

Practical.11

Formation of ANOVA table for completely Randomised design (CRD) with equal replication and comparison of means using critical difference values

Completely Randomized Design (CRD)

CRD is the basic single factor design. In this design the treatments are assigned completely at random so that each experimental unit has the same chance of receiving any one treatment. But CRD is appropriate only when the experimental material is homogeneous. As there is generally large variation among experimental plots due to many factors CRD is not preferred in field experiments.

In laboratory experiments and greenhouse studies it is easy to achieve homogeneity of experimental materials and therefore CRD is most useful in such experiments.

Layout of a CRD

Completely randomized Design is the one in which all the experimental units are taken in a single group which are homogeneous as far as possible.

The randomization procedure for allotting the treatments to various units will be as follows.

Step 1: Determine the total number of experimental units.

Step 2: Assign a plot number to each of the experimental units starting from left to right for all rows.

Step 3: Assign the treatments to the experimental units by using random numbers.

The statistical model for CRD with one observation per unit

$$Y_{ij} = \mu + t_i + e_{ij}$$

μ = overall mean effect

t_i = true effect of the i th treatment

e_{ij} = true effect of the j th unit receiving i th treatment

The arrangements of data in CRD is as follows:

	Treatments				
	T ₁	T ₂	T _i	T _K	
	Y ₁₁	Y ₂	Y _{i1}	Y _{K1}	
	Y ₁₂	Y ₂₂	Y _{i2}	Y _{K2}	
	Y _{1r1}	Y _{2r2}	Y _{iri}	Y _{k rk}	
Total	T ₁	T ₂	T _i	T _k	GT

The null hypothesis will be

H₀: μ₁ = μ₂ = = μ_k or There is no significant difference between the treatments

And the alternative hypothesis is

H₁: μ₁ = μ₂ = = μ_k There is significant difference between the treatments

The different steps in forming the analysis of variance table for a CRD are:

$$1. \quad C.F = \frac{Y_i^2}{n} = \frac{(GT)^2}{n}$$

n= Total number of observations

$$2. \quad \text{Total SS} = \text{TSS} = \sum_{i=1}^k \sum_{j=1}^{v_i} Y_{ij}^2 - C.F$$

$$3. \quad \text{Treatment SS} = \frac{Y_1^2}{r_1} + \frac{Y_2^2}{r_2} + \dots + \frac{Y_k^2}{r_k} - \frac{Y^2}{n}$$

$$= \sum_{i=1}^k \frac{y_i^2}{r_i} - C.F$$

$$4. \quad \text{Error SS} = \sum_{i=1}^k \sum_{j=1}^{r_i} y_{ij}^2 - \sum_{i=1}^k \frac{y_i^2}{r_i}$$

$$\text{Error SS} = \text{TSS} - \text{TrSS}$$

5. Form the following ANOVA table and calculate F value.

Source of variation	df	SS	Ms	F
Treatments	t-1	TrSS	$TrMS = \frac{TSS}{t-1}$	$\frac{TrMS}{EMS}$
Error	n-t	ESS	$EMS = \frac{ESS}{n-t}$	
Total	n-1	TSS		

6. Compare the calculate F with the critical value of F so that acceptance or rejection of the null hypothesis can be determined.

7. If null hypothesis is rejected that indicates there is significant differences between the different treatments.

8. Calculate C D value.

$$C.D. = t \times SE(d)$$

$$\text{where } S.E(d) = \sqrt{EMS \left(\frac{1}{r_i} + \frac{1}{r_j} \right)}$$

and t is the critical t value for error degrees of freedom at 5% level.

Problem

The following table gives the yield in kgs per plot of five varieties of wheat after being applied to each of four plots in a completely randomized design.

Varieties	Yield in kgs				Totals	Treatment means
A	8	8	6	10	32 (T1)	8 (T1)
B	10	12	13	9	44 (T2)	11 (T2)
C	18	17	13	16	64 (T3)	16 (T3)
D	12	10	15	11	48 (T4)	12 (T4)
E	8	11	9	8	36 (T5)	9 (T5)
Grand Total					224	

Analysis

1. Correction Factor (C.F) = $\frac{(Grand\ total)^2}{r \times t}$ where r is the number of replications per treatment and t is the number of treatments.

$$= \frac{(224)^2}{4 \times 5} = 2508.8$$

2. Total sum of squares TSS = $\sum_{i=1}^k \sum_{j=1}^{v_i} Y_{ij} - C.F$

$$= 8^2 + 8^2 + \dots + 9^2 + 8^2 - 2508.8 = 207.2$$

3. varieties Sum of squares VSS = $\frac{T_1^2 + T_2^2 + T_3^2 + T_4^2 + T_5^2}{r} - C.F$

$$= \frac{32^2 + 44^2 + 64^2 + 48^2 + 36^2}{4} - 2508.8$$

4. Error sum of Squares = Total sum of squares – Variety sum of squares = 207.2 - 155.2 = 52.0

Table for Analysis of Variance

Source of variation	D.F.	S.S.	MS (variance)	F (variance ratio)	F at 5%
Between varieties	4	155.2	38.80	11.80*	3.06
Within varieties (error)	15	52.0	3.47		
Total	19	207.2			

*Significant at 5% level of significances

Here, F test indicates that there are significant difference between the variety means since the observed value of the variance ratio is significant at 5% level of significance. Now we wish to know as to which variety is the best and also which varieties show the significant difference among themselves. This can be done with the help of critical difference (c.d.)

Now, standard error of the difference between two treatment means is

S.E.d = $\sqrt{\frac{2XEMS}{r}}$ where E Ms is the error mean square and 'r' is the no. of replications.

$$= \sqrt{\frac{2X3.47}{4}} = 1.32$$

∴ Critical difference (CD) = SEd x 't' 5% value for error d.f.

$$= 1.32 \times 2.131 = 2.81$$

Since the 'F' test in the analysis of variance indicated significant differences between the varieties, we are justified in comparing the varieties with the help of the above C.D. value.

Varieties	A	B	C	D	E	CD
Many yields	8	11	16	12	9	2.81

Conclusions represented symbolically (bar chart notation):

The varieties can be compared by setting them in the descending (or ascending) order of their mean yields in the following manner.

C
D
B
E
A

The varieties which do not differ significantly have been underlined by a bar. This method of underlining the treatments which do not differ significantly is the way of indicating the significance and non-significance of individual comparisons.

Learning Exercise

1) The following table gives the yields of five varieties of paddy with four replications each by using completely randomized Design.

Varieties	Yield in kg.			
A	8	8	6	10
B	10	12	13	9
C	18	17	13	16
D	12	10	15	11
E	8	11	9	8

Analyse the data and draw your conclusions.

2) Below are given the plan and yield in kg per plot of a completely randomized design for testing the effect of five different fertilizers A, B, C, D & E.

D	E	B	E	D
20	17	21	16	15
A	C	A	D	B
8	17	9	13	17
B	D	E	C	A
12	19	18	18	15
C	A	C	A	E
16	8	18	10	15
E	B	D	B	C

13	16	23	14	19
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Analyse the data and state your conclusions.