



## Conducting an On-Farm Research Trial in Wheat

### *A Randomized Complete Block Design with Results Analyzed By MS Excel Using the ANOVA: Two-Factor Without Replication Option*

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This guide discusses a possible scenario for conducting an on-farm research trial using a randomized complete block (RCB) design in wheat. Possible treatments might include a farmer's variety (check variety) along with three new varieties.

Some of the preliminary planning in this scenario is indicated in Table 1 along with one of many possible trial designs. Note the treatments are randomized, and the table also includes a planting order and plot number that often helps reduce errors during planting and harvesting.

**Table 1.** Randomized treatments, planting order, plot number, and plot design for a randomized complete block design with four treatments and blocks in wheat.

Block (B 1- 4)	Treatment (T A-D)	Planting order	Plot no.
1	B	1	1
1	D	5	2
1	C	9	3
1	A	13	4
2	D	6	5
2	A	14	6
2	C	10	7
2	B	2	8
3	C	11	9
3	A	15	10
3	B	3	11
3	D	7	12
4	A	16	13
4	B	4	14
4	D	8	15
4	C	12	16

Field design	
TB	Block #1
TD	
TC	
TA	
TD	Block #2
TA	
TC	
TB	
TC	Block #3
TA	
TB	
TD	
TA	Block #4
TB	
TD	
TC	

**Figure 1.** Wheat yield results (bu/a) from a randomized complete block design with four-treatments and four blocks.

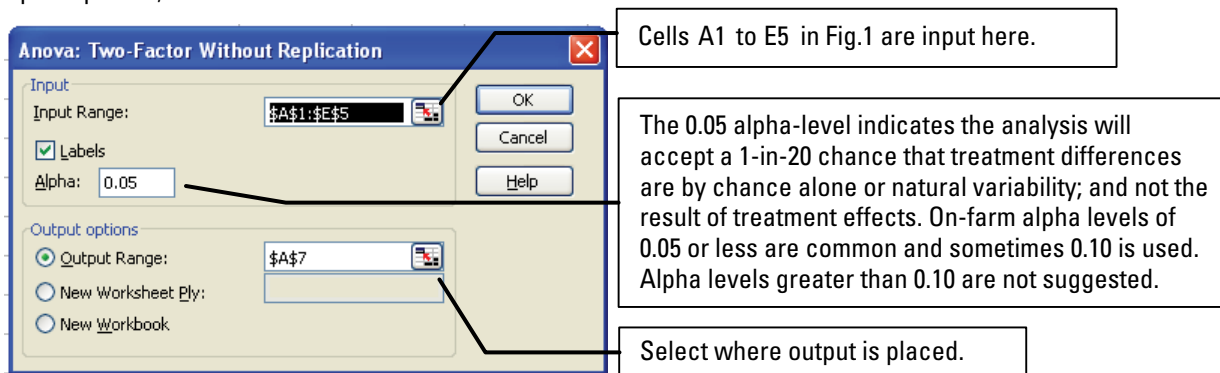
	A	B	C	D	E
1		Block 1	Block 2	Block 3	Block 4
2	Trt A	47	52	56	52
3	Trt B	50	55	57	57
4	Trt C	57	53	59	56
5	Trt D	58	65	68	59

Cells A1 to E5 in Fig.1 will be selected for analysis in Fig. 2.

The **Anova: Two-factor Without Replication** option in Microsoft Excel was used to analyze the data for differences. This option uses analysis of variance (ANOVA) procedures. Access this option by clicking **Tools** and then **Data analysis**. Click the **Anova: Two-factor Without Replication** option and follow the

directions (Figure 2). Note that with this option, treatments and replications or blocks were used as the two factors; therefore, replication was already accounted for; hence, the reason for selecting the Two-factor *Without Replication* option.

**Figure 2.** The Anova: Two-Factor Without Replication dialog box. Note that input range, labels, alpha level = 0.05, and output range (where output is placed) are indicated.



As indicated in the Excel output results (Figure 3), the P-value for rows (treatments) equaled 0.0037; and since this value was less than 0.05, the treatment differences were significant. Although ANOVA indicated there were significant differences

among the treatment means, it did indicate how they differed from one another. The calculation of a LSD (least significant difference) value is commonly used to determine differences among treatment means.

**Table 3.** The summary and analysis of variance (ANOVA) output from MS Excel for the results in Figure 1 using the Two-factor Without Replication option.

	A	B	C	D	E	F	G
9	Anova: Two-Factor Without Replication						
10							
11	<i>SUMMARY</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
12	Trt A	4	212	53	4		
13	Trt B	4	219	54.75	6.91667		
14	Trt C	4	225	56.25	6.25		
15	Trt D	4	247	61.75	14.9167		
16							
17	Block 1	4	219	54.75	10.25		
18	Block 2	4	226	56.5	29.6667		
19	Block 3	4	234	58.5	31		
20	Block 4	4	224	56	8.66667		
21							
22		Rows (treatments) & Columns (blocks)					
23	<b>ANOVA</b>						
24	<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
25	Rows	171.688	3	57.2292	7.68034	0.00749	3.86255
26	Columns	29.1875	3	9.72917	1.30568	0.33138	3.86255
27	Error	67.0625	9	7.45139			
28							
29	Total	267.938	15				

Calculation of LSD value:

The calculation of the LSD value is done using the information from the ANOVA table (shaded cells) in Figure 3. First, a critical-t value is calculated using an alpha level of 0.05 and the error degrees of freedom (*df*) in Figure 3. After the critical-t value is determined by Excel, it is then used to determine the LSD value by Excel (rows 33 and 34 in Figure 4):

$$LSD = \text{Critical-t value} * \sqrt{(2 * MSE / n)}, \text{ where MSE = mean squares for error and } n = \text{number of blocks}$$

In this scenario, the LSD for treatment differences equals **4.49** bushels per acre (bu/a). Treatment means that differ by 4.49 bu/a or more are significantly different.

**Figure 4.** Calculation of LSD values using values from the Excel output in Figure 3.

	A	B	C	D	E	F	G	H
27								
28	Calculation of LSD) value:							
29								
30	Critical t-value =	2.2622	where Critical-t = TINV(alpha level, error <i>df</i> )					
31			= TINV(0.05, C24)					
32								
33	LSD .05 value =	4.4948	where LSD. <sub>.05</sub> = Critical-t* $\sqrt{(2*MSE/ number \text{ blocks})}$					
34			= B30*SQRT(2*D24/4)					

**Figure 5.** Determinations of treatment mean differences using the calculated LSD value in Figure 4.

	A	B	C	D	E	F	G
35							
36	Determination of mean differences (LSD = 4.49):						
37	Treatment means (TM)		Excel	TM	Treatment means		
38	ranked high to low		equation	- LSD	significance*		
39	Treatment D	62.75	=B39-4.49	58.26	62.8	a	
40	Treatment C	56.25	=B40-4.49	51.76	56.3	b	
41	Treatment B	54.25	=B41-4.49	49.76	54.3	b	
42	Treatment A	53	=B42-4.49	48.51	53.0	b	
43							
44	*Means followed by the same letter are not significantly different at $P=0.05$ .						
45							

Mean separation by LSD value:

A common way of using the LSD value for mean separation is to first rank the treatment means from high to low (cells **B39** to **B42**). Next, using the format in the Excel equation column (composite cells **CD39** to **42**), enter the equation in the TM – LSD column (cells **E39** to **E42**) and let Excel calculate the results. Since the mean for treatment D was the highest yield; insert the yield in composite **FG39** along with the letter **a** behind it. Next, find if the other treatment means are significantly lower than treatment D. To do this, subtract the LSD value from the mean for treatment D ( $62.75 - 4.49 = 58.26$  bu/a) - the result is in cell **E39**. Treatment means equal to or higher than 58.26 bu/a are not significantly different from treatment D. In this case, all of the other treatment means (cells **B40** to **B42**) were less than 58.26 and therefore are significantly different and lower in yield compared to treatment D.

Now consider the second highest yield from treatment C (cell **B40**). Since it was already known that treatment mean C was

significantly lower compared to D; the mean yield for C (cell **B40**) is inserted in composite cell **FG40** along with the letter **b** behind it. Next, determine if any of the remaining varieties were similar to treatment C. To do this subtract the LSD value from the treatment mean C ( $56.25 - 4.49 = 51.76$ ) - the result is in cell **E40**. The remaining treatment means equal to or higher than 51.76 bu/a are not significantly different from treatment C. In this case, both of the remaining treatment means, B and A, were greater than 51.76 bu/a, and therefore are not significantly different from C. Since, the treatment means C, B, and A were not significantly different; they were similar. Since they were similar, the mean yield of treatments B and A along with the letter **b** were also inserted in composite cells **FG 41** and **42**. Now, the analysis has accounted for all the possible treatment differences and the analysis is complete. In summary, treatment D resulted in the highest wheat yields; while treatments C, B, and A resulted in similar but significantly lower yields, as indicated in composite cells **FG39** to **42**.