SCIENTIFIC WRITING AND PRESENTATION
ENT-402

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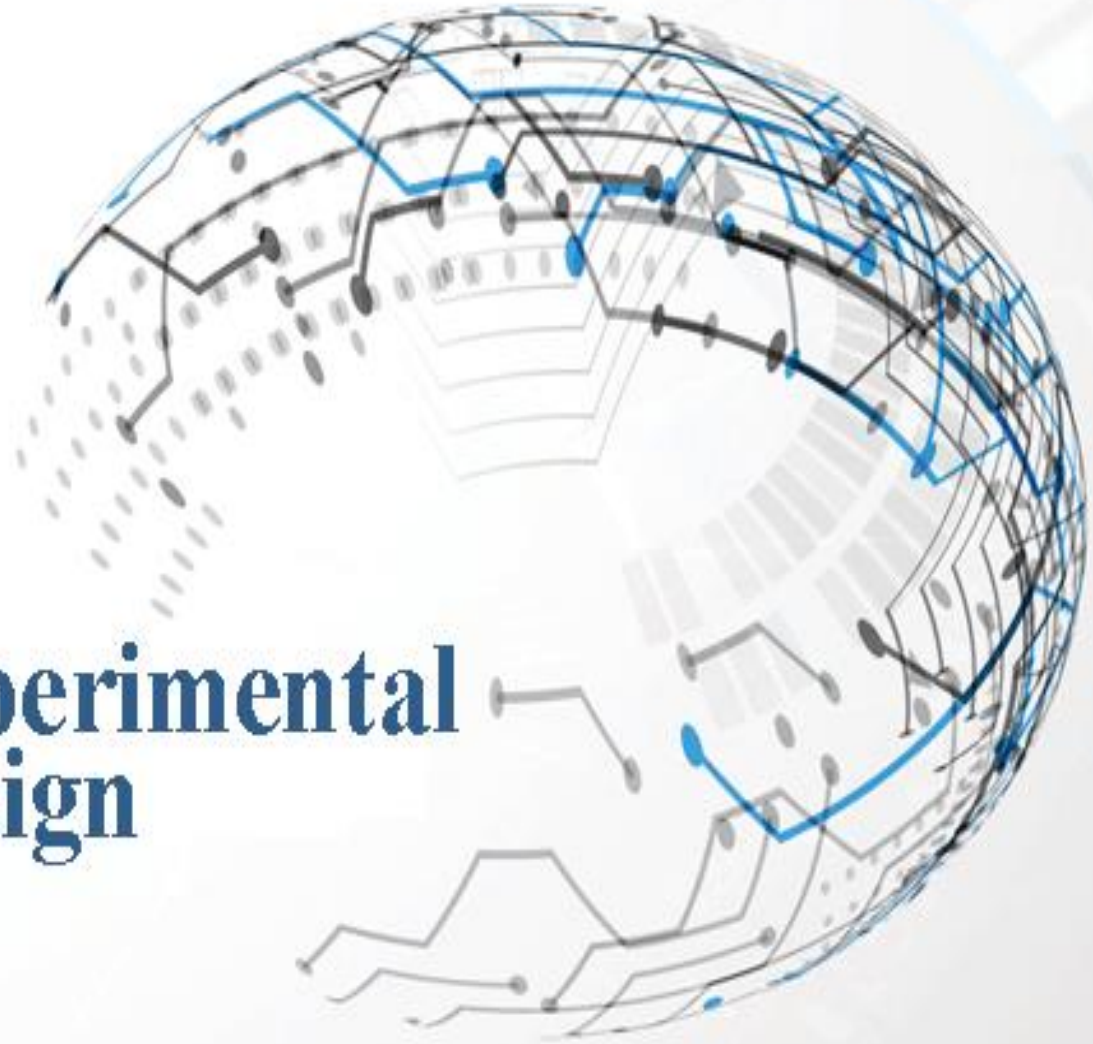
StepUp Analytics



Experimental Design

What is Experimental Design?

- Experimental design is **a way to carefully plan experiments in advance** so that your results are both objective and valid.

Ideally, your experimental design should:

- Describe how participants are allocated to experimental groups.
- Completely randomized design, where participants are assigned to groups at random.
- Randomized block design, where participants are divided into homogeneous blocks before being randomly assigned to groups.
- Minimize or eliminate confounding variables, which can offer alternative explanations for the experimental results.
- Reduce variability, to make it easier for you to find differences in treatment outcomes.

Study Design: basic concepts

- Usually the goal of a study is to find out the relationships between certain explanatory factors and the response variables. The design of a study thus consists of making decisions on the following:
- The set of **explanatory factors.**
- The set of **response variables.**
- The set of **treatments.**
- The set of **experimental units.**
- The method of **randomization** and **blocking.**
- **Sample size** and number of **replications.**
- The outcome measurements on the experimental units - the **response variables.**

What is an Experiment?

- Research method in which conditions are controlled so that 1 or more ***independent variables*** can be manipulated to test a hypothesis about a ***dependent variable***.
- Allows evaluation of causal relationships among variables while all other variables are controlled

Some Definitions

- ***Variable***
- A variable is an object, event, idea, feeling, time period, or any other type of category you are trying to measure.
- ***Dependent Variable***
  - It is something that depends on other factors.
  - For example, a test score could be a dependent variable because it could change depending on several factors
    - how much you studied
    - how much sleep you got the night before you took the test
- ***Independent Variable***
  - An independent variable is the variable that is changed or controlled in a scientific experiment to test the effects on the dependent variable.

Factors

- Factors are explanatory variables to be studied in an investigation.
- Examples:
- In a study of the effects of colors and prices on sales of cars, the factors being studied are color (qualitative variable) and price (quantitative variable).

Factor levels

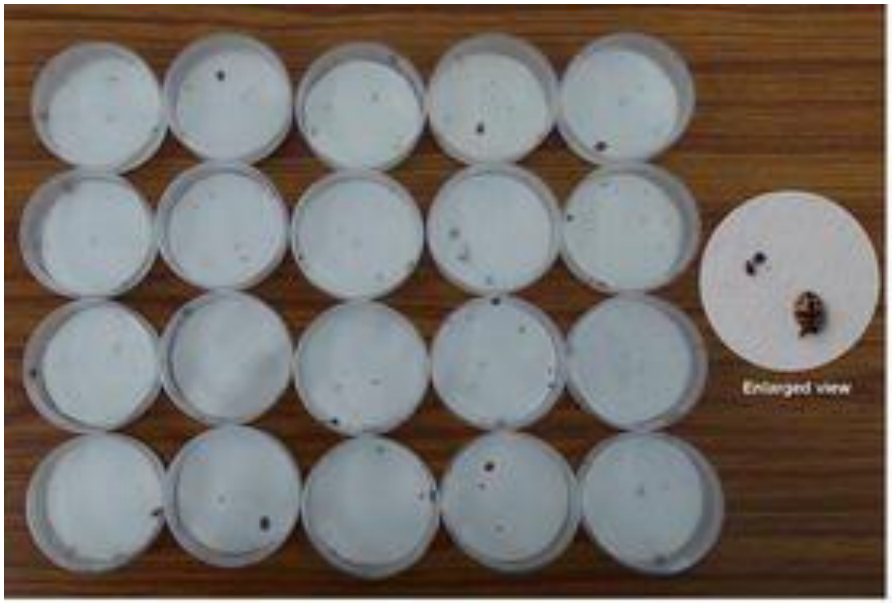
- Factor levels are the "values" of that factor in an experiment.
- For example, in the study involving color of cars, the factor car color could have four levels: red, black, blue and grey.

More Definitions

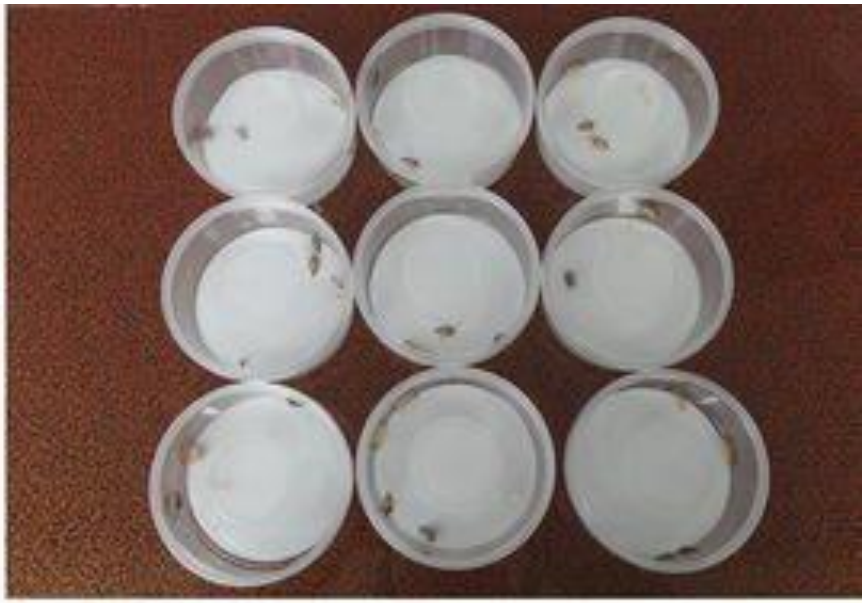
- ***Experimental Treatments***
  - A treatment is the production practice that you are evaluating.
  - Examples
    - choice of variety,
    - different fertilizer rates,
    - different fertilizer timing,
    - choice of cover crops,
    - different pest management strategies
- ***Experimental Group***
  - Group of subjects exposed to the experimental treatment
- ***Control Group***
  - Group of subjects exposed to the control condition
  - Not exposed to the experimental treatment

- ***Experimental units***
  - An experimental unit is the smallest unit of experimental material to which a treatment can be assigned.
- ***Randomization***
  - Random assignment allows the assumption that the groups are identical with respect to all variables
  - Reducing experimental error and determining the true effect of the treatments you are comparing

- ## Sample size
- sample size is the number of experimental units in the study.
- ## Replicates
- Number of times each treatment being repeated and one complete repetition of all treatments (under similar experimental conditions) is called a complete replicate of the experiment.
- ## Why replicates?
- When a treatment is repeated under the same experimental conditions, any difference in the response from prior responses for the same treatment is due to random errors.
- Thus replication provides us some information about random errors.

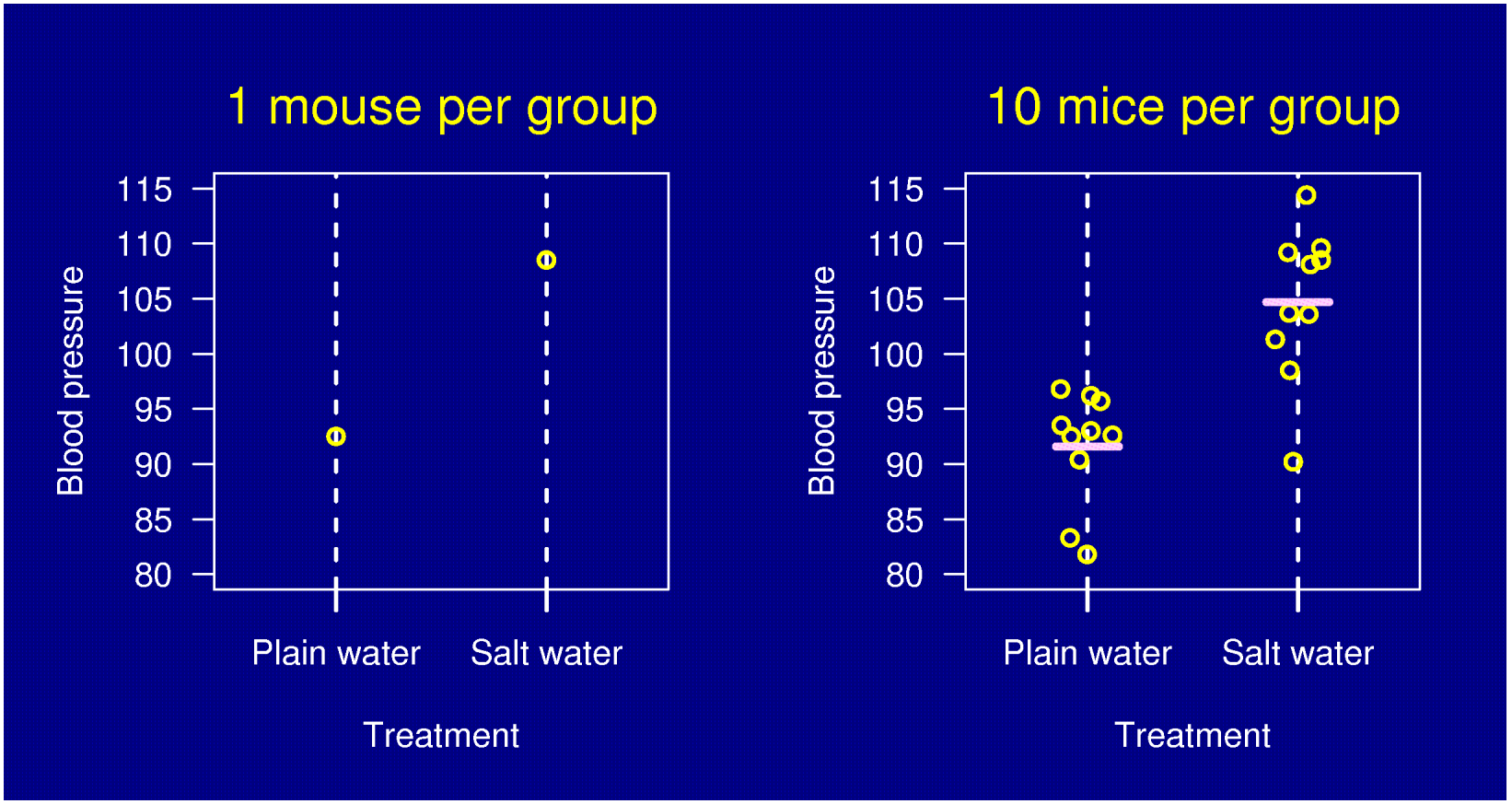


Intoxicated aphids for coccinellids



Topically dosed larva for bugs

Replication



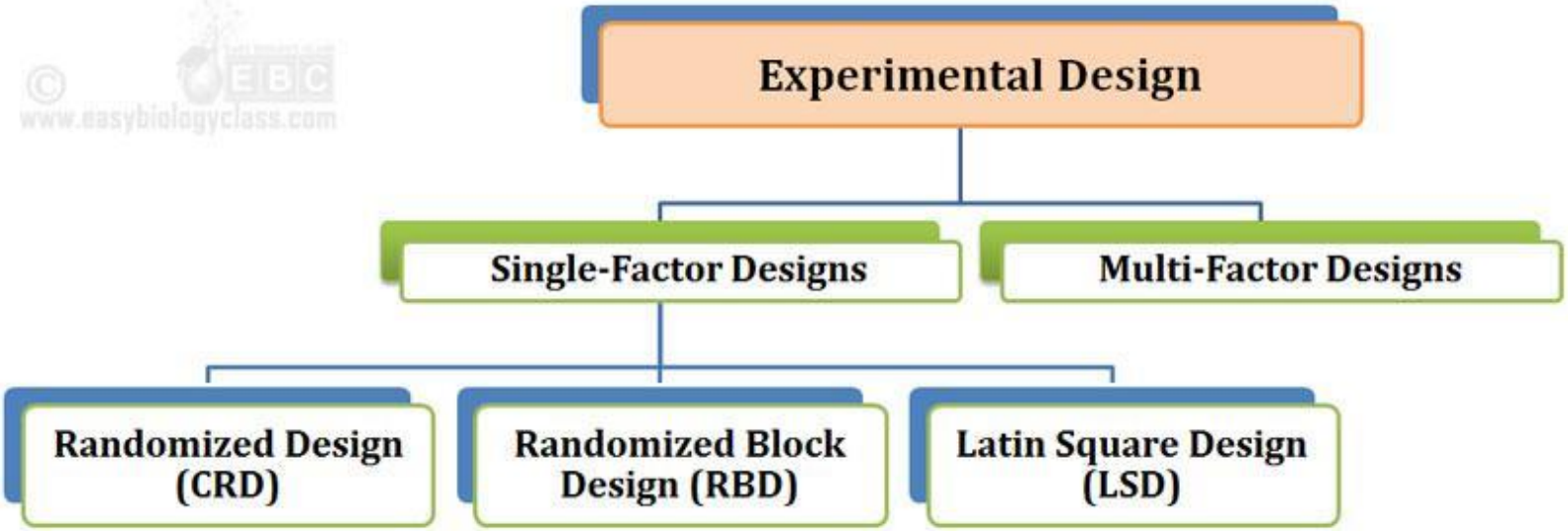
Different types of Experimental Designs

Experimental designs are broadly classified into TWO categories:

- **(A). Single-Factor Experiments**
- **(B). Multi-factor Experiments**

Single-Factor Experiments:

- Single factor experiments are those experiments in which only a single factor varies while all others are kept constant.
- Here the treatments consist exclusively of the different levels of the single variable factor.
- All other factors are applied uniformly to all plots.
- Examples of Single-Factor Experimental Designs:
  - **Completely Randomized Design (CRD)**
  - **Randomized Block Design (RBD)**
  - **Latin-Square Design (LSD)**



Types of Experimental Designs

Completely Randomized Experimental Design.

- A completely randomized design (CRD) is an experiment where the treatments are assigned at random.
- Every experimental unit has the same odds of receiving a particular treatment.
- This design is usually only used in lab experiments, where environmental factors are relatively easy to control for;
- CRD is applicable only when the experimental material is homogenous (Example: Homogenous soil condition in the field).
- It is rarely used out in the field
- When a CRD has two treatments, it is equivalent to a t-test.

- A completely randomized design is generally implemented by:
- Listing the treatment levels or treatment combinations.
- Assigning each level/combination a random number.

A	B	D	A
C	D	B	C
B	A	D	C

Advantages of CRD

- CRD is easy to understand and calculate the variance.
- The number of replications can vary from treatment to treatment.
- Simple statistical analysis is required in the analysis of CRD.

Disadvantages of CRD

- CRD can be applied only to homogenous experiments.

Randomized Complete Block Design

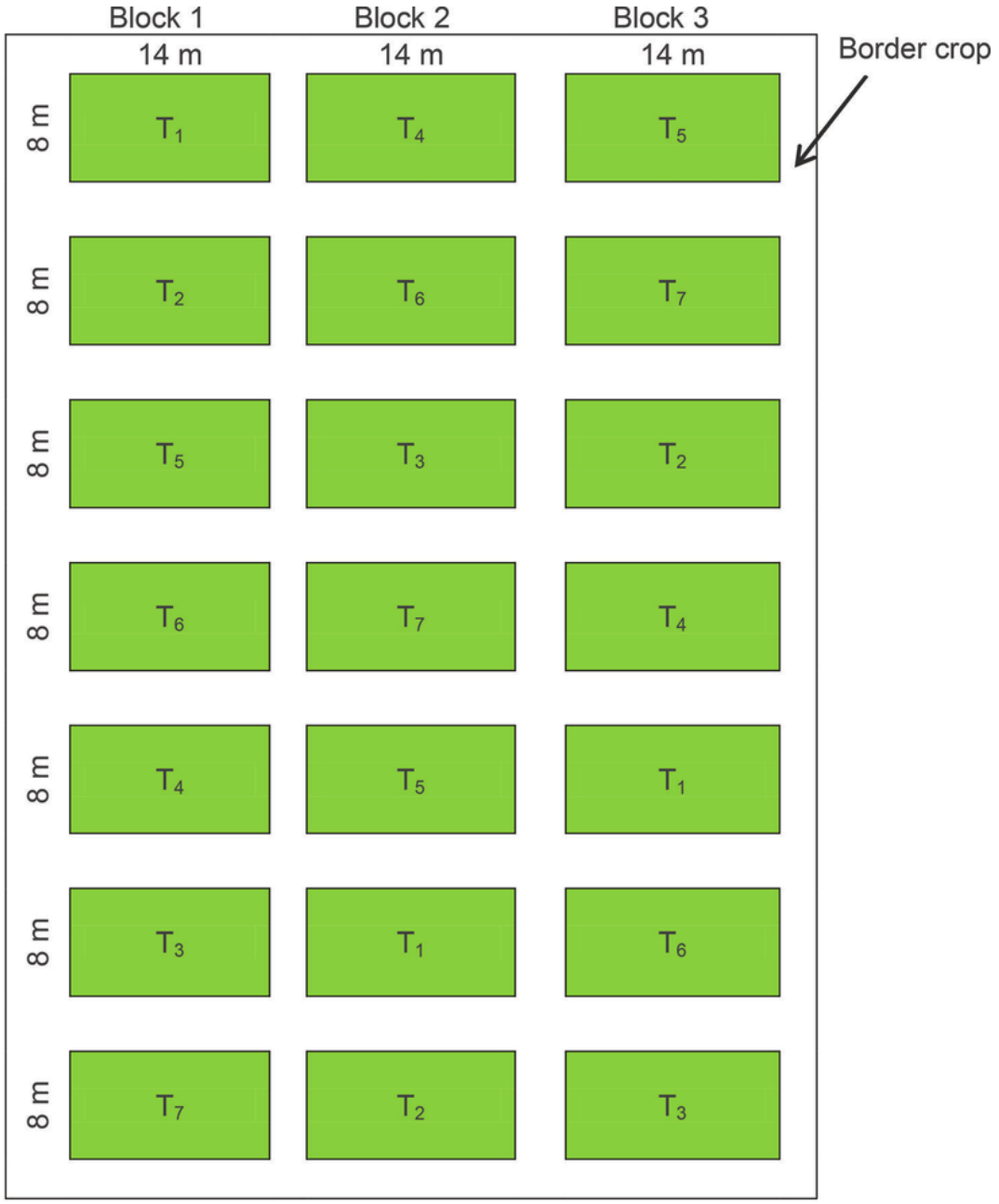
- It is also called RCBD.
- RCBD is the most commonly used experimental design in agriculture.
- Sub-group is called blocks.
- A block contains the entire set of treatments and thus a block is equivalent to a replication.

Advantages of RCBD

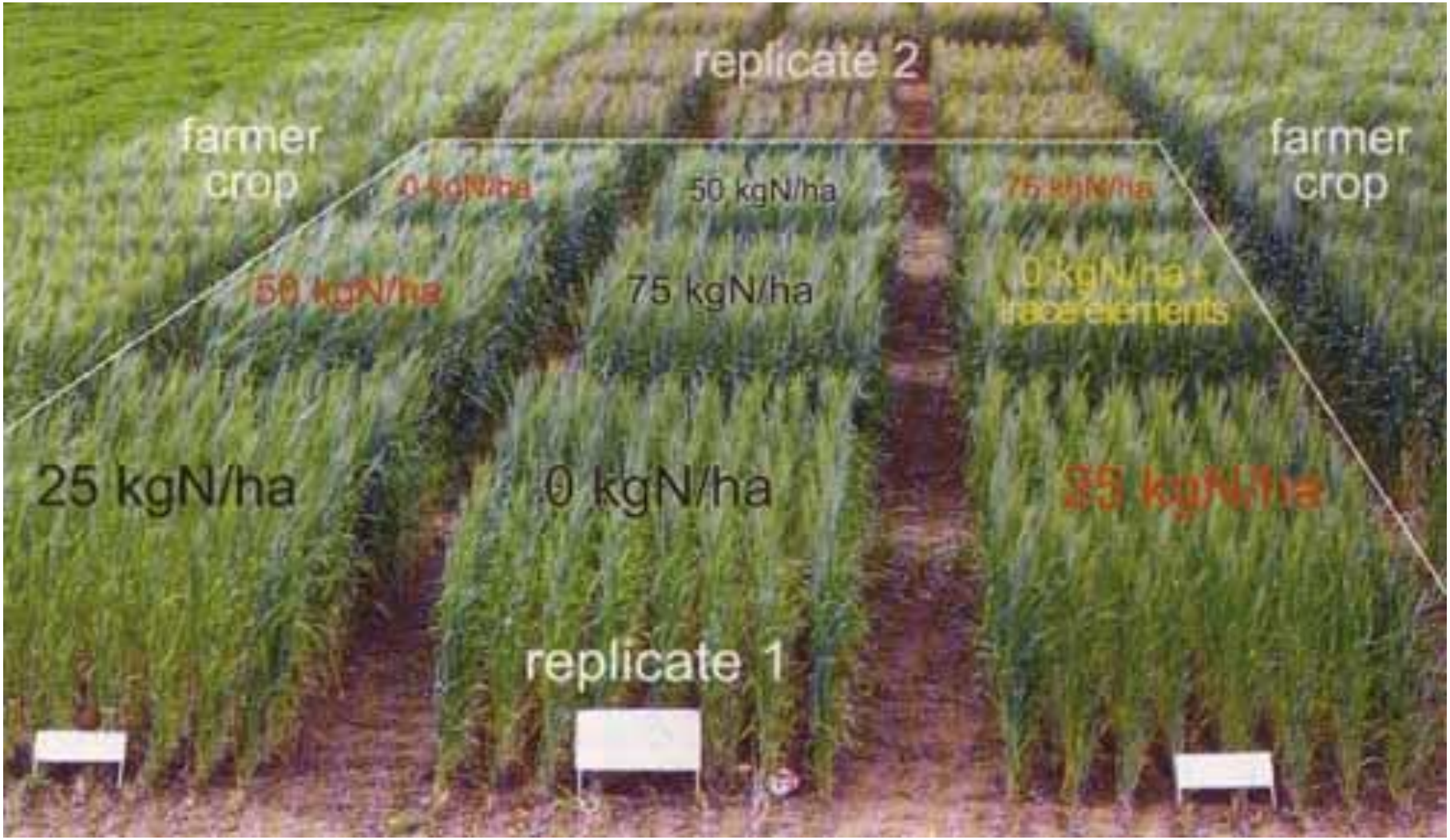
- RBD is more efficient and accurate when compared to CRD.
- Chance of error in RCBD is comparatively less.
- Flexibility is also very high in RCBD and thus any number of treatments and any number of replications can be used.
- Statistical analysis is relatively simple and easy.

Disadvantages of RBD

- RCBD is not advised for very large number of treatments.
- If the heterogeneity of the plot is very high, RBD cannot be applied. When the number of treatments is very large then the size of each block will be increased so that there may be heterogeneous blocks within.
- With large number of treatments, the possibility of experimental errors will be high.


Block 1
Block 2
Block 3
14 m
14 m
14 m
Border crop
8 m
8 m
8 m
8 m
8 m
8 m
8 m
T1
T4
T5
T2
T6
T7
T5
T3
T2
T6
T7
T4
T4
T5
T1
T3
T1
T6
T7
T2
T3

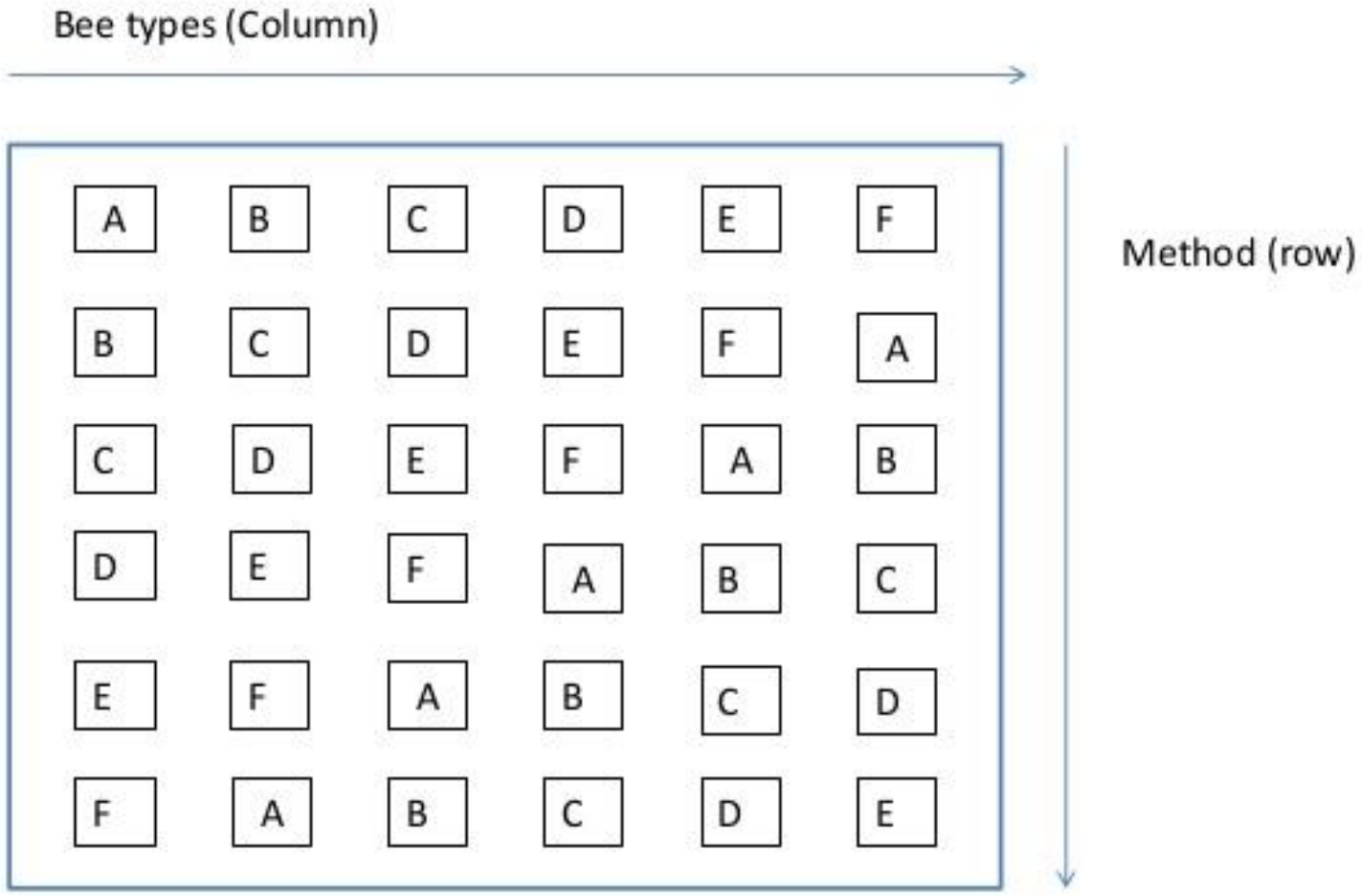
T=treatment


replicate 2
farmer crop
farmer crop
50 kgN/ha
50 kgN/ha
75 kgN/ha
25 kgN/ha
0 kgN/ha
replicate 1

Latin Square Design

- Commonly called as LSD.
- LSD is a design where the experimental material is divided into ‘m’ rows, ‘m’ columns and ‘m’ treatments – assigned by randomization method to rows and columns.
- The randomization is in such a way that each treatment occurs only once in each row and in each column.
- ***Advantages of LSD***
- Statistical analysis is relatively simple
- Statistical analysis is simple if one value is missing.
- Most efficient design when compared to CRD and RBD.
- ***Disadvantages of LSD***
- LSD is not suitable for agricultural experiments.
- Statistical analysis is complicated when two or more values are missing.
- Difficult when treatments are more than ten.

LAYOUT OF LATIN AQUARE DESIGN



Multi-Factor Designs

- A factorial experimental design is used to investigate the effect of two or more independent variables on one dependent variable.
- Multi-factor experimental designs are also called as factorial experiments.
- They are used in the experiments where the effects of more than one factor are to be determined.
- It is used to study a problem that is affected by a large number of factors.
- In factorial experiments, the factors are denoted by capital letters (Example: N, P)
- The level of each factor are denoted by small letters (Example: n, p)
- Example: 2 x 2 Factorial design (Two factors and Two levels)

Main Effect and Interaction Effect

- Two types of effects are considered when analyzing the results from a factorial experiment:
- Main effect - is the effect of an independent variable
- Interaction effect - occurs between factors.

2x2 Design		IV 1	
		IV1: Level 1	IV1: Level 2
IV 2	IV2: Level 1	dv	dv
	IV2: Level 2	dv	dv

2x2 Design		Time of Day	
		Morning	Afternoon
Caffeine	Some Caffeine	dv	dv
	No Caffeine	dv	dv

Split plot design

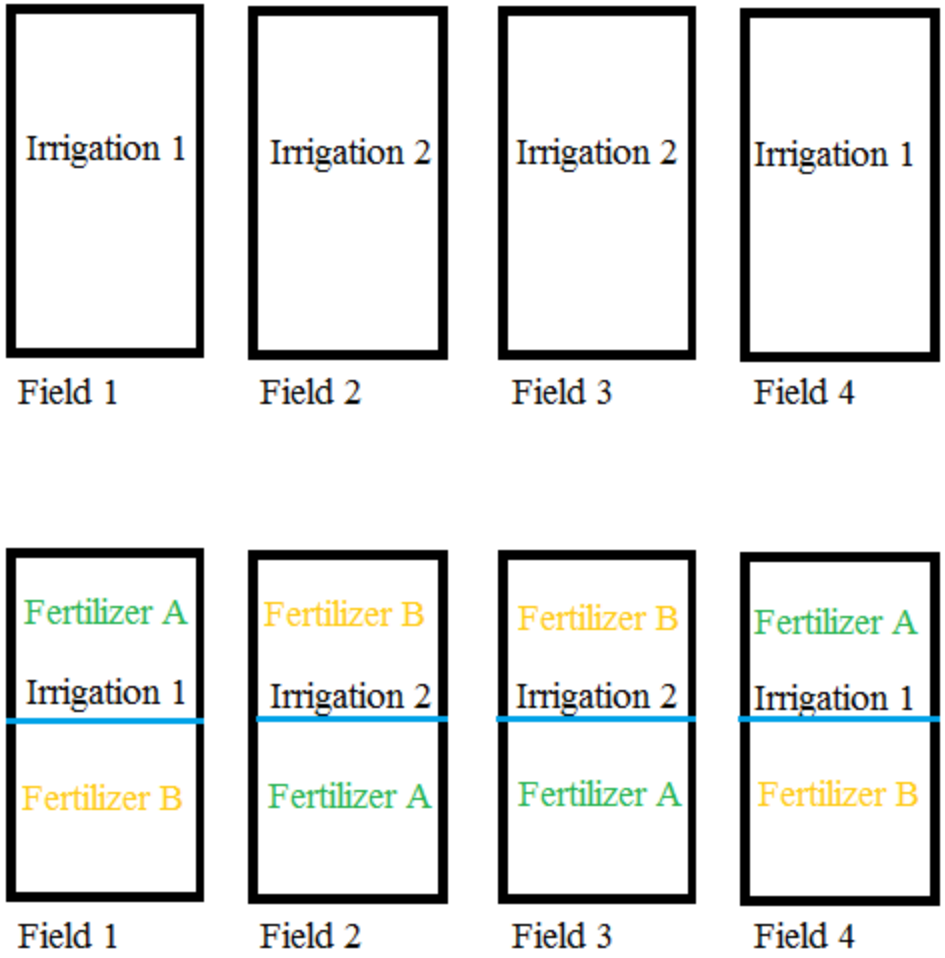
- When some factors (independent variables) are difficult or impossible to change in your experiment, a completely randomized design isn't possible.

- The result is a **split-plot design**, which has a mixture of hard to randomize (or hard-to-change) and easy-to-randomize (or easy-to-change) factors.

- The hard-to-change factors are implemented first, followed by the easier-to-change factors

Example

- You want to study the effects of
  - two irrigation methods (factor 1)
  - two different fertilizer types (factor 2)
  - on four different fields (“whole plots”).
- However, you run into a practical problem with randomization.
- While a field can easily be split into two for the two different fertilizers,
- the field cannot easily be split into two for irrigation:
- One irrigation system normally covers a whole field and the systems are expensive to replace.


Irrigation 1
Irrigation 2
Irrigation 2
Irrigation 1
Field 1
Field 2
Field 3
Field 4
Fertilizer A
Irrigation 1
Fertilizer B
Fertilizer B
Irrigation 2
Fertilizer A
Fertilizer B
Irrigation 2
Fertilizer A
Fertilizer A
Irrigation 1
Fertilizer B
Field 1
Field 2
Field 3
Field 4

Advantages

- Cheaper to run. In the above example, implementing a new irrigation method for each subplot would be extremely expensive.
- Mostly effective for agricultural studies

Disadvantages

- Implementing the design can be difficult
- These designs are difficult to create and to spot– many published papers contain split-slot designs that are incorrectly classified and analyzed (Jones & Nachtsheim, 2009).
- Software packages that assist with the design are hard to find, although SAS and JMP have options.