Example Problems 1

1. An experiment was installed to test 4 rates of Zn on cabbage. There were 3 replicates and the experiment was installed in a randomized complete block design. The yields are given in the table below.

Treatment kg Zn/ha	Block		
	I	II	III
0	3.5	3.8	3.7
5	3.9	4.2	4.4
10	4.0	4.4	4.8
15	4.3	4.2	4.9

A. Calculate the analysis of variance for this data set and perform the appropriate F tests. Write the formula for each statistic calculated.

B. Subdivide the treatment SS into single df using 2 sets of orthogonal comparisons.

C. Calculate the SS for the orthogonal comparisons for trends using the orthogonal comparison method and perform the F tests.

D. Interpret the results.

2. Three varieties of cowpeas were grown in pots arranged in a completely randomized design. The dry matter yields are given in the table below.

Sample	Variety		
	A	B	C
1	2	8	11
2	4	7	10
3	3	9	12

a. Calculate the analysis of variance for the experiment conducted as a CR design.

b. Compare variety A with Others in the analysis of variance.

c. Compare variety B with variety C in the analysis of variance.

d. Perform the appropriate F tests and interpret the results.

e. Write out the analysis of variance (sources of variation and df) for this experiment installed in a randomized complete block design.

3. Provide the ANOVA (sources of variation and df) for an experiment in which 6 varieties of grapefruit were grown in 3 replicates in a randomized complete block design with data collected as indicated.

A. Without sampling.
B. With 5 fruits sampled/variety/rep.
C. With 2 determinations made for acidity per fruit.
D. Indicate the F tests with arrows for the 3 ANOVAs above for the random model.

4. Write our the ANOVA (sources of variation and df) for the following experiments. Subdivide the treatment df where appropriate and indicate the F test(s) with arrows for the fixed and random models.

A. Three (3) varieties of wheat were compared in a completely randomized design with 4 plots of each variety.

B. Four (4) feeding rations were evaluated on 3 breeds of chickens. There were 5 chickens in a pen for each treatment (considered as samples) and the treatments were replicated 4 times. The experiment was installed in a randomized complete block design.

C. Five (5) fruits were taken from each of 4 tangerine trees and each fruit was analyzed for sugar content with 2 determinations being made for each fruit.

D. Three (3) herbicides were evaluated on three (3) varieties of sugarcane. Each treatment was replicated 4 times in a randomized complete block design.

E. The effects of 3 rates of N, 2 rates of P and 4 rates of K in factorial combinations were evaluated with corn. Three (3) replicates were installed in a randomized complete block design.

5. Write out the orthogonal coefficients for the treatment combinations below. Indicate the df for the comparisons.

A. Four (4) varieties of sorghum (A, B, C, D) where variety A is the standard variety for the area.

B. Three (3) levels of P (0, 100, 200 kg/ha) in factorial combination with 2 levels of Zn (0, 10 kg/ha). Write out 2 sets of comparisons.

C. Six (6) herbicides are compared. Two are preemergence herbicides and 4 are postemergence herbicides.

D. Five (5) varieties of sweet corn with 2 varieties that are early maturing and 3 varieties that are late maturing.

6. Red clover plants were inoculated with 6 strains of Rhozobium and the nitrogen content of the plants was later determined. Each treatment was replicated 5 times and the experiment was conducted as a completely randomized design. The analysis of variance indicated that there was a highly significant difference between strains. The MSE was 11.79. The treatment means are given in the table below.

	Rhizobium strains					
	1	2	3	4	5	6
	N content (mg)					
Means	28.8	24.0	14.6	19.9	13.3	19.4

A. Compare the treatment means using the LSD (use lines and letters).

B. Compare the treatment means using Duncan's multiple range test (use letters).

7. Assuming and LSD of 3.4 compare the following means using lines and letters.

Treatments	K0	K1	K2	K3	K4
Means	12	17	21	22	24

8. Assuming Duncan's shortest significant difference values of

p =	2	3	4	5
D =	4.8	5.1	5.4	6.0

Compare the following sets of means.

A. 31, 30, 25, 24, 20
B. 37, 33, 31, 29, 25, 20

Example Problems 1 Answers

1. A.

					F Required	
Source	df	SS	MS	F	F.05	F.01
Block	2	0.552	0.276	7.26*	5.14	10.92
Zn	(3)	1.18	0.393	10.34**	4.76	9.78
Zn linear	1	1.0402	1.0402	27.37**	5.99	13.75
Zn quad	1	0.1408	0.1408	3.7		
Zn cubic	1	0.0015	0.0015			
Error	6	0.228	0.038	Error for all F tests		
Total	11	1.96				

1. B.

	Zn				
	0	5	10	15	df
1st Set					
0 vs others	-3	1	1	1	1
5 vs (10 & 15)	0	-2	1	1	1
10 vs 15	0	0	-1	1	1
2nd Set					
linear	-3	-1	1	3	1
quadratic	1	-1	-1	1	1
cubic	-1	3	-3	1	1

1. C. SSlin = 1.0401 SSquad = 0.1408 SScubic = 0.0015

1. D. There is a highly significant linear response to Zn. Yields increase linearly as Zn applications increase.

2. A.

					F Required	
Source	df	SS	MS	F	F.05	F.01
Bet. Var.	(2)	98	49	49.00**	5.14	10.92
A vs Others	1	84.5	84.5	84.50**	5.99	13.75
B vs C	1	13.5	13.5	13.50*		
Within Var	6	6.0	1.00	Error for all F tests		
Total	8	104.0				

2. B.

	Variety			
	A	B	C	df
A vs Others	-2	1	1	1
B vs C	0	-1	1	1

2. C. SS A vs Others = 84.5 SS B vs C = 13.5

2. D. Dry matter yields of variety A were highly significantly lower than those of varieties B and C, which were not significantly different from each other.

2. E. As RCBD

Source	df	
Block	2	
Variety	2	
Error	4	Error for all F tests
Total	8	

3. A.

Source	df	
Block	2	
Variety	5	
Error	10	Error for all F tests
Total	17	

3. B.

Source	df	
Block	2	
Variety	5	
Expt Error	10	Error for testing block and variety
Sampling Error	72	(s-1) b v = 4 x 3 x6, Error for testing Expt Error
Total	89	

3. C.

Source	df	
Block	2	
Variety	5	
Expt Error	10	Error for testing block and variety
Fruit (Blk, Var)	72	(s-1) b v = 4 x 3 x 6, Error for testing Expt Error
Dtm (Frt/Blk,Var)	90	(d-1) s b v = 1 x 5 x 3 x 6, Error for testing Fruit
Total	179	

3. D. F tests shown above

4. A.

Source		df	Random
Between Var	M1	2	M1/M2
Within Var	M2	9	
Total		11	

4. B.

Source		df	Fixed	Random
Block	M1	3	M1/M6	M1/M6
Trt	M2	(11)	M2/M6	M2/M6
Breeds	M3	2	M3/M6	M3/M5
Rations	M4	3	M4/M6	M4/M5
B x R	M5	6	M5/M6	M5/M6
Expt Error	M6	33	M6/M7	M6/M7
Sample Error	M7	192		
Total		239		

4. C.

Source		df	Random
Trees	M1	3	M1/M2
Fruit/Tree	M2	16	M2/M3
Dtm/Fruit/Tree	M3	20	
Total		39	

4. D.

Source		df	Fixed	Random
Block	M1	3	M1/M6	M1/M6
Trt	M2	(8)	M2/M6	M2/M6
Herb	M3	2	M3/M6	M3/M5
Var	M4	2	M4/M6	M4/M5
Herb x Var	M5	4	M5/M6	M5/M6
Error	M6	24		
Total		35		

4. E.

Source		df	Fixed	Random
Block	M1	2	M1/M10	M1/M10
Trt	M2	(23)	M2/M10	M2/M10
N	M3	2	M3/M10	M3/M5
P	M4	1	M4/M10	M4/M5
NxP	M5	2	M5/M10	M5/M9
K	M6	3	M6/M10	M6/M9
NxK	M7	6	M7/M10	M7/M9
PxK	M8	3	M8/M10	M8/M9
NxPxK	M9	6	M9/M10	M9/M10
Error	M10	46		
Total		71		

5. A.

	Varieties				
	A (std)	B	C	D	df
A vs others	-3	1	1	1	1
B vs C+D	0	-2	1	1	1
C vs D	0	0	-1	1	1

5. B.

	P0Z0	P0Z10	P100Z0	P100Z10	P200Z0	P200Z10	df
P0 vs P100+P200	-2	-2	1	1	1	1	1
P100 vs P200	0	0	-1	-1	1	1	1
Z0 vs Z10	-1	1	-1	1	-1	1	1
P0vsP100+P200xZ	2	-2	-1	1	-1	1	1
P100vsP200xZ	0	0	1	-1	-1	1	1

	P0Z0	P0Z10	P100Z0	P100Z10	P200Z0	P200Z10	df

P linear	-1	-1	0	0	1	1	1
P quadratic	1	1	-2	-2	1	1	1
Z0 vs Z10	-1	1	-1	1	-1	1	1
Plin x Z	1	-1	0	0	-1	1	1
Pquad x Z	-1	1	2	-2	-1	1	1

5. C.

	Preemergence		Postemergence				
	A	B	C	D	E	F	df
Pre vs Post	-2	-2	1	1	1	1	1
A vs B	-1	1	0	0	0	0	1
C vs DEF	0	0	-3	1	1	1	1
D vs EF	0	0	0	-2	1	1	1
E vs F	0	0	0	0	-1	1	1

5. D.

	Early		Late			
	Sf	La	Nb	Ks	Ia	df
Early vs Late	-3	-3	2	2	2	1
Sf vs La	-1	-	0	0	0	1
Nb vs Ks+Ia	0	0	-2	1	1	1
Ks vs Ia	0	0	0	-1	1	1

6.

	Rhizobium strains					
	1	2	3	4	5	6
	N content (mg)					
Means	28.8	24.0	14.6	19.9	13.3	19.4

ANOVA

Source	df
Bet Trt	5

Within Trt 24
Total 29

a. LSD
LSD = t.05*SED (SED = standard error of a difference)
SED = sqrt((2)(11.79)/5) = 2.17
t.05,24 df = 2.064
LSD = 4.48

Make array of means:

	Rhizobium strains					
	1	2	4	6	3	5
Means	28.8	24.0	19.9	19.4	14.6	13.3
LSD	___	_____	_____		_____	
LSD	a	b	bc	c	d	d

b. DMR

DMR	a	b	b	b	c	c

p =	2	3	4	5
R =	1.00	1.05	1.08	1.10
D = R*LSD	4.48	4.70	4.84	4.93

7.

Treatments	K0	K1	K2	K3	K4
Means	12	17	21	22	24
	c	b	a	a	a

8. A.

31	30	25	24	20
a	a	b	b	b

8. B.

37	33	31	29	25
a	ab	b	bc	c