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A COMPARATIVE STATISTICAL ANALYSIS OF RICE CULTIVARS DATA

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Abstract

In this paper, rice cultivars data have been analysed by three different statistical techniques viz. Split-plot analysis in RBD, two-factor factorial analysis in RBD and analysis of two-way classified data with several observations per cell. The powers of the tests under different methods of analysis have been calculated. The method of two-way classified data with several observations per cell is found better followed by two-factor factorial technique in RBD and split plot analysis for analyzing the given data.

Key words: Rice Cultivars Data, Nitrogen Response Trials, Split-plot, Sub-plot, Grain Yield, Panicle Number, Panicle Weight, 1000 Grain Weight, Days of 50% Flowering and Seed to Seed Days.

1. Introduction

Research and projects on rice have been carried out for many years in order to increase the yield productivity by choosing the suited variety for cultivation as well as for consumption. In carrying out such research, many statistical methods have been used for taking the right decision. Experimentation is the backbone of research in agricultural systems. Whenever we want to ascertain the validity of any assertion, we need to generate data and then on the basis of data generated we draw valid conclusions. Thus, any experimentation has two major components, viz. designing the experiment (or the way of generating the data) and the analysis of data generated to draw meaningful and valid conclusions.

The design should be cost effective keeping in view the scarce and expensive resources. The design should be such that it provides precise estimates of the comparisons of interest to the experimenter. The design should be able to absorb various shocks like loss of data, presence of outliers, interchange and/or exchange of treatments, model inadequacy etc., besides providing as small an experimental error as possible or in other words as small a C.V. value as possible.

Split plot designs are particularly useful when there are one (or more) classification factors that are included in the experiment to see if they modify the action of the other factor or indicate how the other factors work. They are included primarily to examine their possible interaction with the other factors. Lower precision is accepted for comparisons of the classification factors, in order that the precision of the other factors and their interactions can be increased. In the terminology associated with split plot experiments, the classification factors are called the whole plot factors, and they are arranged to be at the same level for all subplots within any one whole plot. Cox (1958) recommended that split-plot experiment should only be used if there is a suitable classification factor for which the main effects are not of major interest, when it is convenient to arrange the experiment with a particular factor constant within each whole plot or if the number of treatment combinations exceeds the number that can be accommodated in a block of reasonably homogeneous subplots.

Factorial experiments are experiments that investigate the effects of two or more factors or input parameters on the output response of a process. Factorial experiment design, or simply factorial design, is a systematic method for formulating the steps needed to successfully implement a factorial experiment. It can be used in CRD, RBD or LSD.

The analysis of variance is closely related to experimental designs; it is one of the most important methods for the analysis of data in experimental sciences. If data from experiment are classified with one factor namely treatment then one way analysis of variance is used and if data are in two-way classification, then two-way analysis of variance is performed.

A number of studies are carried out on rice cultivars data which include Hasegawa et al. (1991), Noureldin (2000), Patra and Biswas (2009), Rajarathinam (2010), Zhao et al. (2010) and Cyprien and Kumar (2011).

2. Materials and Methods

The present study was carried out to have a comparative statistical analysis of rice cultivars data obtained as the outcome of two nitrogen response trials on selected advanced varietal trial-2 Basmati Type (AVT-2BT) and Irrigated Medium (AVT-IM) rice cultures under high and low input management, carried out at experimental area of the Department of Agronomy, College of Agriculture situated at Crop Research Centre (CRC) of G.B Pant University of Agriculture & Technology, Pantnagar during Kharif season 2010. The experiment was conducted in split plot design and the data generated by Nitrogen response trials on AVT-2(BT) and AVT-2(IM) were recorded. We have information on three nitrogen levels, a number of varieties with respect to grain yield (kg/plot), panicle no./sq.m., panicle weight (g), 1000 grain weight (g), days of 50% flowering and seed to seed days. The data are shown in the Appendix.

3. Statistical techniques used for data analysis

3.1 Split-Plot Design in RBD

The mathematical model for split plot design in randomized block design is $Y_{ijk}=\mu+r_i+m_j+\epsilon_{ij}+s_k+ms_{jk}+e_{ijk}$, i=1,2,....,r; j=1,2,....,m; k=1,2,....,s (1)

In which ϵ_{ij}'s are normally and independently distributed with mean zero and variance σ^2_w and the e_{ijk}'s are normally and independently distributed with mean zero and variance σ^2_s. In that case, we have $\sigma^2 = \sigma^2_s + s\,\sigma^2_w$. Here, Y_{ijk} is the observation of i[th] replication, j[th] main plot and k[th] sub-plot, μ is the overall mean, r_i is the i[th] replication effect, m_j is the j[th] main treatment effect, ϵ_{ij} is the main plot error (a), $s_k$is the k[th] sub-plot treatment effect, $(ms)_{jk}$ is the interaction effect and e_{ijk} is the error component for sub-plot and interaction [error(b)] and r, m and s are the number of replications, levels of main-plot treatments (A) and sub-plot treatments (B) respectively. Table 1 shows the ANOVA Table for the abovesaid model.

Source of variation	**d.f.**	**SS**	**MS**	**F-ratio**
Replication	r-1	SS_R	$MS_R = \frac{SS_R}{r-1}$	
A	m-1	SS_A	$MS_A = \frac{SS_A}{m-1}$	$F_A = \frac{MS_A}{MS_{Ea}}$
Error(a)	(r-1)(m-1)	SS_{Ea}	$MS_{Ea} = \frac{SS_{Aa}}{(r-1)(m-1)}$	
B	s-1	SS_B	$MS_B = \frac{SS_B}{s-1}$	$F_B = \frac{MS_B}{MS_{Eb}}$
A×B	(m-1)(s-1)	SS_{AB}	$MS_{AB} = \frac{SS_{AB}}{(a-1)(s-1)}$	$F_{AB} = \frac{MS_{AB}}{MS_{Eb}}$
Error(b)	m(r-1)(s-1)	SS_{Eb}	$MS_{Eb} = \frac{SS_{Eb}}{m(r-1)(s-1)}$	
Total	rms-1	SS_{Tot}		

Table 1 : ANOVA Table for Split-plot Design in RBD

Here,

$$\text{Total Sum of Squares} = SS_{Tot} = \sum_{i,j,k} y_{ijk}^2 - \frac{Y^2}{rms}$$

$$\text{Replicate Sum of Squares} = SS_R = \sum_i \frac{Y^2{}_{i..}}{ms} - \frac{Y^2{}_{...}}{rms}$$

$$\text{Main Plot Treatment Sum of Squares} = SS_A = \sum_J \frac{Y^2{}_{.j.}}{rs} - \frac{Y^2{}_{...}}{rms}$$

$$Error\ (a)\ \text{Sum of Squares} = SS_{Ea} = \sum_{i,j} \frac{Y^2{}_{ij.}}{s} - \sum_i \frac{Y^2{}_{i..}}{ms} - \sum_j \frac{Y^2{}_{.j.}}{rs} + \frac{Y^2{}_{...}}{rms}$$

$$\text{Sub plot Treatment Sum of Squares} = SS_B = \sum_k \frac{Y^2{}_{..k}}{rm} - \frac{Y^2{}_{...}}{rms}$$

Main plot x sub plot Treatment Sum of Squares =

$$SS_{AB} = \sum_{j,k} \frac{Y^2_{.jk}}{r} - \sum_{j} \frac{Y^2_{.j.}}{rs} - \sum_{k} \frac{Y^2_{..k}}{rm} + \frac{Y^2_{...}}{rms}$$

Error (b) Sum of Squares = $SS_{Eb} = SS_{Tot} - (SS_R + SS_A + SS_{Ea} + SS_B + SS_{AB})$

$$Y_{...} = \sum_{i,j,k} y_{ijk}\,, \quad Y_{i..} = \sum_{j,k} y_{ijk}, \; Y_{.j.} = \sum_{i,k} y_{ijk} \; and \; Y_{..k} = \sum_{i,j} y_{ijk}$$

If F-ratio for the A, B or A×B is larger than the corresponding F-values obtained from the statistical tables at a level of significance α, then the corresponding effect (main or interaction) is significant otherwise it is insignificant. Further, since in split-plot analysis, sub-plot treatments are tested with a higher degree of precision than the main-plot treatments, hence, a pair-wise comparison of sub-plot treatments may be made by using Duncan's Multiple Range Tests (DMRT). DMRT method is as follows;
We calculate following quantities $D_p = d_p \times SE_M$, p=2,3,…..,s;
where standard error of mean $SE_M = \sqrt{\frac{MS_{Eb}}{r}}$ and d_2, d_3,…..,d_s are table values of Duncan test corresponding to error degree of freedom.
Having obtained D_p values, we arrange treatment means in increasing order of magnitude. Let it be as given bellow;
$\overline{y_1}, \overline{y_2}, \overline{y_3}, \ldots\ldots\ldots, \overline{y_s}$ where $\overline{y_1}$ denotes the smallest mean and $\overline{y_s}$ the highest mean.
Calculate $\overline{y_s} - \overline{y_1}$ and compare it with D_s.
If ($\overline{y_s} - \overline{y_1}$) > D_s, means are said to be heterogeneous (not equal to each other). Therefore divide the treatment means into two groups, first containing $\overline{y_1}$, $\overline{y_2}, \overline{y_3}$ ......,$\overline{y_{s-1}}$, and second containing, $\overline{y_2}, \overline{y_3}$ ...... $\overline{y_s}$ Compare difference between highest and smallest with D_{s-1} in both the groups. If the difference is less than D_{s-1}, the groups of treatment means is said to be homogeneous. If the difference is more than D_{s-1}, divide the group into 2, both containing (s-2) treatments means. In each group, difference between highest and lowest will be compared with D_{s-2}. Continue in this manner till all treatments are covered or when all sub groups are found to be homogeneous. Present the result by using either the line notation or alphabet notation to indicate which treatments are at par and which are significantly different. The SAS program for calculations is given below:

SAS Program

```
proc ANOVA;
class Replication A B;
model Response = Replication A Replication*A B A*B;
test h=A e=Replication*A;
means treatment/DUNCAN;
run;
```

We can also find the coefficient of variation (C.V.) for the main-plot and sub-plot treatments (or interaction) by using

C.V. (Main-plot) $= \frac{\sqrt{MS_{Ea}}}{over\ all\ mean} X\ 100$

C.V. (Sub-plot or interaction) = . $= \frac{\sqrt{MS_{Eb}}}{over\ all\ mean} X\ 100$ (2)

3.2 Two-factor factorial experiment analysis in RBD

The mathematical model for an experiment having two factors A and B with a and b levels respectively and conducted in RBD is given by

$$Y_{ijk=}\mu + \gamma_i + a_j + b_k + (ab)_{jk} + e_{ijk}$$
$$i=1,2,....,r;\ j=1,2,....,a;\ \ k=1,2,....,b \qquad (3)$$

In whiche_{ijk}'s are normally and independently distributed with mean zero and variance σ^2. Here, Y_{ijk} is the observation of i^{th} replication, j^{th} main plot and k^{th} sub-plot, μ is the overall mean, $\gamma_i$is the i^{th} replication effect, a_j is the j^{th} level of factor A effect, b_k is the k^{th} level of factor B effect, $(ab)_{jk}$ is the interaction effect and e_{ijk} is the error component and r, a and b are the number of replications, levels of factor A and factor B respectively. Table 2 shows the ANOVA Table for the abovesaid model.

Source of variation	**d.f.**	**SS**	**MS**	**F-ratio**
Replication	r-1	SS_R	$MS_R = \frac{SS_R}{r-1}$	$F_R = \frac{MS_R}{MS_E}$
A	a-1	SS_A	$MS_A = \frac{SS_A}{a-1}$	$F_A = \frac{MS_A}{MS_E}$
B	b-1	SS_B	$MS_B = \frac{SS_B}{b-1}$	$F_B = \frac{MS_B}{MS_E}$
A×B	(a-1)(b-1)	SS_{AB}	$MS_{AB} = \frac{SS_{AB}}{(a-1)(b-1)}$	$F_{AB} = \frac{MS_{AB}}{MS_E}$
Error	ab(r-1)	SS_E	$MS_E = \frac{SS_E}{ab(r-1)}$	
Total	rab-1	SS_{Tot}		

Table 2 : ANOVA Table for Two-factor Factorial Experiment in RBD

Here;

Total Sum of Squares = $SS_{Tot} = \sum_{i,j,k} y_{ijk}^2 - \frac{Y^2}{rab}$

Replicate Sum of Squares = $SS_R = \sum_{i,} \frac{Y_{i..}^2}{ab} - \frac{Y^2}{rab}$

Sum of Squares due to factor A = $SS_A = \sum_{j} \frac{Y_{.j.}^2}{rb} - \frac{Y^2}{rab}$

Sum of Squares due to factor B = SS_B= $\sum_k \frac{Y_{..k}^2}{ra} - \frac{Y^2}{rab}$

Sum of Squares due to factor AxB = SS_{AB}= $\sum_{j,k} \frac{Y_{.jk}^2}{r} - \sum_j \frac{Y_{.j.}^2}{rb} - \sum_k \frac{Y_{..k}^2}{ra} + \frac{Y^2}{rab}$

Sum of Squares due to Error = SS_E = $SS_{Tot} - SS_R - SS_A - SS_B - SS_{AB}$

If F-ratio for the A, B or A×B is larger than the corresponding F-values obtained from the statistical tables at a level of significance α, then the corresponding effect (main or interaction) is significant otherwise it is insignificant. It should be noted here that in split-plot analysis, sub-plot treatments are tested with a higher degree of precision than the main-plot treatments, whereas all effects (main or interaction) are tested with equal precisions in a factorial experiment.

SAS Program

```
proc anova data;
class Replication A B;
model Response = Replication A|B;
run;
```

We can also find the coefficient of variation (C.V.) for the factors A or B or AxB by using

$$C.V.=\frac{\sqrt{MS_E}}{over\ all\ mean} x100 \quad (4)$$

3.3 Analysis of two-way classified data with m observations per cell

The mathematical model is given by

$$Y_{ijk} = \mu + a_j + b_k + (ab)_{jk} + e_{ijk}$$

i=1, 2, 3...m ; j=1, 2, 3…a and k=1, 2, 3…b (5)

Where Y_{ijk} is the ith observation corresponding to jth level of factor A and kth level of factor B, μ is the general mean effect, a_j is the effect of jth level of factor A, b_k is the effect of kth level of factor B, $(ab)_{jk}$ is the interaction effect and e_{ijk} is the error effect due to chance such that e_{ijk} are independently normally distributed with means 0 and variance σ^2_e. ANOVA Table for this model is given in Table 3.

Source of variation	d.f.	Sum of Squares (SS)	Mean Square (MS)	F
Factor A	a-1	SS_A	$MS_A = \frac{SS_A}{a-1}$	$F_A = \frac{MS_A}{MS_E}$
Factor B	b-1	SS_B	$MS_B = \frac{SS_B}{b-1}$	$F_B = \frac{MS_B}{MS_E}$

Interaction A×B	(a-1)(b-1)	SS_{AB}	$MS_{AB} = \frac{SS_{AB}}{(a-1)(b-1)}$	$F_{AB} = \frac{MS_{AB}}{MS_E}$
Error	ab(m-1)	SS_E	$MS_E = \frac{SS_E}{ab(m-1)}$	
Total	abm-1	SS_{Tot}		

Table 3: ANOVA Table for Two-way Classified Data with m observations per cell

Here; Total Sum of Squares = $SS_{Tot} = \sum_{i,j,k} y_{ijk}^2 - \frac{Y^2}{mab}$

Sum of Squares due to factor A = $SS_A = \sum_j \frac{Y_{.j.}^2}{mb} - \frac{Y^2}{mab}$

Sum of Squares due to factor B = $SS_B = \sum_k \frac{Y_{..k}^2}{ma} - \frac{Y^2}{mab}$

Sum of Squares due to factor AxB = $SS_{AB} = \sum_{j,k} \frac{Y_{.jk}^2}{m} - \sum_j \frac{Y_{.j.}^2}{mb} - \sum_k \frac{Y_{..k}^2}{ma} + \frac{Y^2}{mab}$

Sum of Squares due to Error = $SS_E = SS_{Tot} - SS_A - SS_B - SS_{AB}$

If F-ratio for the A, B or A×B is larger than the corresponding F-values obtained from the statistical tables at a level of significance α, then the corresponding effect (main or interaction) is significant otherwise it is insignificant. In this case, all effects (main or interaction) are tested with equal precisions.

SAS program

```
proc anova ;
class Replication A B;
model Response =  A|B;
run;
```

In this case too, we can find the coefficient of variation (C.V.) for the factors A or B or A×B by using

$$C.V. = \frac{\sqrt{MS_E}}{over\ all\ mean} x100 \quad (6)$$

3.4 Power of the test

The frequency function of F' has not been extensively tabulated, but P.C Tang has compiled tables that can be used to evaluate $\int_0^{F_\alpha} f(F')\,dF'$ for certain values of α. These tables are not given explicitly in terms of F', but in terms of E^2,

Where $E^2 = \frac{pF'}{(q + pF')}$; p and q being the degrees of freedom for F'.

The tables calculated by P.C Tang allow us to obtain β(λ) for various values of p, q, λ (λ being non-centrality parameter of F' and for α=0.05 and 0.01.

Tang evaluated the integral

$$P(II) = 1 - \beta(\phi) = \int_0^{E_\alpha^2} g(E^2, p, q, \phi)\, dE^2 \qquad (7)$$

Instead of using the non centrality parameter λ, Tang used the parameter ϕ, where $\phi = \sqrt{\frac{2\lambda}{p+1}}$

The procedure for computing the power β(λ) for a given λ is as follows (p and q will be given):

1. Choose the probability of type I error; that is, set α=0.05 and α=0.01.
2. Find E_α^2 from the Tang tables.
3. Compute $\phi = \sqrt{\frac{2\lambda}{p+1}}$.
4. Find p(II) for the appropriate values of p, q and ϕ.
5. Then β(λ)= 1-P(II)

3.5 Analysis of Data

3.5.1 Split plot ANOVA

The two sets of data were analyzed by split-plot ANOVA technique by considering the nitrogen levels as main-plot treatments and varieties as sub-plot treatments and the significance of Nitrogen levels, Varieties and their interaction was tested by using SAS software. Proc ANOVA of SAS was used to display the results. Table 4 shows the results of ANOVA of split plot design for grain yield (kg/plot) in AVT-2 (BT) trial.

Class Level Information for AVT-2(BT) trial
Class: Replication, N (nitrogen levels) and V (varieties)
Levels: 3 (for replication), 3 (three nitrogen levels) and 5 (number of varieties)
Number of observations read: 45
Number of observations used: 45
Dependent variable: Grain yield

Source of variation	**d.f.**	**Sum of Squares**	**Mean square**	**F Value**	**Pr > F**
Model	20	1.19294667	0.05964733	11.30	< 0.0001
Error	24	0.12665333	0.00527722		
Corrected Total	44	1.31960000			

R-Square	Coeff . Var.	Root MSE	Yield Mean
0.904021	6.985047	0.072644	1.040000

Source of variation	d.f.	ANOVA SS	Mean square	F Value	Pr > F
Replication	2	0.04521333	0.02260667	4.28	0.0257
N	2	0.08764000	0.04382000	8.30	0.0018
Replication*N	4	0.06906667	0.01726667	3.27	0.0282
V	4	0.93104444	0.23276111	44.11	<0.0001
N*V	8	0.05998222	0.00749778	1.42	0.2384

Tests of hypotheses using the ANOVA MS for replication*N as an Error Term

Source of variation	d.f.	ANOVA SS	Mean square	F Value	Pr > F
N	2	0.08764000	0.04382000	2.54	0.1943

Table 4: ANOVA of split plot design for AVT-2 (BT) trial

By comparing the probabilities [Pr>F] obtained for each effect with α=0.01 or α=0.05, the ANOVA model is found to be highly significant and the proportion of variability in the grain yield explained by the model is 0.904 (90.4%). The nitrogen effect is not significant [(Pr>F) =0.1943]. Varieties effect is found to be highly significant, whereas, the interaction effect between nitrogen levels and varieties is found to be insignificant. Duncan Multiple Range Test (DMRT) was performed for comparison of varietal means and the results are given in Table 5.

Alpha (α)	0.05
Error degrees of freedom	24
Error mean square	0.005277

Number of Means	2	3	4	5
Critical Range	.07068	.07423	.07652	.07813

Duncan Grouping	Mean	N	Variety S. No.
A	1.20444	9	3
A	1.17000	9	5
B	1.03778	9	1
B	0.98556	9	2
C	0.80222	9	4

Means with the same letter are not significantly different.

Table 5: Duncan's Multiple Range Test for grain yield means in AVT-2(BT) trial

NOTE: This test controls the Type I comparison-wise error rate, not the experiment-wise error rate.

The Table 5 reveals that the grain yield means of all varietal pairs except 3 & 5 (Pusa Basmati1 and Pant S Dhan- 17) and 1 & 2 (IET 20827 and IET 20847) are significantly different. The highest mean yield is observed for variety 1 (Pusa Basmati1) and lowest for variety 4 (Taroari Basmati). Table 6 reveals the results of ANOVA of split plot design for AVT-2 (IM) trial.

Class Level Information for AVT-2 (IM) trial
Class: Replication, N (nitrogen levels) and V (varieties)
Levels:3 (number replications), 3 (three nitrogen levels) and 12 (number of varieties)
Number of observations read: 108
Number of observations used: 108
Dependent variable: Grain yield

Source of variation	d.f.	Sum of Squares	Mean square	F Value	Pr > F
Model	41	3.14164907	0.07662559	3.98	<0.0001
Error	66	1.27129444	0.01926204		
Corrected Total	107	4.41294352			

R-Square	Coeff. Var.	Root MSE	Yield Mean
0.711917	8.932171	0.138788	1.553796

Source of variation	d.f.	ANOVA SS	Mean Square	F Value	Pr > F
Replication	2	0.27036852	0.13518426	7.02	0.0017
N	2	1.30856296	0.65428148	33.97	<0.0001
Replication*N	4	0.23273704	0.05818426	3.02	0.0238
V	11	1.00154352	0.09104941	4.73	<0.0001
N*V	22	0.32843704	0.01492896	0.78	0.7432

Tests of hypotheses using the ANOVA MS for Replication*N as an Error Term

Source of variation	d.f.	ANOVA SS	Mean square	F Value	Pr > F
N	2	1.30856296	0.65428148	11.24	0.0228

Table 6: ANOVA of split plot design for AVT-2 (IM) trial

Table 6 reveals that the model is highly significant and proportion of variability in grain yield explained by the model is 0.712 (71.2%). The nitrogen effect is significant at 5% level of significance [(Pr>F)=0.0228], varieties are highly significant, whereas, the interaction effect between nitrogen levels and varieties is insignificant. Duncan Multiple Range Test (DMRT) was performed for comparison of varietal means and the results are given in Table 7.

Alpha (α)	0.05
Error degrees of freedom	66
Error mean square	0.019262

Number of Means	Critical Range	Number of Means	Critical Range
2	0.1306	8	0.1514
3	0.1374	9	0.1528
4	0.1419	10	0.1540
5	0.1452	11	0.1551
6	0.1477	12	0.1560
7	0.1497		

Duncan Grouping				Mean	N	Variety S. No.
		A		1.77000	9	12
B		A		1.68889	9	6
B		C		1.59889	9	1
B		C	D	1.57556	9	10
B		C	D	1.57333	9	4

B	E	C	D	1.55222	9	3
B	E	C	D	1.54889	9	8
	E	C	D	1.52000	9	9
	E	C	D	1.48111	9	5
	E	C	D	1.47556	9	7
	E		D	1.44556	9	2
	E			1.41556	9	11

Means with the same letter are not significantly different.

Table 7: Duncan's Multiple Range Test for grain yield means in AVT-2 (IM) trial

Table 7 reveals that means of varieties 12 & 6 (Local-PD-18 and IET20735), varieties 6, 1, 10, 4, 3 & 8 (IET20735, IET20926, KRH-2, IET20937, IET20934 and IET20734), varieties 3, 8, 9, 5, 7, 2 & 11 (IET20934, IET20734, Jaya, IET20944, IET20744, IET20930 and Narendra359), varieties 1, 10, 4, 3, 8, 9, 5 & 7 (IET20926, KRH-2, IET20937, IET20934, IET20734, Jaya, IET20944 and IET20744) and varieties 10, 4, 3, 8, 9, 5 & 7 (KRH-2, IET20937, IET20934, IET20734, Jaya, IET20944 and IET20744) are not significantly different, when considered together. All other comparisons are significantly different. The largest mean yield is observed for variety 12 (Local-PD-18), whereas lowest mean yield for variety 11 (Narendra359).

3.5.2 Two-factor factorial experiment ANOVA

The ANOVA for two-factor factorial RBD was performed for testing the significance of nitrogen levels, varieties and their interaction. Proc ANOVA of SAS was used to calculate and to display the results. The Table 8 shows the results of ANOVA of 3×5 factorial experiment in Randomized Block Design (RBD) with 3 replications for AVT-2 (BT) trial.

Class Level Information for AVT-2 (BT) trial
Class: Replication, N (nitrogen levels) and V (varieties)
Levels: 3 (for replication), 3 (three nitrogen levels N1=50kg, N2=100kg and N3=150kg) and 5 (number of varieties which are: IET 20827, IET 20847, Pusa Basmati 1, Taroari Basmati, and Pant S Dhan- 17)
Number of observations read: 45
Number of observations used: 45

Source of variation	d.f.	Sum of Squares	Mean square	F Value	Pr > F
Model	16	1.12388000	0.07024250	10.05	<0.0001
Error	28	0.19572000	0.00699000		
Corrected Total	44	1.31960000			

R-Square	Coeff. Var.	Root MSE	Yield Mean
0.851682	8.039060	0.083606	1.040000

Source of variation	d.f.	ANOVA SS	Mean square	F Value	Pr > F
Replication	2	0.04521333	0.02260667	3.23	0.0545
N	2	0.08764000	0.04382000	6.27	0.0056
V	4	0.93104444	0.23276111	33.30	<0.0001
N*V	8	0.05998222	0.00749778	1.07	0.4097

Table 8: ANOVA of two factor factorial in RBD for AVT-2 (BT) trial

The results exhibit that the model is highly significant and the proportion of variability in grain yield explained by the model is 0.851 (85.1%). Nitrogen levels as well as varieties are found to have highly significant effects on grain yield. However, no significant effect of interaction between nitrogen levels and varieties is found. Similar results were obtained by split-plot analysis, although the proportion of variability in grain yield explained by the former model is a bit higher. The Table 9 shows the results of ANOVA of 3×12 factorial experiment in RBD with 3 replications for AVT-2 (IM) trial.

Class Level Information for AVT-2(IM) trial
Class: Replication, N (nitrogen levels) and V (varieties)
Levels: 3 (for replication), 3 (three nitrogen levels N_1=60kg, N_2=120kg and N_3=180kg) and 12 (number of different varieties used in AVT-2(IM))
Number of observations read: 108
Number of observations used: 108

Source of variation	d.f.	Sum of Squares	Mean square	F Value	Pr > F
Model	37	2.90891204	0.07861924	3.66	<0.0001
Error	70	1.50403148	0.02148616		
Corrected Total	107	4.41294352			

R-Square	Coeff. Var.	Root MSE	Yield Mean
0.659177	9.433772	0.146582	1.553796

Source of variation	d.f	ANOVA SS	Mean square	F Value	Pr > F
Replication	2	0.27036852	0.13518426	6.29	0.0031
N	2	1.30856296	0.65428148	30.45	<0.0001
V	11	1.00154352	0.09104941	4.24	<0.0001
N*V	22	0.32843704	0.01492896	0.69	0.8296

Table 9: ANOVA of two factor factorial in RBD for AVT-2 (IM)

It is concluded from Table 9 that the model used as well as nitrogen effect, varieties are highly significant, however, the interaction between nitrogen levels and varieties is insignificant. The proportion of variability in grain yield explained by the model is 0.659 (65.9%).

3.5.3 ANOVA for two-way classified data with several observations per cell

The ANOVA was performed by considering the number of replications as the number of observations in each cell (m=3) for testing the significance of nitrogen levels, varieties and their interaction. Proc ANOVA of SAS was used to analyze and to display the results. The results are displayed in Tables 10 and 11 respectively for the two trails.

Source of variation	d.f.	Sum of Squares	Mean square	F Value	Pr > F
Model	14	1.07866667	0.07704762	9.59	<0.0001
Error	30	0.24093333	0.00803111		
Corrected Total	44	1.31960000			

R-Square	Coeff. Var.	Root MSE	Yield Mean
0.817419	7.616968	0.089616	1.040000

Source of variation	d.f.	ANOVA SS	Mean square	F Value	Pr > F
N	2	0.08764000	0.04382000	5.46	0.0095
V	4	0.93104444	0.23276111	28.98	<0.0001
N*V	8	0.05998222	0.00749778	0.93	0.5039

Table 10: ANOVA for two-way classified data with several (m) observations per Cell for AVT-2 (BT) trial

For this trial, the model is found to be highly significant. Nitrogen levels as well varieties are found to have significant effects on grain yield whereas interaction between nitrogen levels and varieties is found to be insignificant. The proportion of variability in grain yield explained by the model is 0.817 (81.7%).

Source of variation	d.f.	Sum of Squares	Mean square	F Value	Pr > F
Model	35	2.63854352	0.07538696	3.06	<0.0001
Error	72	1.77440000	0.02464444		
Corrected Total	107	4.41294352			

R-Square	Coeff. Var.	Root MSE	Yield Mean
0.597910	10.10335	0.156985	1.553796

Source of variation	d.f.	ANOVA SS	Mean square	F Value	Pr > F
N	2	1.30856296	0.65428148	26.55	<0.0001
V	11	1.00154352	0.09104941	3.69	0.0003
N*V	22	0.32843704	0.01492896	0.61	0.9064

Table 11: ANOVA for two-way classified data with several (m) observations per Cell for AVT-2 (IM) trial

For this trial, the model is found to be highly significant. Nitrogen levels as well varieties are found to have significant effects on grain yield whereas interaction between nitrogen levels and varieties is found to be insignificant. The proportion of variability in grain yield explained by the model is 0.598 (59.8%).

3.6 Comparison of the three methods

For comparison of the three methods, we have calculated the powers of the tests under these methods at various values of the non-centrality parameters under the alternative hypotheses. Considering the probability of type I error α=0.05, the value of E_α^2 are obtained from Tang tables corresponding to the degrees of freedom n_1 for numerator and n_2 for denominator of F statistic. The values of ϕ and P (II) (probability of second type error) and the power of the test β (λ) have been computed and are given in Table 12, 13 and 14 respectively under the three methods.

Effect	**p**	**q**	E_α^2	**Λ**	$\phi = \sqrt{\frac{2\lambda}{p+1}}$	**P (II)**	**β (λ)**
N	2	4	.776	1.5	1	0.824	0.176
				3.375	1.5	0.661	0.339
				6	2	0.460	0.540
				9.375	2.5	0.272	0.728
				13.5	3	0.135	0.865
V	4	24	.316	2.5	1	0.670	0.330
				5.625	1.5	0.322	0.678
				10	2	0.080	0.920
				15.625	2.5	0.009	0.991
N*V	8	24	.440	4.5	1	0.600	0.400
				10.125	1.5	0.201	0.799
				18	2	0.024	0.976
				28.125	2.5	0.001	0.999

Table 12: Power of the test under split plot analysis

Effect	**p**	**q**	E_α^2	**Λ**	$\phi = \sqrt{\frac{2\lambda}{p+1}}$	**P (II)**	**β (λ)**
N	2	28	0.193	1.5	1	0.708	0.292
				3.375	1.5	0.411	0.589
				6	2	0.155	0.845
				9.375	2.5	0.035	0.965
				13.5	3	0.005	0.995
V	4	28	0.279	2.5	1	0.661	0.339
				5.625	1.5	0.309	0.691
				10	2	0.072	0.928
				15.625	2.5	0.008	0.992
N*V	8	28	0.396	4.5	1	0.584	0.416
				10.125	1.5	0.182	0.818
				18	2	0.019	0.981
				28.125	2.5	–	–

Table 13: Power of the test under two-factor factorial analysis in RBD

Effect	p	q	E_{α}^{2}	Λ	$\phi = \sqrt{\frac{2\lambda}{p+1}}$	P (II)	β (λ)
N	2	30	0.181	1.5	1	0.706	0.294
				3.375	1.5	0.408	0.592
				6	2	0.153	0.847
				9.375	2.5	0.034	0.966
				13.5	3	0.004	0.996
V	4	30	0.264	2.5	1	0.658	0.342
				5.625	1.5	0.303	0.697
				10	2	0.069	0.931
				15.625	2.5	0.049	0.951
N*V	8	30	0.377	4.5	1	0.578	0.422
				10.125	1.5	0.175	0.825
				18	2	0.017	0.983
				28.125	2.5	_	_

Table 14: Power of the test under 2-way classified data with m observations per cell

4. Conclusion

It can be observed from the above mentioned tables that the method of two-way classified data with several (m) observations per cell is better followed by two-factor factorial technique in RBD and split plot analysis for analyzing the given data. The results equally hold for nitrogen levels, varieties as well as for their interaction. The highest powers (0.996, 0.951, and 0.983) are found corresponding to values (13.5, 15.625 and 18) of non-centrality parameters respectively for nitrogen levels, varieties and their interaction.

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Appendix

Nitro-gen levels Main	Varieties (Sub-Plot)	Grain yield (kg/plot)			Panicle No. /sq.m.			Panicle weight (g)		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
N_1	IET 20827	0.99	0.88	0.97	188	194	184	1.6	1.6	1.54
	IET 20847	0.85	0.91	1.05	194	186	200	1.53	1.09	1.83
	Pusa Basmati 1	1.05	1.13	1.25	195	200	210	1.34	1.55	1.74
	Taroari Basmati	0.70	0.75	0.90	191	196	202	1.35	1.92	1.19
	Pant S Dhan- 17	1.05	1.08	1.12	200	210	205	1.62	1.46	1.43
N_2	IET 20827	1.02	0.97	1.15	195	205	180	1.74	2.04	1.78
	IET 20847	1.20	0.88	0.99	183	189	210	1.79	1.64	1.88
	Pusa Basmati 1	1.26	1.17	1.33	195	210	205	2.06	2.29	1.66
	Taroari Basmati	0.93	0.85	0.88	193	205	207	1.87	1.34	1.43
	Pant S Dhan- 17	2.25	1.07	1.26	195	219	212	1.89	2.19	1.92
N_3	IET 20827	1.11	1.25	1.00	185	204	190	1.52	1.77	1.55
	IET 20847	1.10	0.91	0.98	180	203	190	2.1	1.19	1.81
	Pusa Basmati 1	1.24	1.16	1.25	243	203	205	1.7	2.02	1.6
	Taroari Basmati	0.73	0.73	0.75	192	204	216	1.34	1.13	1.12
	Pant S Dhan- 17	1.18	1.25	1.27	203	211	222	1.74	1.82	2

Nitro-gen levels Main	Varieties (Sub-Plot)	1000- grain wt (g)			Days to 50% flowering			Seed to Seed (days)		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
N_1	IET 20827	18.3	18.5	18.4	100	104	105	135	137	135
	IET 20847	18.7	19.5	19.0	107	109	108	139	141	138
	Pusa Basmati 1	20.4	19.2	19.8	104	106	107	135	141	138
	Taroari Basmati	22.7	22.8	22.1	108	112	108	138	142	140
	Pant S Dhan- 17	21.4	20.6	20.7	103	99	100	135	130	134
N_2	IET 20827	18.4	18.2	18.8	105	110	108	135	140	139
	IET 20847	18.8	19.6	19.3	112	108	110	143	140	142
	Pusa Basmati 1	19.2	20.5	19.1	108	109	108	136	139	141
	Taroari Basmati	21.8	23.1	22.1	110	109	108	140	141	140
	Pant S Dhan- 17	19.7	20.3	20.5	100	100	101	132	130	132
N_3	IET 20827	18.0	18.5	18.4	108	110	100	139	140	138
	IET 20847	19.1	19.4	19.4	109	110	109	142	140	139
	Pusa Basmati 1	20.0	19.9	19.3	108	106	109	138	136	139
	Taroari Basmati	21.9	21.7	21.8	110	111	112	140	142	144
	Pant S Dhan- 17	19.6	19.7	19.8	101	100	102	130	132	134

Table 15: Data obtained on selected AVT-2 (BT) rice culture

Nitrogen levels (Main)	**Varieties (Sub-plot)**	**Grain yield(kg/plot)**			**Panicle (No./sq.m)**			**Panicle weight(g)**		
		R_1	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**	**R_1**	**R_2**	**R_3**
N_1	IET20926	1.37	1.40	1.45	148	153	162	2.96	2.76	2.80
	IET20930	1.28	1.25	1.52	158	151	162	2.44	2.35	2.90
	IET20934	1.38	1.68	1.25	180	170	158	2.69	2.35	2.09
	IET20937	1.55	1.60	1.45	180	178	168	2.41	2.28	2.65
	IET20944	2.48	1.38	1.25	185	191	177	2.37	2.046	2.26
	IET20735	1.30	1.60	1.45	192	202	169	2.34	2.48	2.28
	IET20744	1.20	1.15	1.50	154	154	142	3.12	2.68	2.46
	IET20734	1.40	1.50	1.25	153	153	166	2.90	2.75	2.60
	Jaya	1.25	1.38	1.35	1.73	158	159	2.08	2.67	2.46
	KRH-2	1.35	1.25	1.55	153	168	182	2.52	2.49	2.57
	Narendra359	1.05	1.48	1.35	158	158	180	2.37	2.47	2.28
	Local-PD-18	1.78	1.60	1.60	171	203	186	2.81	2.55	2.52
N_2	IET20926	1.88	1.70	1.48	173	190	195	2.44	3.06	2.56
	IET20930	1.68	1.40	1.45	172	184	190	2.22	2.31	2.72
	IET20934	1.78	1.65	1.50	200	210	205	2.17	2.30	3.59
	IET20937	1.88	1.60	1.65	179	164	180	3.15	2.54	2.74
	IET20944	1.63	1.75	1.35	205	189	188	2.65	2.14	2.41
	IET20735	1.85	2.00	1.75	181	190	200	2.35	3.04	3.36
	IET20744	1.45	1.65	1.75	188	164	155	2.94	2.63	2.65
	IET20734	1.85	1.68	1.75	190	183	179	2.95	2.23	2.36
	Jaya	1.58	1.45	1.65	180	178	175	2.78	2.70	2.91
	KRH-2	1.85	1.70	1.63	195	208	214	2.56	2.59	2.43
	Narendra359	1.38	1.65	1.45	175	182	191	2.68	2.20	2.65
	Local-PD-18	1.70	2.10	1.90	206	214	202	2.91	3.07	2.60
N_3	IET20926	1.68	1.83	1.60	198	191	202	2.63	2.46	2.87
	IET20930	1.25	1.80	1.38	180	172	190	2.36	2.30	2.63
	IET20934	1.45	1.78	1.50	208	188	195	2.25	2.33	2.56
	IET20937	1.28	1.55	1.60	192	170	180	2.22	2.23	2.68
	IET20944	1.51	1.68	1.30	200	205	195	2.04	2.44	2.63
	IET20735	1.80	1.95	1.50	188	195	199	2.61	3.21	2.74
	IET20744	1.53	1.65	1.40	183	178	179	2.83	2.37	2.29
	IET20734	1.45	1.68	1.38	198	190	195	2.36	2.11	2.56
	Jaya	1.68	1.78	1.56	192	198	200	2.19	2.45	2.75
	KRH-2	1.75	1.60	1.50	198	202	210	2.32	2.56	2.38
	Narendra359	1.60	1.53	1.25	182	185	194	2.19	2.25	2.55
	Local-PD-18	1.75	1.85	1.65	211	210	208	2.33	2.34	2.25

Nitrogen levels (Main)	Varieties (Subplot)	1000- grain wt (g)			Days to 50% flowering			Seed to Seed (days)		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
N_1	IET20926	22.80	22.80	23.05	126	124	126	158	159	156
	IET20930	17.85	17.75	18.05	110	109	112	142	144	142
	IET20934	22.92	23.20	23.36	104	105	107	135	136	138
	IET20937	16.85	17.21	16.95	108	108	107	140	142	140
	IET20944	17.40	17.65	17.30	107	106	107	138	140	141
	IET20735	23.45	23.25	23.65	108	108	109	142	141	143
	IET20744	24.78	25.00	24.83	103	102	104	135	137	135
	IET20734	22.30	22.50	23.00	104	104	106	136	134	136
	Jaya	27.30	27.45	27.80	104	104	105	136	134	135
	KRH-2	22.55	22.38	22.65	104	106	105	134	136	137
	Narendra359	26.65	26.90	26.35	105	106	106	137	136	136
	Local-PD18	26.65	26.85	27.01	104	104	103	134	134	133
N_2	IET20926	22.90	22.90	23.10	124	125	126	156	156	159
	IET20930	17.95	18.05	17.65	109	111	112	141	142	143
	IET20934	23.35	23.15	23.55	105	105	106	137	136	135
	IET20937	17.05	17.15	16.83	108	109	106	140	142	143
	IET20944	17.64	17.35	17.52	109	107	108	139	140	140
	IET20735	23.65	23.38	23.98	109	109	108	143	144	144
	IET20744	25.05	24.95	24.82	103	103	105	135	133	135
	IET20734	22.65	22.72	22.92	106	107	107	139	138	138
	Jaya	27.25	27.55	27.80	104	104	105	136	135	136
	KRH-2	12.50	22.45	23.01	104	105	105	135	137	137
	Narendra359	26.76	26.85	26.68	107	106	106	139	137	137
	Local-PD18	26.95	27.12	27.26	104	105	103	134	135	135
N_3	IET20926	22.95	22.80	23.05	124	124	126	156	156	158
	IET20930	17.89	18.50	18.00	112	112	110	143	140	142
	IET20934	23.55	23.29	23.38	106	107	105	139	138	138
	IET20937	16.85	16.88	17.05	107	106	106	139	139	140
	IET20944	17.70	17.55	17.60	107	106	107	138	139	138
	IET20735	23.65	23.35	23.65	109	108	109	142	141	143
	IET20744	25.25	24.65	24.95	104	104	103	137	136	136
	IET20734	22.80	22.65	22.58	109	107	108	141	139	140
	Jaya	27.45	27.60	27.78	105	104	105	136	138	107
	KRH-2	22.38	22.90	22.40	107	105	105	138	137	139
	Narendra359	26.45	27.01	26.68	108	107	107	139	138	139
	Local-PD-18	27.22	26.95	27.65	105	105	104	135	135	134

Table 16: Data obtained on selected AVT-2 (IM) rice culture