block 4		
A	B	B	A	C	B	C	D	D	A	C	D
B	D	D	B	A	D	A	C	B	C	A	C
D	A	C	C	D	C	D	A	A	B	B	B
C	C	A	D	B	A	B	B	C	D	D	A

Seed Date 1
Seed Date 2
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

Flax Cultivar X Seeding Date

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
  - 12x3x4x6

Experimental design

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

Row	Column 1									Column 2									Column 3									Column 4								
1	2	12	10	12	3	9	2	7	8	8	5	11	1	3	9	5	11	10	4	7	2	3	12	1	8	4	6	10	6	1	6	4	9	7	5	11
2	1	8	5	10	7	6	6	1	10	2	1	3	11	10	6	12	3	9	8	5	12	11	8	4	7	3	9	4	9	11	5	2	7	4	2	12
3	6	11	4	11	4	5	9	12	3	7	6	9	8	7	5	4	7	2	10	3	1	5	10	6	10	12	2	12	8	2	11	8	1	9	3	1
4	7	3	9	1	8	2	5	11	4	4	12	10	4	2	12	6	8	1	11	6	9	7	2	9	11	5	1	5	3	7	12	3	10	8	6	10
	Seed Date 3			Seed Date 2			Seed Date 1			Seed Date 2			Seed Date 3			Seed Date 1			Seed Date 2			Seed Date 1			Seed Date 3			Seed Date 2			Seed Date 1			Seed Date 3		
	REP 1									REP 2									REP 3									REP 4								

2	7	8
6	1	10
9	12	3
5	11	4
Seed Date 1		

5	11	10
12	3	9
4	7	2
6	8	1
Seed Date 1		

3	12	1
11	8	4
5	10	6
7	2	9
Seed Date 1		

6	4	9
5	2	7
11	8	1
12	3	10
Seed Date 1		

Experimental design

- Row and Column design
- 4 rows and 4 columns

Row	Column 1									Column 2									Column 3									Column 4								
1	2	12	10	12	3	9	2	7	8	8	5	11	1	3	9	5	11	10	4	7	2	3	12	1	8	4	6	10	6	1	6	4	9	7	5	11
2	1	8	5	10	7	6	6	1	10	2	1	3	11	10	6	12	3	9	8	5	12	11	8	4	7	3	9	4	9	11	5	2	7	4	2	12
3	6	11	4	11	4	5	9	12	3	7	6	9	8	7	5	4	7	2	10	3	1	5	10	6	10	12	2	12	8	2	11	8	1	9	3	1
4	7	3	9	1	8	2	5	11	4	4	12	10	4	2	12	6	8	1	11	6	9	7	2	9	11	5	1	5	3	7	12	3	10	8	6	10
	Seed Date 3			Seed Date 2			Seed Date 1			Seed Date 2			Seed Date 3			Seed Date 1			Seed Date 2			Seed Date 1			Seed Date 3			Seed Date 2			Seed Date 1			Seed Date 3		
	REP 1									REP 2									REP 3									REP 4								

Split plot, partially Latinized, row and column design

2	7	8
6	1	10
9	12	3
5	11	4
Seed Date 1		

5	11	10
12	3	9
4	7	2
6	8	1
Seed Date 1		

3	12	1
11	8	4
5	10	6
7	2	9
Seed Date 1		

6	4	9
5	2	7
11	8	1
12	3	10
Seed Date 1		

Model statement (Proc mixed)

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

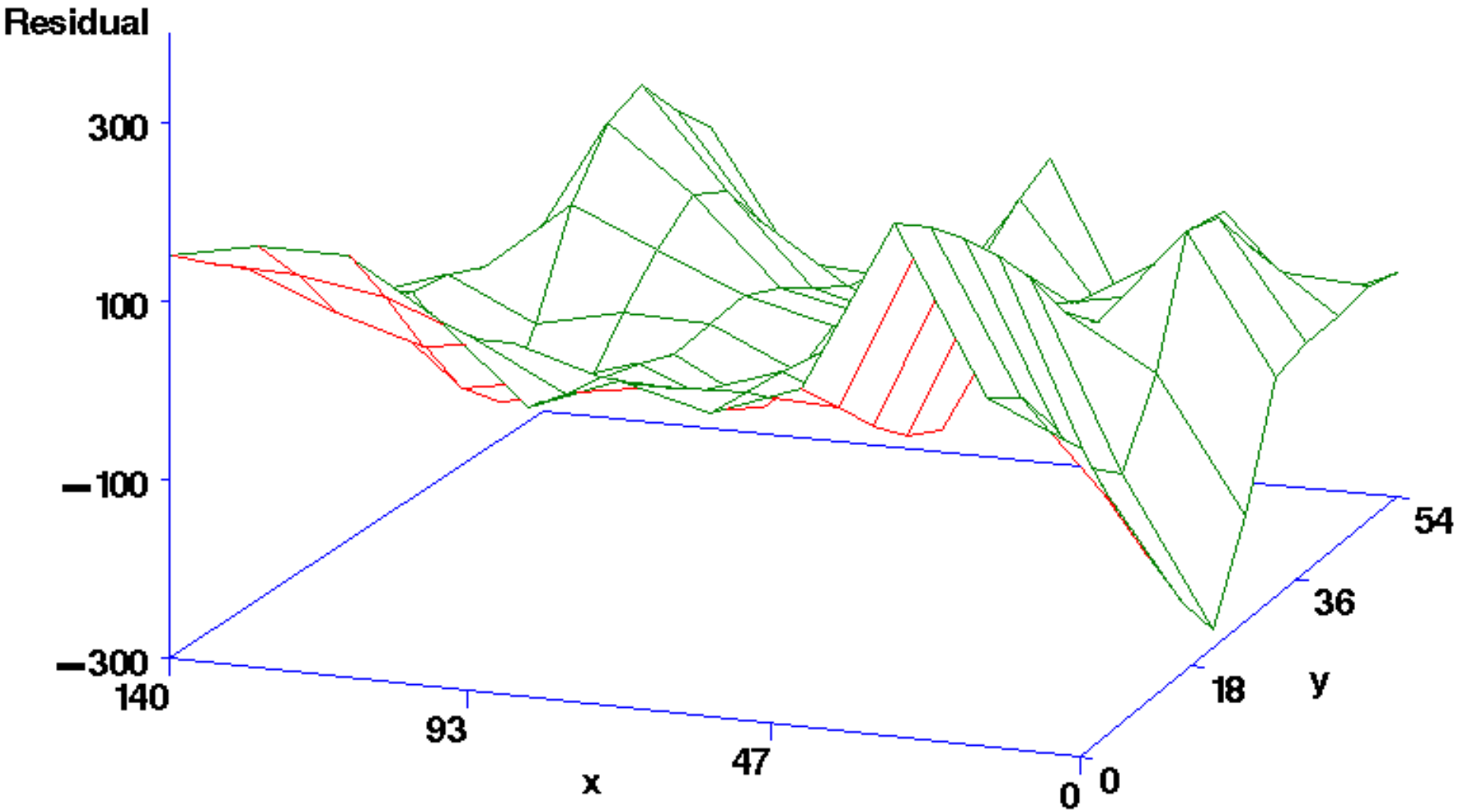
```
model Yield =  sd cult sd*cult;
random column sd*column;
```

Model statement (Proc mixed)

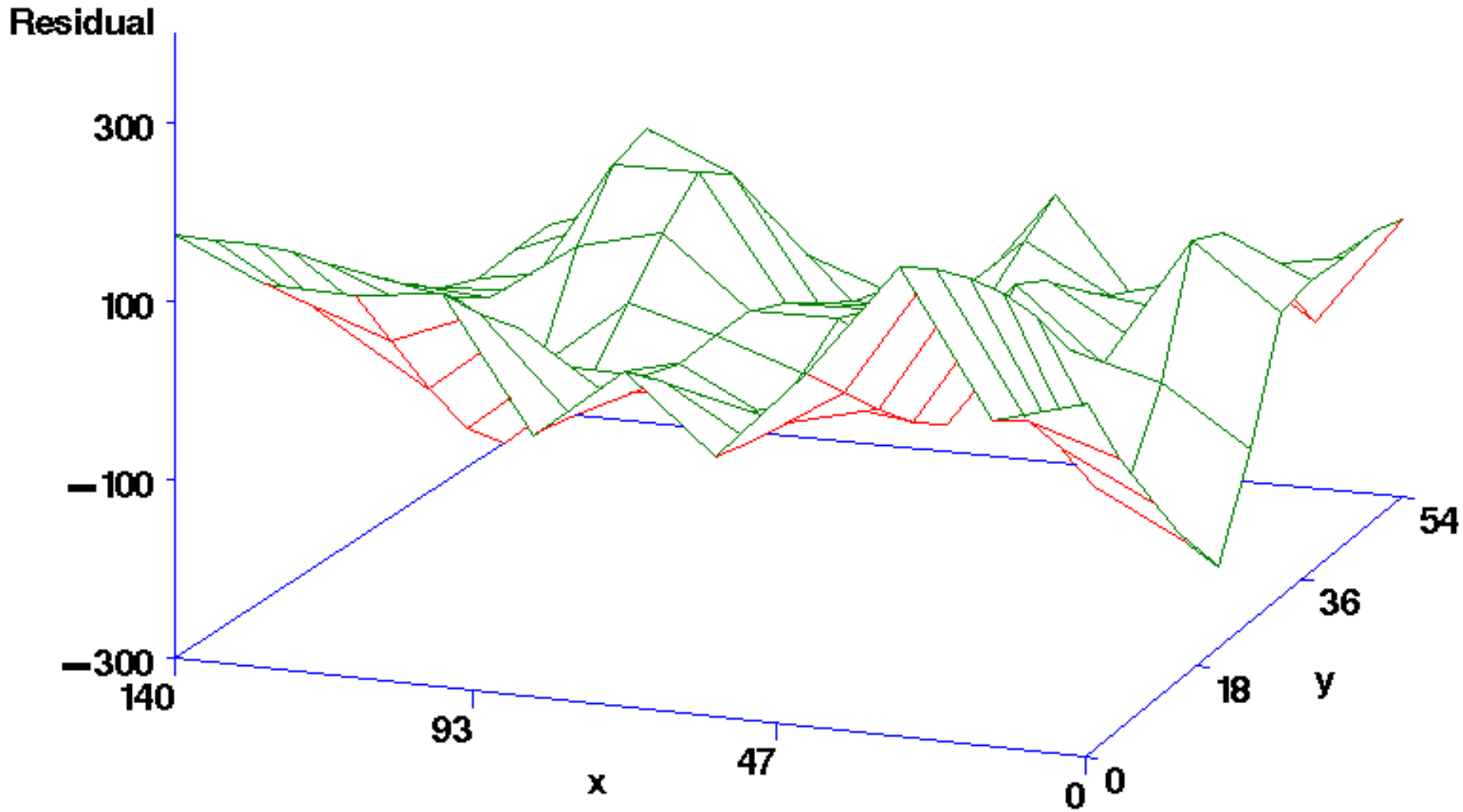
Single location RCBD analyzed as a split plot (columns are blocks) with rows added

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

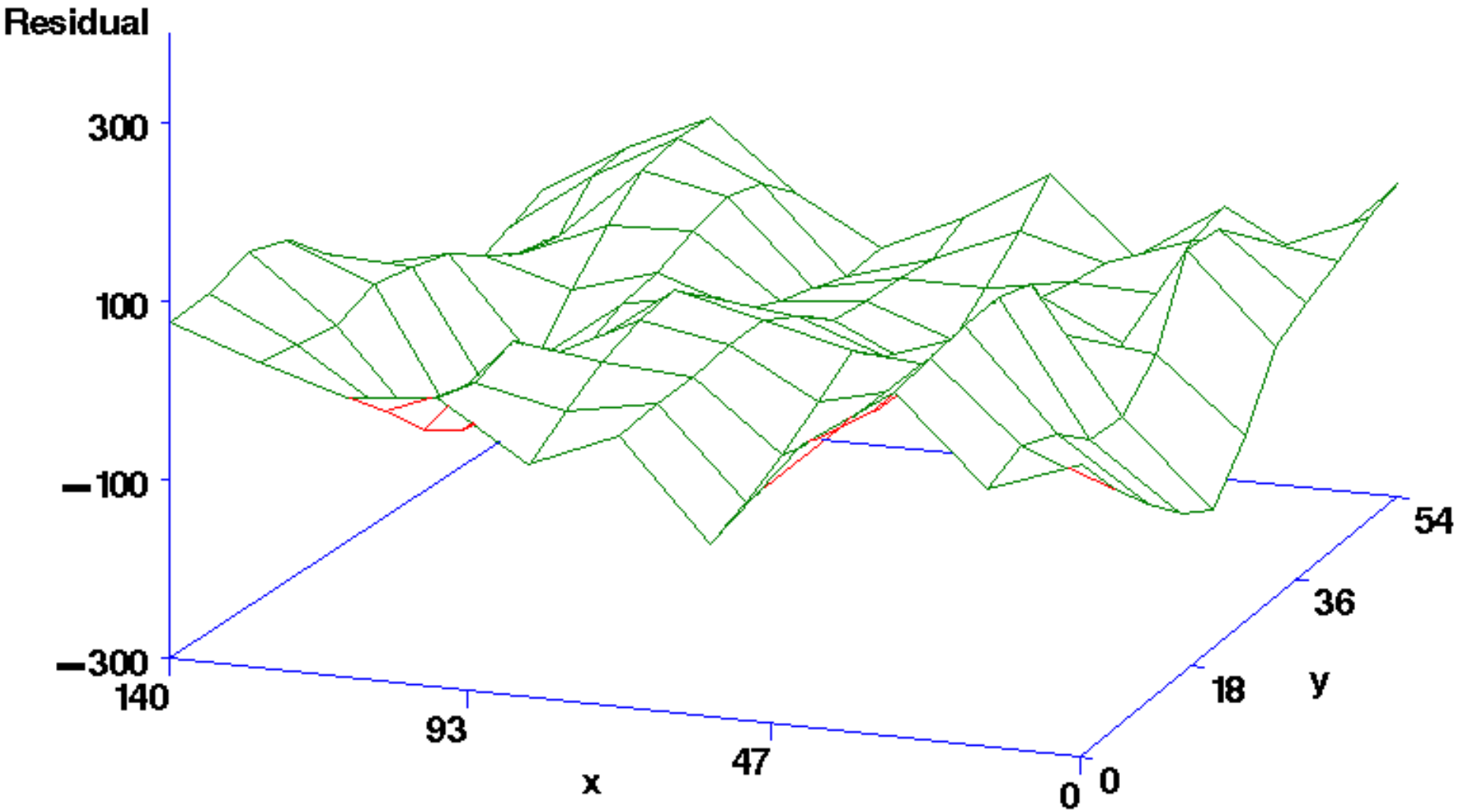
Mel05 spatial no row column resids



Mel05 column resids



Mel05 row column resids

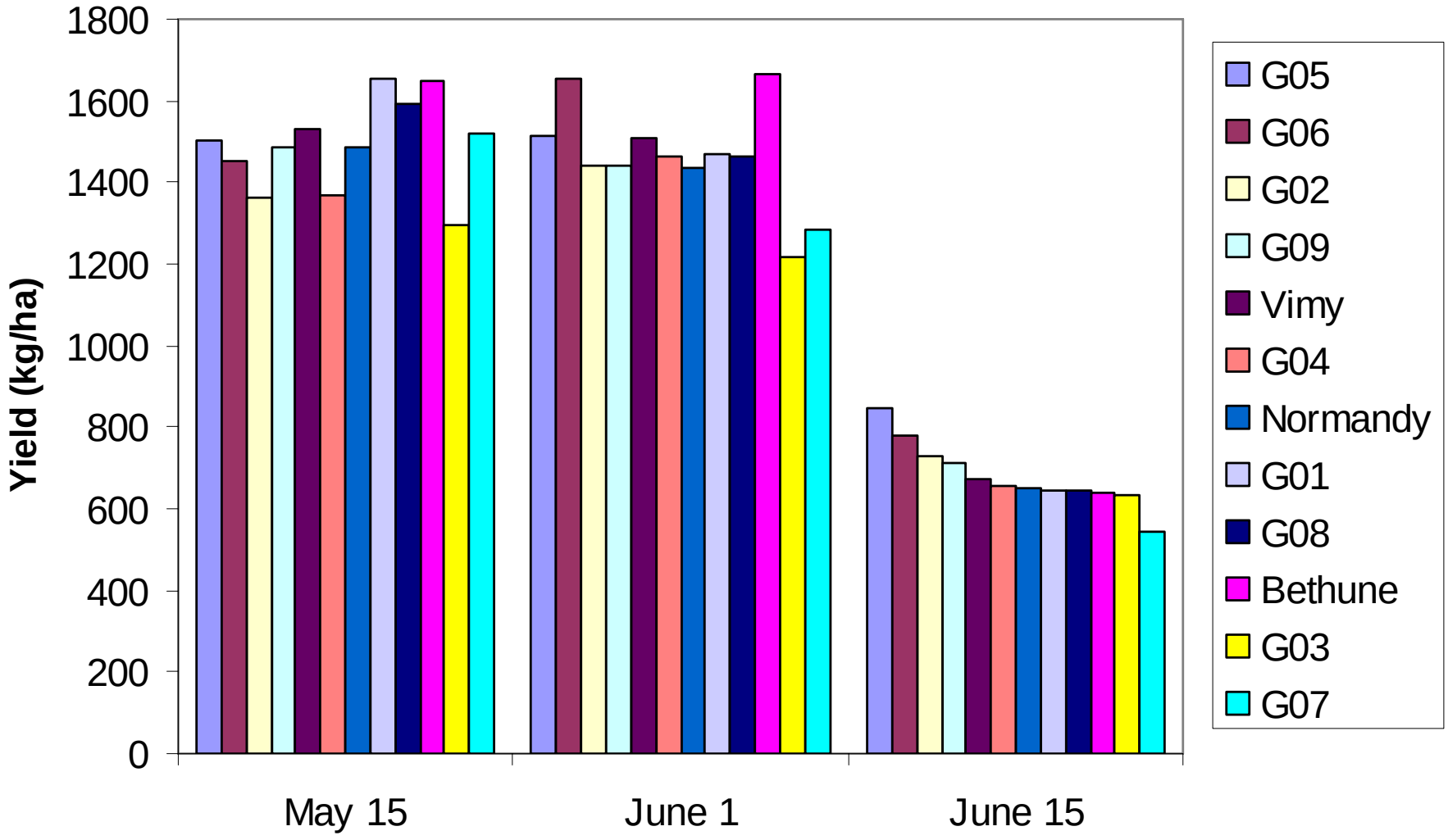


Model statement

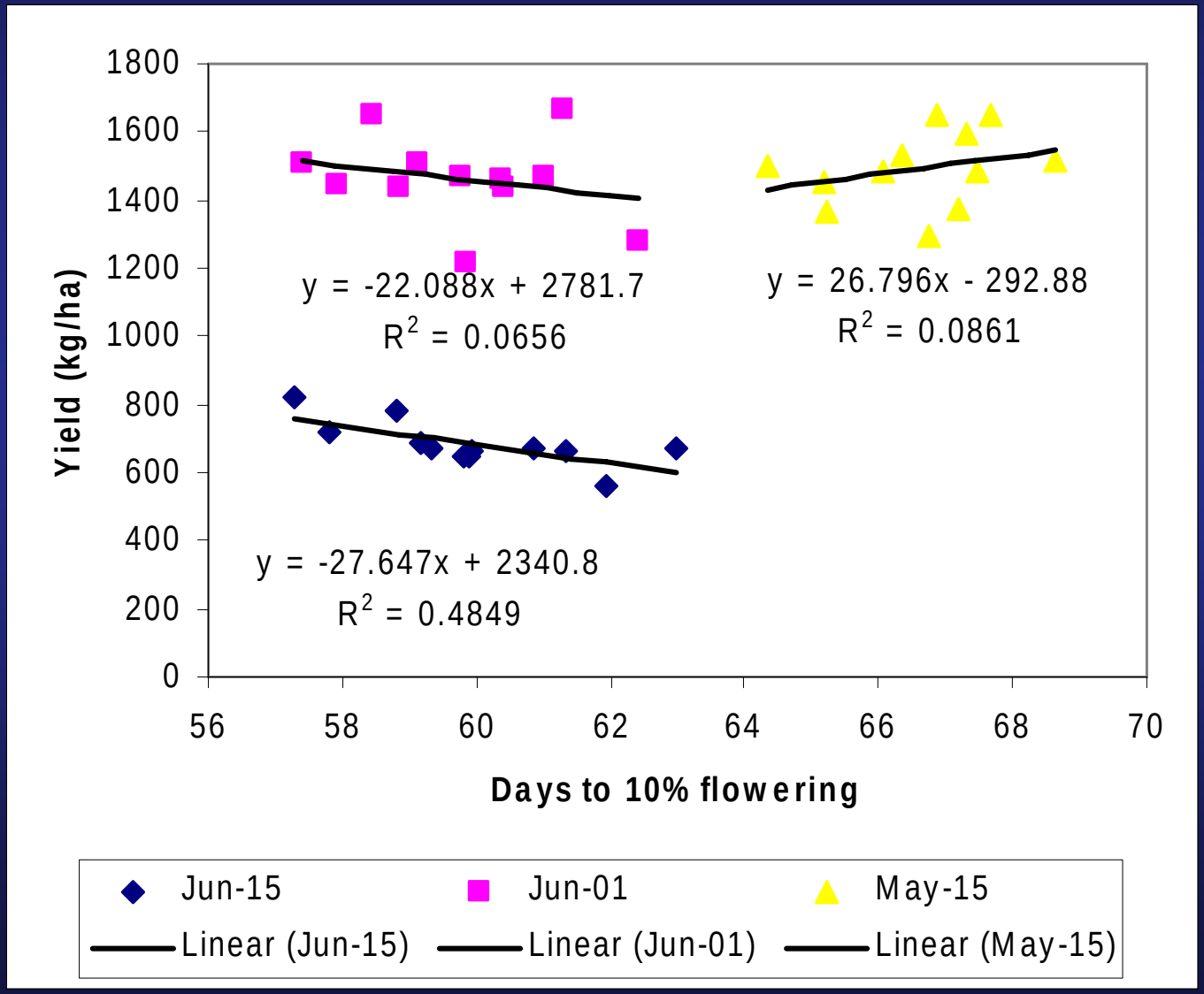
Multi location RCBD analyzed as a split plot (columns are blocks) with rows added

```
model Yield =  sd cult sd*cult;
random siteyr row(siteyr) sd*column(siteyr)
  siteyr*sd siteyr*cult siteyr*sd*cult;
```

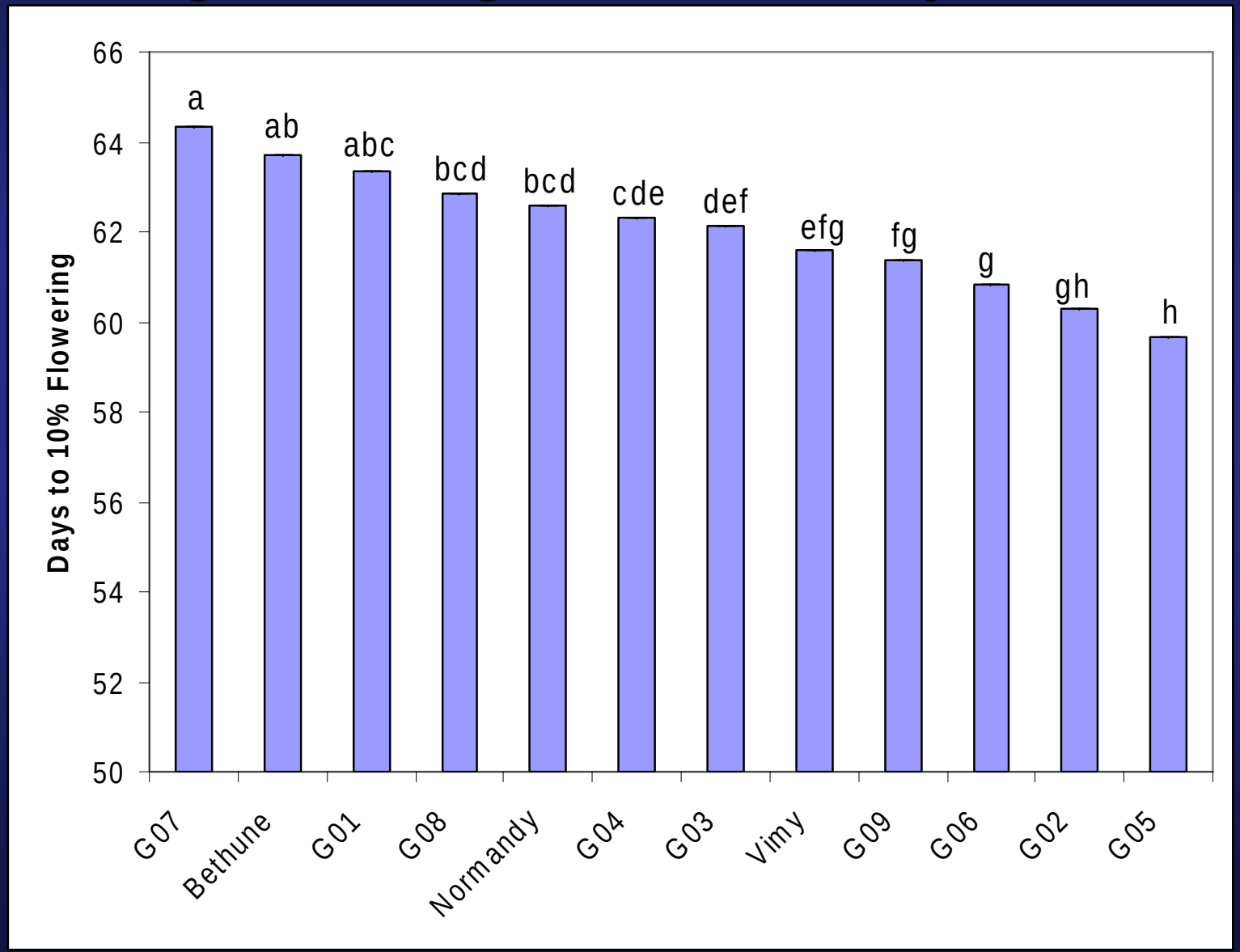
Effect of seeding date and genotype on flax yield. Average of six site years.



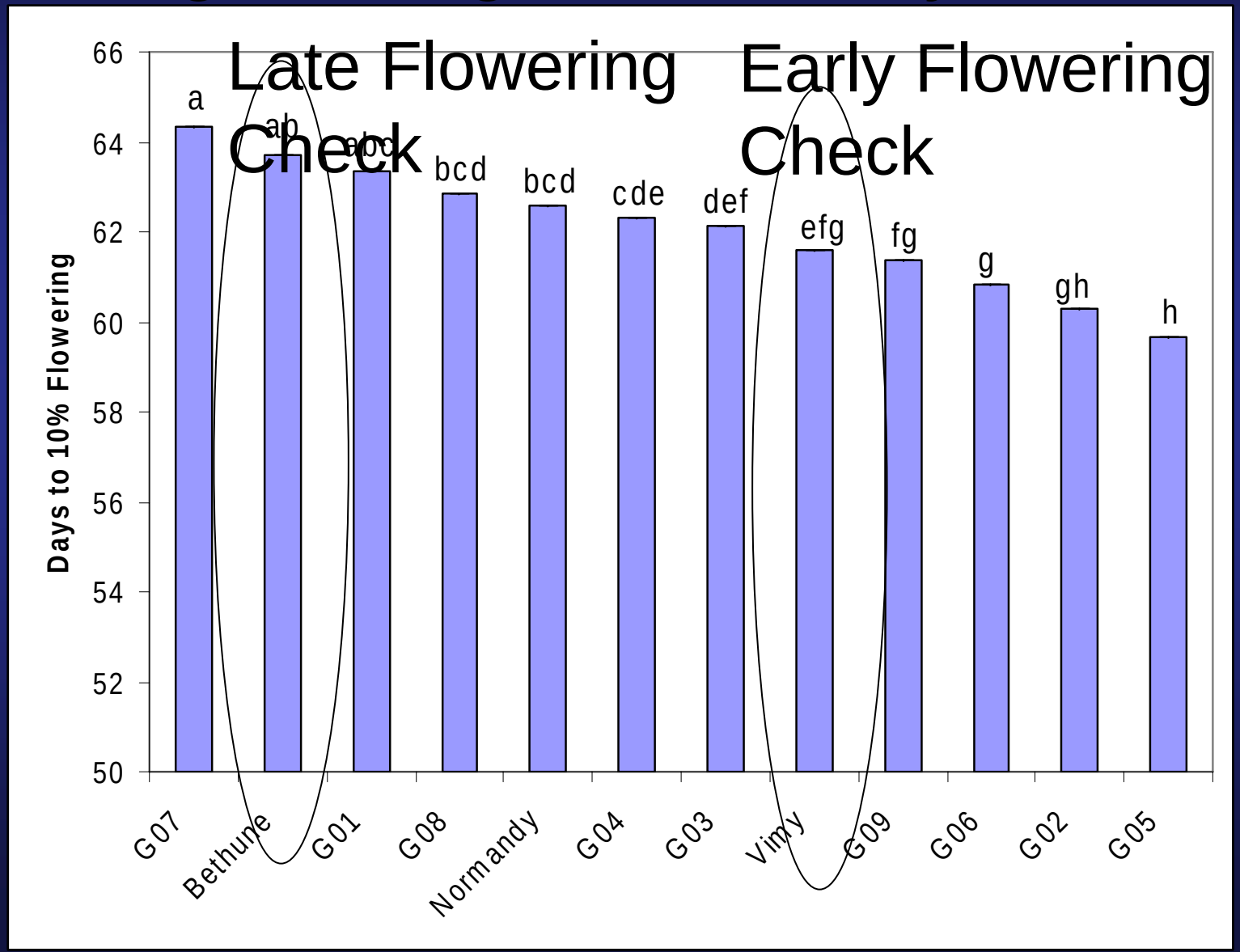
Relationship between time to flowering and yield. Average of six site years.



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 subtreatments

Those who paid for this:

Saskatchewan Agriculture, Food and Rural Revitalization

University of Saskatchewan

Questions?

Seeding rate trial design: Two factor RCB
Seeding date and other treatment

Block 1	A	B	A	A	B	B
Block 2	B	B	A	A	B	A
Block 3	A	A	B	A	B	B
Block 4	A	A	B	A	B	B

Seed Date 1
Seed Date 2
Seed Date 3

Two treatments
A and B

Seeding rate trial design: Two factor Split plot Seeding date (main plot) and other treatment

Block 1	A	B	A	B	B	A
Block 2	B	A	A	B	B	A
Block 3	A	B	B	A	A	B
Block 4	A	B	B	A	B	A

Seed Date 1
Seed Date 2
Seed Date 3

Two treatments
A and B

Seeding rate trial design: Two factor "Herb design" Seeding date (main plot) and other treatment

Block 1	A	B	A	B	B	A
Block 2	B	A	A	B	B	A
Block 3	A	B	B	A	A	B
Block 4	A	B	B	A	B	A

Seed Date 1
Seed Date 2
Seed Date 3

Two treatments
A and B