Lecture 6:
Factorial Experiments

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Introduction

Suppose we want to introduce a new crop into an area in which it has never before been grown. We want to conduct an experiment to see how it will yield.

Questions:

1. When should the crop be planted?
2. What should be the seeding rate?
3. Should the seed be drilled or broadcast?
4. Must we use fertilizer?
5. …

Traditional approach:

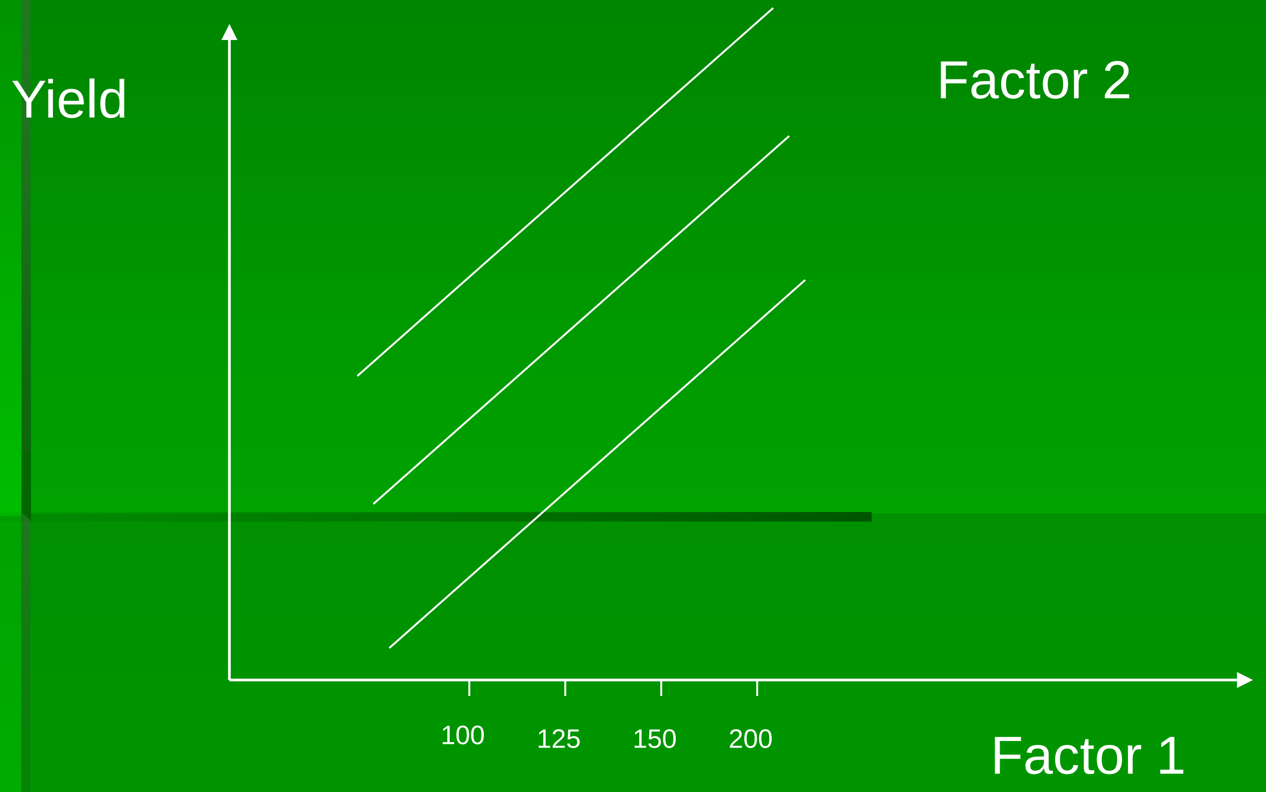
- One factor at a time
- Conduct an experiment to study different planting time, holding others constant.
- Another experiment: to study seed rate, another for nitrogen, etc.
- Is it good? Why and why not?
- A planting date which produce a maximum yield for one variety might not be the date which would produce a maximum yield with a different variety.

Independent and Interaction

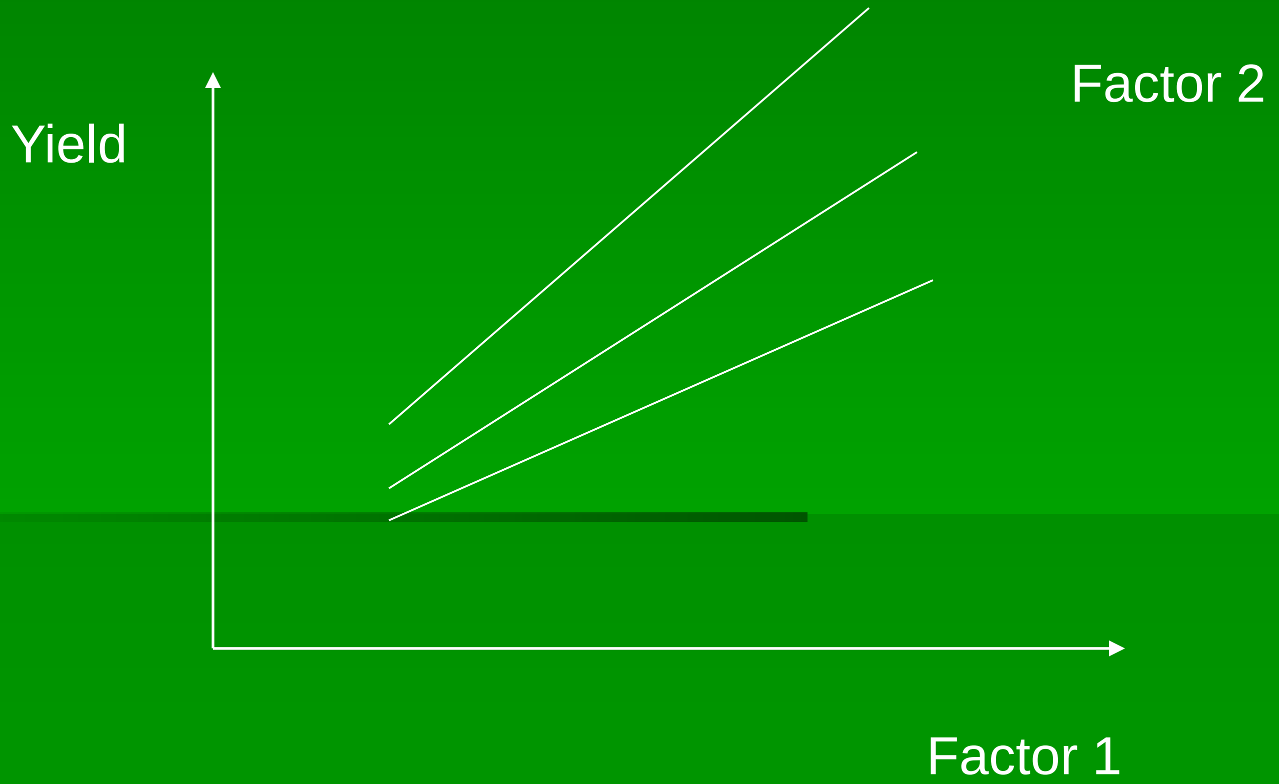
- Independent: changing the level of one factor produces the same effect at all levels of another factor
  - e.g. effect of different row spacing is the same at all planting date
- Interaction: the failure of the differences in response to changes in levels of one factor to be the same at all levels of another factor

  (perubahan suatu faktor mengakibatkan perubahan respon yg berbeda pada tiap taraf faktor lainnya)
  - e.g. as the level of fertilizer is increased the difference among yields also increased

No interaction (react independently)



Interaction



Factorial Eksperimen

- The number of treatment combination is the product of the number of levels of all factors
  - 2 climates (C1, C2), 2 wood types (W1, W2): 2 x 2 factorial experiment
  - We have 4 treatment combinations: (C1, W1), (C1, W2), (C2, W1), (C2,W2).

- Factorial experiment refers to treatment combination, NOT the type of experimental design. You can use CRD, RBD, etc.

Advantages

- When factors are independents:
  - All of simple effects of a factor are equal to the main effect. Main effect only is OK.
  - To get the same precision as factorial, we require small number of unit for single-factor.
- When there is interaction, factorial experiment provide a systematic set of factor combination for estimating all interaction

Disadvantages

- As the number of factors increases the size of the experiment becomes very large.
  - 8 factors each at 2 levels: 256 treatment combinations

- Large factors may be difficult to interprete, particularly when interactions are present

Two-factor Experiments

- Effect of storage temperature and the length of storage on the quality of frozen fruit
  - 2 temperatures: t1=-10C, t2=-20C
  - 4 storage times: s1=1 mo, s2=2mo
    s3=mo, s4=4 mo
  - Treatment combinations:

    t1s1, t1s2, t1s3, t1s4

    t2s1, t2s2, t2s3, t2s4

- In general, suppose we have 2 factors: factor *A* at *a* levels and factor *B* at *b* levels

Model: $$y_{ijk} = \mu + \rho_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + \varepsilon_{ijk}$$

where y_{ijk}=yield of the j^th^ level of factor *A*, …

- overall mean
- block effect
- main effect of A
- main effect of B
- interaction effect of (AB)
- random error

Data Analysis (cont.)

- First, compute Tjk=total for each block
- Then total for factor A x Factor B

Block	1	2	…	r	Sum
Sum	R1	R2	…	Rr	G

Layout Factor A x Factor B Totals

A \ B	1	2	…	b	Sum
1	T11	T12	…	T1b	A1
2	T21	T22	…	T2b	A2
…	…			…	…
a	Ta1	Ta2	…	Tab	Aa
Sum	B1	B2	…	Bb	G

ANOVA, Two factor factorial experiment with RBD

Source	Df	SS	MS	F
Block	r-1	SSR		F_R
A	a-1	SSA	MSR	F_A
B	b-1	SSB	MSB	F_B
AB	(a-1)(b-1)	SSAB	MSAB	F_{AB}
Error	(r-1)(ab-1)	SSE	MSE	
Total	rab-1	SSTot		

Interpretation

- If the AxB interaction is significant then main effects have no real meaning whether they are significant or not

  (In this case, the results of the experiment are best summarized in a two-way table of means of the various A x B combinations)

- If the interaction is not significant then all of the information in the trial is contained in the significant of main effects

  (In this case, the results my be summarized in tables of means for factors)

Numerical example

- An agronomist wanted to study the effect of different rates of phosporus fertilizer on two types broad bean (*Vicia faba*) plants. She thought that the plant types might respond differentially to fertilization so she decided to do a factorial experiment with two factors:
- Plant type at two levels
  - T1=short, bushy
  - T2=tall, erect
- Phosporus rate at three levels
  - P1=none
  - P2=25kg/ha
  - P3=50 kg/ha
- Full factorial set of treatment combinations
  - T1P1, T1P2, T1P3, T2P1, T2P2, T2P3

Layout data table

T2P2 8.3	T2P1 11.2	T1P2 17.6	T1P3 18.9
T2P1 11.0	T2P2 10.5	T1P1 14.3	T2P2 12.8
T1P1 11.5	T2P3 16.7	T2P1 12.1	T2P3 17.5
T2P3 15.7	T1P2 17.6	T1P3 18.2	T2P1 12.6
T1P3 18.2	T1P1 13.6	T2P3 16.6	T1P2 18.1
T1P2 17.1	T1P3 17.6	T2P2 9.1	T1P1 14.5

Analysis Data

- Selanjutnya diperoleh tabel total blok

Block	1	2	3	4	Sum
Sum	81.8	87.2	87.9	94.4	351.3

Tabel total untuk Type X Phosporus

	P1	P2	P3	Sum
T1	53.9	70.4	72.9	197.2
T2	46.9	40.7	66.5	154.1
Sum	100.8	111.1	139.4	351.3

Gunakan statistical softwares

- Bagaimana dengan 3 faktor? Analog
- Contoh di kelas:
- You may use SAS, get experience on them!