**Modern College of Arts, Science and Commerce, Pune-05**

**Department of Statistics**

**M.Sc. II (Semester IV)**

**Date: Submission date:**

**Practical No. – 6**

**Title: 32  Factorial Experiments.**

Q.1 Following table shows yield of grain from paddy grown in 39' x 12' plots for 9 treatments.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variety | Fertilizer | I | II | III | IV | V | VI |
| Red Aus | Ammophos | 112 | 128 | 118 | 128 | 92 | 152 |
|  | Ammonium | 168 | 116 | 144 | 100 | 100 | 80 |
|  | Sulphate  Control | 106 | 84 | 68 | 156 | 156 | 128 |
| Ashiful | Ammophos | 112 | 81 | 108 | 96 | 96 | 48 |
|  | Ammonium | 61 | 98 | 58 | 86 | 86 | 98 |
|  | Sulphate Control | 97 | 86 | 92 | 80 | 80 | 66 |
| Dadkalma | Ammophos | 134 | 112 | 116 | 114 | 114 | 128 |
|  | Ammonium | 125 | 106 | 110 | 102 | 102 | 110 |
|  | Sulphate Control | 62 | 60 | 99 | 90 | 90 | 87 |

Analyze the above data and give your comments.

Q.2 A machine is used to fill 5-gallon metal container with soft drink syrup.  The variable of interest is the amount of syrup loss due to frothing.  Three factors are thought to influence frothing;  the nozzle design (A), the filling speed (B) and the operating pressure (C). Three nozzles, three filling speeds and three pressures are chosen and two replicates of a 33 factorial experiment are run.  The data is as shown in the following table.

NOZZLE TYPE 'A'

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Pressure (in psi) | 1 | | | 2 | | | 3 | | |
|  |  |  | Speed (in RPM) (B) | | |  |  |  |
|  | 100 | 120 | 140 | 100 | 120 | 140 | 100 | 120 | 140 |
| 10 | -35 | -45 | -40 | 17 | -65 | 20 | -39 | -55 | 15 |
| -25 | -60 | -15 | 24 | -58 | 4 | -35 | -67 | -30 |
| 15 | 110 | -10 | -80 | 55 | -55 | 110 | -90 | -28 | 110 |
| 75 | 30 | 54 | 120 | -44 | 44 | 113 | -26 | 135 |
| 20 | 4 | -40 | 31 | -23 | -64 | -20 | -30 | -61 | 54 |
| 5 | -30 | 36 | -5 | -62 | -31 | -55 | -52 | 4 |

Analyse the data and interpret the results.

**Answer-sheet 🡪**

**Que 1) Ans 🡪**



From the above graph it can be seen that the data follows normality.



It can be seen that the data points are randomly evenly distributed which concludes that variance in constant i.e homoscedasticity is observed. Therefore both the assumptions are satisfied.

**General Factorial Regression: Y versus A, B**

Factor Information

Factor Levels Values

A 3 1, 2, 3

B 3 1, 2, 3

**Analysis of Variance**

Source DF Adj SS Adj MS F-Value P-Value

Model 8 15325 1915.6 4.10 0.001

Linear 4 12804 3200.9 6.86 0.000

A 2 10265 5132.4 11.00 0.000

B 2 2539 1269.4 2.72 0.077

2-Way Interactions 4 2521 630.3 1.35 0.266

A\*B 4 2521 630.3 1.35 0.266

Error 45 21003 466.7

Total 53 36328

**Model Summary**

S R-sq R-sq(adj) R-sq(pred)

21.6042 42.18% 31.91% 16.75%

Coefficients

Term Coef SE Coef T-Value P-Value VIF

Constant 102.33 2.94 34.81 0.000

A

1 16.33 4.16 3.93 0.000 1.33

2 -17.39 4.16 -4.18 0.000 1.33

B

1 8.17 4.16 1.96 0.056 1.33

2 0.44 4.16 0.11 0.915 1.33

A\*B

1 1 -5.17 5.88 -0.88 0.384 1.78

1 2 -1.11 5.88 -0.19 0.851 1.78

2 1 -2.94 5.88 -0.50 0.619 1.78

2 2 -4.22 5.88 -0.72 0.476 1.78

**Regression Equation**

**Y = 102.33 + 16.33 A\_1 - 17.39 A\_2 + 1.06 A\_3 + 8.17 B\_1 + 0.44 B\_2 - 8.61 B\_3 - 5.17 A\*B\_1 1**

**- 1.11 A\*B\_1 2 + 6.28 A\*B\_1 3 - 2.94 A\*B\_2 1 - 4.22 A\*B\_2 2 + 7.17 A\*B\_2 3 + 8.11 A\*B\_3 1**

**+ 5.33 A\*B\_3 2 - 13.44 A\*B\_3 3**

Fits and Diagnostics for Unusual Observations

Obs Y Fit Resid Std Resid

2 168.00 118.00 50.00 2.54 R

21 68.00 116.33 -48.33 -2.45 R

30 156.00 116.33 39.67 2.01 R

39 156.00 116.33 39.67 2.01 R

49 48.00 90.17 -42.17 -2.14 R

**Inverse Cumulative Distribution Function**

F distribution with 2 DF in numerator and 45 DF in denominator

P( X ≤ x ) x

0.95 3.20432

**Inverse Cumulative Distribution Function**

F distribution with 4 DF in numerator and 45 DF in denominator

P( X ≤ x ) x

0.95 2.57874

**Decision**

F1 = 11 > F 0.05, 2, 45 = 3.2043, we Reject H01 at 5% l.o.s.

F2 = 2.75< F 0.05, 2, 45 = 3.2043, We Accept H02 at 5% l.o.s.

F3 = 1.35< F 0.05, 4, 45 = 2.57874, we Accept H03 at 5% l.o.s.

**Conclusion:** Main effects B and Interaction effect AB do not differ significantly. Main effect A differs significantly.

**Main Effects Plot for Y**



It can be seen that; main effect Varieties (A) significantly contribute to estimate the response variable that is yield of grain from paddy (Y),but main effect Fertilizers (B) has no significant difference.

**Interaction Plot for Y**



Interaction is not observed in the data that it is not significantly contributing to estimate in the yield of grain from paddy (Y) .

**Que 2) Ans 🡪**



From the above graph it can be seen that the data follows normality.



It can be seen that the data points are randomly evenly distributed which concludes that variance in constant i.e homoscedasticity is observed. Therefore both the assumptions are satisfied.

**General Factorial Regression: Y versus Blocks, A, B, C**

Factor Information

Factor Levels Values

A 3 1, 2, 3

B 3 1, 2, 3

C 3 1, 2, 3

**Analysis of Variance**

Source DF Adj SS Adj MS F-Value P-Value

Model 27 136233 5045.7 3.49 0.001

Blocks 1 1700 1700.2 1.18 0.288

Linear 6 85772 14295.3 9.89 0.000

A 2 393 196.5 0.14 0.874

B 2 44925 22462.6 15.53 0.000

C 2 40453 20226.7 13.99 0.000

2-Way Interactions 12 32279 2689.9 1.86 0.090

A\*B 4 20523 5130.7 3.55 0.019

A\*C 4 6489 1622.3 1.12 0.368

B\*C 4 5267 1316.8 0.91 0.472

3-Way Interactions 8 16482 2060.3 1.42 0.233

A\*B\*C 8 16482 2060.3 1.42 0.233

Error 26 37595 1446.0

Total 53 173829

**Model Summary**

S R-sq R-sq(adj) R-sq(pred)

38.0260 78.37% 55.91% 6.71%

Coefficients

Term Coef SE Coef T-Value P-Value VIF

Constant -3.80 5.17 -0.73 0.470

Blocks

1 -5.61 5.17 -1.08 0.288 1.00

A

1 1.85 7.32 0.25 0.802 1.33

2 1.96 7.32 0.27 0.791 1.33

B

1 14.13 7.32 1.93 0.064 1.33

2 -40.20 7.32 -5.49 0.000 1.33

C

1 -23.37 7.32 -3.19 0.004 1.33

2 38.41 7.32 5.25 0.000 1.33

A\*B

1 1 10.1 10.3 0.98 0.336 1.78

1 2 16.3 10.3 1.58 0.127 1.78

2 1 19.0 10.3 1.84 0.077 1.78

2 2 -16.0 10.3 -1.54 0.135 1.78

A\*C

1 1 -11.4 10.3 -1.10 0.283 1.78

1 2 -6.6 10.3 -0.64 0.527 1.78

2 1 15.5 10.3 1.50 0.145 1.78

2 2 1.8 10.3 0.17 0.866 1.78

B\*C

1 1 -2.5 10.3 -0.24 0.814 1.78

1 2 15.1 10.3 1.46 0.157 1.78

2 1 9.0 10.3 0.87 0.391 1.78

2 2 -16.6 10.3 -1.60 0.121 1.78

A\*B\*C

1 1 1 -15.1 14.6 -1.03 0.310 2.37

1 1 2 23.3 14.6 1.59 0.124 2.37

1 2 1 -1.0 14.6 -0.07 0.947 2.37

1 2 2 20.6 14.6 1.41 0.171 2.37

2 1 1 -0.5 14.6 -0.04 0.971 2.37

2 1 2 0.9 14.6 0.06 0.951 2.37

2 2 1 -4.7 14.6 -0.32 0.750 2.37

2 2 2 -15.1 14.6 -1.03 0.312 2.37

**Regression Equation**

**Y = -3.80 + 1.85 A\_1 + 1.96 A\_2 - 3.81 A\_3 + 14.13 B\_1 - 40.20 B\_2 + 26.07 B\_3 - 23.37 C\_1**

**+ 38.41 C\_2 - 15.04 C\_3 + 10.1 A\*B\_1 1 + 16.3 A\*B\_1 2 - 26.5 A\*B\_1 3 + 19.0 A\*B\_2 1**

**- 16.0 A\*B\_2 2 - 3.1 A\*B\_2 3 - 29.2 A\*B\_3 1 - 0.4 A\*B\_3 2 + 29.5 A\*B\_3 3 - 11.4 A\*C\_1 1**

**- 6.6 A\*C\_1 2 + 18.0 A\*C\_1 3 + 15.5 A\*C\_2 1 + 1.8 A\*C\_2 2 - 17.3 A\*C\_2 3 - 4.2 A\*C\_3 1**

**+ 4.9 A\*C\_3 2 - 0.7 A\*C\_3 3 - 2.5 B\*C\_1 1 + 15.1 B\*C\_1 2 - 12.6 B\*C\_1 3 + 9.0 B\*C\_2 1**

**- 16.6 B\*C\_2 2 + 7.5 B\*C\_2 3 - 6.6 B\*C\_3 1 + 1.5 B\*C\_3 2 + 5.1 B\*C\_3 3 - 15.1 A\*B\*C\_1 1 1**

**+ 23.3 A\*B\*C\_1 1 2 - 8.1 A\*B\*C\_1 1 3 - 1.0 A\*B\*C\_1 2 1 + 20.6 A\*B\*C\_1 2 2 - 19.6 A\*B\*C\_1**

**2 3 + 16.1 A\*B\*C\_1 3 1 - 43.9 A\*B\*C\_1 3 2 + 27.8 A\*B\*C\_1 3 3 - 0.5 A\*B\*C\_2 1 1**

**+ 0.9 A\*B\*C\_2 1 2 - 0.4 A\*B\*C\_2 1 3 - 4.7 A\*B\*C\_2 2 1 - 15.1 A\*B\*C\_2 2 2 + 19.8 A\*B\*C\_2 2**

**3 + 5.2 A\*B\*C\_2 3 1 + 14.2 A\*B\*C\_2 3 2 - 19.4 A\*B\*C\_2 3 3 + 15.7 A\*B\*C\_3 1 1**

**- 24.2 A\*B\*C\_3 1 2 + 8.5 A\*B\*C\_3 1 3 + 5.7 A\*B\*C\_3 2 1 - 5.5 A\*B\*C\_3 2 2 - 0.1 A\*B\*C\_3 2**

**3 - 21.4 A\*B\*C\_3 3 1 + 29.7 A\*B\*C\_3 3 2 - 8.4 A\*B\*C\_3 3 3**

Equation averaged over blocks.

Fits and Diagnostics for Unusual Observations

Obs Y Fit Resid Std Resid

8 -80.0 -18.6 -61.4 -2.33 R

20 -90.0 5.9 -95.9 -3.63 R

35 54.0 -7.4 61.4 2.33 R

47 113.0 17.1 95.9 3.63 R

**Inverse Cumulative Distribution Function**

F distribution with 2 DF in numerator and 26 DF in denominator

P( X ≤ x ) x

0.95 3.36902

**Inverse Cumulative Distribution Function**

F distribution with 4 DF in numerator and 26 DF in denominator

P( X ≤ x ) x

0.95 2.74259

**Inverse Cumulative Distribution Function**

F distribution with 8 DF in numerator and 26 DF in denominator

P( X ≤ x ) x

0.95 2.32053

**Decision**

F1 (A) = 0.14 < F 0.05, 2, 26 = 3.36902, we Accept H01 at 5% l.o.s.

F2 (B) = 15.53 > F 0.05, 2, 26 = 3.36902, we Reject H02 at 5% l.o.s.

F3 (C) = 13.99 > F 0.05, 2, 26 = 3.36902, we Reject H03 at 5% l.o.s.

F4 (AB) = 3.55 > F 0.05, 4, 26 = 2.74259, we Reject H04 at 5% l.o.s.

F5 (AC) = 1.12 < F 0.05, 4, 26 = 2.74259, we Accept H05 at 5% l.o.s.

F6 (BC) = 0.91 < F 0.05, 4, 26 = 2.74259, we Accept H06 at 5% l.o.s.

F7 (ABC)= 1.42 < F 0.05, 8, 26 = 2.32053,we Accept H07 at 5% l.o.s.

**Conclusion:** Main effects Filling speed (B) and Operating pressure (C) with interaction effect AB significantly contribute to estimate response variable that is amount of syrup loss due to frothing (Y) .

**Main Effects Plot for Y**



It can be seen that; main effects filling speed (B) and operating pressure (C) significantly contribute to estimate response variable that is amount of syrup loss due to frothing (Y).

**Interaction Plot for Y**



The interaction effect that are coincident to each other are significantly mainly the effect AB