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Research Communication

Innovations in statistical analysis of the data from an experiment on sources and levels of fertilizers

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ABSTRACT

Routine statistical analysis of data does not separate out main effect of rates and sources of nitrogen and their interaction. The innovated technique of statistical analysis of data separates out these effects and increases the efficiency of design by reducing the CD value for comparing the main effects of rate and source of nitrogen and gives an opportunity for comparing control with individual level of nitrogen.

Key words : Efficiency, Interaction effect, Levels of N, Main effect, Sources of N

Adoption of an appropriate experimental design is a must in a field experiment and this also applies to fertilizer experiments involving different levels and sources of nutrients. The problem arises from the zero level, which truly speaking is not attended by sources. Hence, control is compared with mean of rest of treatments i.e. control vs. rest. This comparison has no meaning. A research worker takes the control to compare it with individual level of plant nutrient rather than mean of all the levels. There is a technique for proper and logical comparison of control with other levels of a plant; the procedure is explained with taking an example of an experiment conducted in randomized block design.

An example experiment was conducted with ten treatments including four levels of nitrogen (0, 40, 80 and 120 kg N/ha) and three sources of nitrogen (urea, ammonium sulphate and calcium ammonium nitrate). Since, 0 kg N/ha does not include any source of nitrogen, hence, there are only 10 treatments instead of 12 as often mistaken. The treatments are: (i) Control, (ii) 40 kg N/ha as urea, (iii) 80 kg N/ha as urea,(iv) 120 kg N/ha as urea, (v) 40 kg N/ha as AS, (vi) 80 kg N/ha as AS, (vii) 120 kg N/ha as AS, (viii) 40 kg N/ha as CAN (ix) 80 kg N/ha as CAN, (x) 120 kg N/ha as CAN. There were four replications.

The grain yield (t/ha) of rice obtained in the experiment is presented in Table 1, and the routine analysis of variance (Gomez and Gomez, 1984) is given in Table 2.

The analysis of variance indicates that there is a significant difference between two treatment means. Hence, we have to calculate critical differences for comparing means of two treatments as per procedure given below:

CD for comparing means of two treatments = SEd × t value at error df

where, $SEd = \sqrt{\frac{2V_E}{r}} = \sqrt{\frac{2 \times 0.163}{4}} = 0.2855$

t value at error df = 2.052

Hence, CD = 0. 2855 × 2.052 = 0.58

Results indicated that application of 40 kg N/ha as urea significantly increased the yield over control, whereasapplication of 40 kg N/ha as AS or CAN significantly increased the yield over 40 kg N/ha as urea. Similarly, application of 80 kg N/ha as AS or CAN significantly increased the yield over 80 kg N/ha as urea. Application of 120 kg N/ha as urea, AS and CAN being at par, significantly increased the yield over 80 kg N/ha as AS and CAN. However, such routine statistical analysis of data does not give a clear picture about the effect of levels and source of nitrogen separately and their interaction. Hence an innovation is proposed.

Innovation: Innovation in the statistical analysis of data of such experiment may be done by two methods as given below:

Method I

In this method, the variability due to treatments is divided into two groups: (i) control, and (ii) nitrogen plots. The variability among the nitrogen plots is further divided into: (i) rates of nitrogen, (ii) sources of nitrogen and (iii) rates of nitrogen × sources of nitrogen. For calculating

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Table 1. Grain yield of rice (t/ha) as affected by level and source of nitrogen

Treatment	R I	R II	R III	R IV	Total	Mean yield (t/ha)
Control	1.8	1.6	1.5	1.7	6.6	1.65
40 kg N/ha as urea	2.3	2.4	2.5	2.7	9.9	2.47
80 kg N/ha as urea	3.7	2.8	3.6	4.1	14.2	3.55
120 kg N/ha as urea	5.1	5.4	6.4	6.5	23.4	5.85
40 kg N/ha as AS	4.0	3.1	3.2	3.3	13.6	3.35
80 kg N/ha as AS	4.7	3.8	3.9	5.0	17.4	4.35
120 kg N/ha as AS	5.0	6.2	6.4	6.4	24.0	6.00
40 kg N/ha as CAN	3.5	3.6	3.4	3.9	14.4	3.60
80 kg N/ha as CAN	4.8	4.1	4.5	4.5	17.9	4.47
120 kg N/ha as CAN	5.0	5.1	5.4	5.6	21.1	5.27
Total	39.9	38.1	40.8	43.7	162.5	CD (P=0.05)0.58

Table 2. Analysis of variance

Source of variation	DF	SS	MS	F-Value		
				Calculated	Observed	
					5%	1%
Replication	3	1.64	0.547	3.35	2.96	4.60
Treatments	9	71.71	7.968	48.88	2.25	3.14
Error	27	4.40	0.163	–	–	
Total	39	77.75	1.994			

Table 3. Grain yield of rice as influenced by rates and sources of nitrogen

Rates of N (kg N/ha)	Sources of N			Total	Mean
	Urea	AS	CAN		
40	9.9	13.6	14.4	37.9	3.96
80	14.2	17.4	17.9	49.5	4.58
120	23.4	24.0	21.1	68.5	4.45
Total	47.5	55.0	53.4	155.9*	
Mean	3.16	4.12	5.71		

1. *Grand total of nitrogen plots only

Table 4. Innovated Analysis of Variance

Source of Variation	DF	SS	MS	F-value		
				Calculated	Tabulated	
					5%	1%
Replication	3	1.64	0.547	3.35	2.96	4.60
Treatments	9	71.71	7.968	48.88	2.25	3.14
Nitrogen rates (NR)	2	39.78	19.890	122.02	3.35	5.49
Nitrogen source (NS)	2	2.60	1.300	7.97	3.35	5.49
NR NS	4	3.47*	0.867	5.32	2.73	4.11
Control vs nitrogen	1	25.86	25.860	158.65	4.21	7.68
Error	27	4.40	0.163			
Total	39	77.75	1.994			

*N_0 does not contain nitrogen source, For details see Sharma (2012)

sum of squares for sources, and sum of squares for rates and sum of squares for rates × sources, we have to construct a two-way as shown in Table 3. The analysis of variance as per this break up is presented in Table 4.

Analysis of various indicates that all the factors were highly significant; hence, CD for comparing the means of various factors is calculated as per procedure given below:

(a) CD for comparing means of nitrogen rates or nitro-

gen sources: Since means of both nitrogen rates and nitrogen sources are based on 12 values (4 replication 3 rates or sources of N), the critical difference for comparing means of nitrogen rates or sources is calculated with the help of following expression.

CD = SEd t value at error df

Where, SEd = $\sqrt{\frac{2V_E}{r(nr \text{ or } ns)}} = \sqrt{\frac{2 \times 0.163}{4 \times 3}} = 0.1648$

t value at error df = 2.052

Hence, CD = 0.1648 × 2.052 = 0.338

(b) CD for comparing different rates of N at different sources or vice versa: The variance due to interaction between rates and sources of nitrogen is based on the values of 4 plots (replications) and CD for interaction between nitrogen rates and nitrogen sources is calculated using following expression:.

CD = SEd t value at error df

Where, SEd = $\sqrt{\frac{2V_E}{r}} = \sqrt{\frac{2 \times 0.163}{4}} = 0.2855$

t value at error df = 2.052

Hence, CD = 0.2855 × 2.052 = 0.5858

(c) CD for comparing mean of control with mean of all nitrogen plots: Since, mean of control is based on 4 values and mean of all nitrogen plots is based on 36 values (4 replication 3 rates of N 3 sources of N), the critical difference for comparing mean of control with mean of all nitrogen plots is calculated with the help of following expression.

CD = SEd t value at error d. f.

Where, SEd = $\sqrt{\text{Error MS}\left(\frac{1}{r} + \frac{1}{r \times nr \times ns}\right)} = \sqrt{0.163\left(\frac{1}{4} + \frac{1}{4 \times 3 \times 3}\right)} = 0.2128$

t value at error d. f. = 2.052

Hence, CD = 0.2128 × 2.052 = 0.44

The results are summarized in Table 5

Results presented in table 5 indicated that the grain yield of rice increased significantly with each successive increase in rate of nitrogen up to 120 kg N/ha. The interaction between rates and source of nitrogen was significant and indicated that at 40 and 80 kg N/ha there was no significant difference between AS and CAN, whereas at 120 kg N/ha, AS gave significantly higher grain yield than CAN. Further CAN was significantly superior to urea at 40 and 80 kg N/ha, whereas at 120 kg N/ha urea and CAN were at par.

Table 5. Interaction effect between rates of N and sources of N

Source of N	Rates of N			
	N_{40}	N_{80}	N_{120}	Mean
Urea	2.47 a	3.55 a	5.85 a	3.96
AS	3.40 b	4.35 b	6.00 b	4.58
CAN	3.60 b	4.47 b	5.27 a	4.45
Mean	3.16	4.12	5.71	
CD (P=0.05)				
Nitrogen rates (NR)		0.34		
Nitrogen source (NS)		0.34		
NR NS		0.58		

Method II

In this method, the variability due to treatments is divided into different components in such a way so that control can be compared with individual level of nitrogen. The sum of squares for treatments is split into: (a) sum of squares for nitrogen rates, (b) sum of squares for nitrogen sources, and (c) sum of squares for nitrogen rates nitrogen sources. The sum of squares for nitrogen rates is calculated on the basis of all the plots (40) including control plots instead on the basis of 36 plots as calculated in Method I. In this way we can compare control with other nitrogen rates instead of comparing control with the mean of nitrogen rates as done in Method I. The sum of squares for nitrogen rates, nitrogen sources and nitrogen rates nitrogen sources is calculated as shown below:-

(a) SS for nitrogen rates (NR) = $\left[\frac{C^2}{r} + \frac{\sum(NR)^2}{r \times ns}\right] - CF$

$= \left[\frac{(6.6)^2}{4} + \frac{(37.9)^2 + \cdots + (68.5)^2}{4 \times 3}\right] - 660.16 = (10.89 + 714.91) - 660.16 = 725.80 - 660.16 = 65.64$

(b) SS for nitrogen sources (NS) = $\frac{\sum(NS)^2}{r\,(nr-1)^*} - CF_1$

$= \frac{(47.5)^2 + \cdots + (53.4)^2}{4 \times 3} - 675.13 = \frac{8132.81}{12} - 675.13 = 677.73 - 675.13 = 2.60$

(c) SS for (NR × NS) = $\frac{\sum(NRNS)^2}{r} - CF_1 - NR\ SS_1 - NS\ SS$

Where, NR SS_1 = $\frac{\sum(\text{NR excluding } N_0 \text{plots})^2}{r \times ns} - CF_1$

$= \frac{(37.9)^2 + \ldots + (68.5)^2}{4 \times 3} - 675.73 = \frac{8578.91}{12} - 675.13 = 714.91 - 675.13 = 39.78$

Hence, (NR × NS) SS = $\frac{(9.9)^2 + \cdots + (21.1)^2}{4} - 675.73 - 39.78 - 2.60$

$= \frac{2883.91}{4} - 675.13 - 39.78 - 2.60 = 720.98 - 675.13 - 39.78 - 2.60 = 3.47$

***Note*:** It may be verified that sum of nitrogen rates SS, nitrogen sources SS and (nitrogen rates nitrogen sources) SS is equal to treatment SS. *N_0 does not contain nitrogen source

The analysis of variance is given table 6.

It can be seen from the Table 6 that differences among rates of nitrogen, and sources of nitrogen as well as the interaction between rates of N and sources of N were highly significant, hence, critical differences for comparing rates of N, sources of N and comparing rates of N at different sources of N and vice versa have to be calculated as per procedure given below.

(a) CD for control vs 40/ 80/ 120 kg N/ha: Since, mean of control is based on 4 values (4 replications) and mean of 40/80/120 kg N/ha is based on 12 values (4 replications × 3 sources of N), the critical difference for comparing control with different rates of N is calculated with the help of following expression.

CD = SEd t value at error df

Where, $SEd = \sqrt{\text{Error MS}\left(\frac{1}{r} + \frac{1}{r \times ns}\right)} = \sqrt{0.163\left(\frac{1}{4} + \frac{1}{4 \times 3}\right)} = 0.2331$

t value at error df = 2.052

Hence, CD = 0.2331 × 2.052 = 0.478

(b) CD for 40 vs 80/120 or 80 vs 120 kg N/ha: The mean of all the levels are based on 12 values (4 replications 3 nitrogen sources) and the CD is calculated as follows:

CD = S Ed t value at error df

Where, $SEd = \sqrt{\frac{2\text{Error MS}}{r \times ns}} = \sqrt{\frac{2 \times 0.163}{4 \times 3}} = 0.1648$

t value at error df = 2.052

Hence, CD = 0.1648 × 2.052 = 0.338

(c) CD for comparing sources of nitrogen: The critical difference for comparing means of different sources of N is also calculated on the basis of values of 12 values (4 replications 3 rates of N (40, 80 and 120 kg/ha) as in case of rates of nitrogen. Hence, CD calculated for rates of nitrogen will be used for comparing means of source of nitrogen

(d) CD for comparing different rates of N at different sources or vice versa: The variance due to interaction between rates and sources is based on the values of 4 plots (replications) and CD for interaction between nitrogen rates and nitrogen sources is calculated using following expression:

CD = SEd t value at Error df

$SEd = \sqrt{\frac{2\text{Error MS}}{r}} = \sqrt{\frac{2 \times 0.163}{4}} = 0.2855$

t value at error df = 2.052

Hence, CD = 0.2855 × 2.052 = 0.5858

The results are summarized in Table 7.

Table 6. Innovated Analysis of Variance

Source of Variation	DF	SS	MS	F-value		
				Calculated	Tabulated	
					5%	1%
Replications	3	1.64	0.547	3.35*	2.96	4.60
Treatments	9	71.71	7.968	48.88	2.25	3.14
Rates of N	3	65.64	21.880	134.23**	2.96	4.60
Source of N	2	2.60	1.300	7.97*	3.35	5.49
Rates of N sources of N	4	3.47	0.867	5.32**	2.73	4.11
Error	27	4.40	0.163			
Total	39	77.75				

Table 7. Effect of rates and sources of nitrogen on gain yield of rice

Rates of N	Source of N			
	Urea	AS	CAN	Mean
N_0	-	-	-	1.65 a
N_{40}	2.47 a	3.55 a	5.85 a	3.16 b
N_{80}	3.40 b	4.35 b	6.00 b	4.12 c
N_{120}	3.60 b	4.47 b	5.27 a	5.71 d
Mean	3.96 a	4.58 b	4.45 b	-
CD (P=0.05)				
Rates of N (Control vs other rates)			0.48	
(Between other rates)			0.34	
Source of N			0.34	
Rates			0.58	

Results Presented in Table 7 indicate that grain yield of rice increased significantly with each successive increase in rate of nitrogen.

The sources and level interaction was significant. At 40 and 80 kg/ha there was no significant difference between AS and CAN, whereas at 120 kg N/ha, AS gave significantly higher grain yield than CAN. Further CAN was significantly superior to urea at 40 and 80 kg N/ha, whereas at 120 kg N/ha urea and CAN were at par.

It is concluded that in innovated method I, we could separate out the effect of rates and sources and their interaction. Moreover, the CD value for comparing nitrogen rates and nitrogen sources calculated in innovated method was less (0.34) as compared to the CD value for comparing treatment means calculated in traditional method (0.58). However, the comparison of control with mean of nitrogen plots has no meaning. Method II provides an opportunity to compare control with other nitrogen rates.

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