

| Covariance Parameter Estimates |          |
|--------------------------------|----------|
| Cov Parm                       | Estimate |
| block                          | 27.8552  |
| block*variety                  | 0.3536   |
| Residual                       | 0.2265   |

| Type 3 Tests of Fixed Effects |        |        |         |        |
|-------------------------------|--------|--------|---------|--------|
| Effect                        | Num DF | Den DF | F Value | Pr > F |
| variety                       | 2      | 4      | 232.60  | <.0001 |
| phosphorus                    | 3      | 18     | 601.04  | <.0001 |
| phosphorus*variety            | 6      | 18     | 86.40   | <.0001 |

| Least Squares Means |         |            |          |                |    |         |         |       |         |         |
|---------------------|---------|------------|----------|----------------|----|---------|---------|-------|---------|---------|
| Effect              | variety | phosphorus | Estimate | Standard Error | DF | t Value | Pr >  t | Alpha | Lower   | Upper   |
| phosphorus*variety  | v1      | 0          | 56.3667  | 3.0787         | 18 | 18.31   | <.0001  | 0.05  | 49.8985 | 62.8348 |
| phosphorus*variety  | v2      | 0          | 46.8000  | 3.0787         | 18 | 15.20   | <.0001  | 0.05  | 40.3319 | 53.2681 |
| phosphorus*variety  | v3      | 0          | 54.2333  | 3.0787         | 18 | 17.62   | <.0001  | 0.05  | 47.7652 | 60.7015 |
| phosphorus*variety  | v1      | 30         | 62.9667  | 3.0787         | 18 | 20.45   | <.0001  | 0.05  | 56.4985 | 69.4348 |
| phosphorus*variety  | v2      | 30         | 53.1000  | 3.0787         | 18 | 17.25   | <.0001  | 0.05  | 46.6319 | 59.5681 |
| phosphorus*variety  | v3      | 30         | 58.2000  | 3.0787         | 18 | 18.90   | <.0001  | 0.05  | 51.7319 | 64.6681 |
| phosphorus*variety  | v1      | 60         | 64.2333  | 3.0787         | 18 | 20.86   | <.0001  | 0.05  | 57.7652 | 70.7015 |
| phosphorus*variety  | v2      | 60         | 53.5333  | 3.0787         | 18 | 17.39   | <.0001  | 0.05  | 47.0652 | 60.0015 |
| phosphorus*variety  | v3      | 60         | 63.3000  | 3.0787         | 18 | 20.56   | <.0001  | 0.05  | 56.8319 | 69.7681 |
| phosphorus*variety  | v1      | 120        | 62.5667  | 3.0787         | 18 | 20.32   | <.0001  | 0.05  | 56.0985 | 69.0348 |
| phosphorus*variety  | v2      | 120        | 52.5000  | 3.0787         | 18 | 17.05   | <.0001  | 0.05  | 46.0319 | 58.9681 |
| phosphorus*variety  | v3      | 120        | 68.0333  | 3.0787         | 18 | 22.10   | <.0001  | 0.05  | 61.5652 | 74.5015 |

| Differences of Least Squares Means |         |            |          |             |          |                |    |         |         |              |        |       |          |          |           |           |
|------------------------------------|---------|------------|----------|-------------|----------|----------------|----|---------|---------|--------------|--------|-------|----------|----------|-----------|-----------|
| Effect                             | variety | phosphorus | _variety | _phosphorus | Estimate | Standard Error | DF | t Value | Pr >  t | Adjustment   | Adj P  | Alpha | Lower    | Upper    | Adj Lower | Adj Upper |
| phosphorus*variety                 | v1      | 0          | v2       | 0           | 9.5667   | 0.6218         | 18 | 15.38   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 8.2802   | 10.8731  | 7.2510    | 11.8824   |
| phosphorus*variety                 | v1      | 0          | v3       | 0           | 2.1333   | 0.6218         | 18 | 3.43    | 0.0030  | Tukey-Kramer | 0.0871 | 0.05  | 0.8269   | 3.4398   | -0.1824   | 4.4490    |
| phosphorus*variety                 | v1      | 0          | v1       | 30          | -6.8000  | 0.3888         | 18 | -16.99  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -7.4164  | -5.7838  | -8.0470   | -5.1530   |
| phosphorus*variety                 | v1      | 0          | v2       | 30          | 3.2667   | 0.6218         | 18 | 5.25    | <.0001  | Tukey-Kramer | 0.0023 | 0.05  | 1.9802   | 4.5731   | 0.9510    | 5.5824    |
| phosphorus*variety                 | v1      | 0          | v3       | 30          | -1.8333  | 0.6218         | 18 | -2.95   | 0.0086  | Tukey-Kramer | 0.2030 | 0.05  | -3.1398  | -0.5269  | -4.1490   | 0.4824    |
| phosphorus*variety                 | v1      | 0          | v1       | 60          | -7.8667  | 0.3888         | 18 | -20.25  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -8.6830  | -7.0503  | -9.3137   | -6.4197   |
| phosphorus*variety                 | v1      | 0          | v2       | 60          | 2.8333   | 0.6218         | 18 | 4.56    | 0.0002  | Tukey-Kramer | 0.0095 | 0.05  | 1.5269   | 4.1398   | 0.5176    | 5.1490    |
| phosphorus*variety                 | v1      | 0          | v3       | 60          | -6.9333  | 0.6218         | 18 | -11.15  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -8.2398  | -5.6269  | -9.2490   | -4.6176   |
| phosphorus*variety                 | v1      | 0          | v1       | 120         | -6.2000  | 0.3888         | 18 | -15.96  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -7.0164  | -5.3836  | -7.6470   | -4.7530   |
| phosphorus*variety                 | v1      | 0          | v2       | 120         | 3.8667   | 0.6218         | 18 | 6.22    | <.0001  | Tukey-Kramer | 0.0003 | 0.05  | 2.5602   | 5.1731   | 1.5510    | 6.1824    |
| phosphorus*variety                 | v1      | 0          | v3       | 120         | -11.6667 | 0.6218         | 18 | -18.76  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -12.9731 | -10.3802 | -13.9824  | -9.3510   |
| phosphorus*variety                 | v2      | 0          | v3       | 0           | -7.4333  | 0.6218         | 18 | -11.95  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -8.7398  | -6.1269  | -9.7490   | -5.1176   |
| phosphorus*variety                 | v2      | 0          | v1       | 30          | -16.1667 | 0.6218         | 18 | -26.00  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -17.4731 | -14.8802 | -18.4824  | -13.8510  |
| phosphorus*variety                 | v2      | 0          | v2       | 30          | -6.3000  | 0.3888         | 18 | -16.21  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -7.1164  | -5.4836  | -7.7470   | -4.8530   |
| phosphorus*variety                 | v2      | 0          | v3       | 30          | -11.4000 | 0.6218         | 18 | -18.33  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -12.7064 | -10.0938 | -13.7157  | -9.0843   |
| phosphorus*variety                 | v2      | 0          | v1       | 60          | -17.4333 | 0.6218         | 18 | -28.03  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -18.7398 | -16.1269 | -19.7490  | -15.1176  |
| phosphorus*variety                 | v2      | 0          | v2       | 60          | -6.7333  | 0.3888         | 18 | -17.33  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -7.5497  | -5.9170  | -8.1803   | -5.2863   |
| phosphorus*variety                 | v2      | 0          | v3       | 60          | -16.5000 | 0.6218         | 18 | -26.53  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -17.8064 | -15.1938 | -18.8157  | -14.1843  |
| phosphorus*variety                 | v2      | 0          | v1       | 120         | -15.7667 | 0.6218         | 18 | -25.35  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -17.0731 | -14.4802 | -18.0824  | -13.4510  |
| phosphorus*variety                 | v2      | 0          | v2       | 120         | -5.7000  | 0.3888         | 18 | -14.67  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -6.5164  | -4.8836  | -7.1470   | -4.2530   |
| phosphorus*variety                 | v2      | 0          | v3       | 120         | -21.2333 | 0.6218         | 18 | -34.15  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -22.5398 | -19.9269 | -23.5490  | -18.9176  |
| phosphorus*variety                 | v3      | 0          | v1       | 30          | -8.7333  | 0.6218         | 18 | -14.04  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -10.0398 | -7.4269  | -11.0490  | -6.4176   |
| phosphorus*variety                 | v3      | 0          | v2       | 30          | 1.1333   | 0.6218         | 18 | 1.82    | 0.0850  | Tukey-Kramer | 0.7875 | 0.05  | -0.1731  | 2.4398   | -1.1824   | 3.4490    |
| phosphorus*variety                 | v3      | 0          | v3       | 30          | -3.9667  | 0.3888         | 18 | -10.21  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -4.7830  | -3.1503  | -5.4137   | -2.5197   |
| phosphorus*variety                 | v3      | 0          | v1       | 60          | -10.0000 | 0.6218         | 18 | -16.08  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -11.3064 | -8.6936  | -12.3157  | -7.6843   |
| phosphorus*variety                 | v3      | 0          | v2       | 60          | 0.7000   | 0.6218         | 18 | 1.13    | 0.2751  | Tukey-Kramer | 0.9889 | 0.05  | -0.8064  | 2.0064   | -1.6157   | 3.0157    |
| phosphorus*variety                 | v3      | 0          | v3       | 60          | -9.0667  | 0.3888         | 18 | -23.33  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -9.8830  | -8.2503  | -10.5137  | -7.6197   |
| phosphorus*variety                 | v3      | 0          | v1       | 120         | -8.3333  | 0.6218         | 18 | -13.40  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -9.6398  | -7.0269  | -10.6490  | -6.0176   |
| phosphorus*variety                 | v3      | 0          | v2       | 120         | 1.7333   | 0.6218         | 18 | 2.79    | 0.0122  | Tukey-Kramer | 0.2622 | 0.05  | 0.4269   | 3.0398   | -0.5824   | 4.0490    |
| phosphorus*variety                 | v3      | 0          | v3       | 120         | -13.8000 | 0.3888         | 18 | -35.51  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -14.6164 | -12.9836 | -15.2470  | -12.3530  |
| phosphorus*variety                 | v1      | 30         | v2       | 30          | 9.8667   | 0.6218         | 18 | 15.87   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 8.5802   | 11.1731  | 7.5510    | 12.1824   |
| phosphorus*variety                 | v1      | 30         | v3       | 30          | 4.7667   | 0.6218         | 18 | 7.67    | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 3.4602   | 6.0731   | 2.4510    | 7.0824    |
| phosphorus*variety                 | v1      | 30         | v1       | 60          | -1.2667  | 0.3888         | 18 | -3.26   | 0.0044  | Tukey-Kramer | 0.1189 | 0.05  | -2.0830  | -0.4503  | -2.7137   | 0.1803    |
| phosphorus*variety                 | v1      | 30         | v2       | 60          | 9.4333   | 0.6218         | 18 | 15.17   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 8.1269   | 10.7398  | 7.1176    | 11.7490   |
| phosphorus*variety                 | v1      | 30         | v3       | 60          | -0.3333  | 0.6218         | 18 | -0.54   | 0.5985  | Tukey-Kramer | 1.0000 | 0.05  | -1.6398  | 0.9731   | -2.6490   | 1.9824    |
| phosphorus*variety                 | v1      | 30         | v1       | 120         | 0.4000   | 0.3888         | 18 | 1.03    | 0.3169  | Tukey-Kramer | 0.9945 | 0.05  | -0.4164  | 1.2164   | -1.0470   | 1.8470    |
| phosphorus*variety                 | v1      | 30         | v2       | 120         | 10.4667  | 0.6218         | 18 | 16.83   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 9.1802   | 11.7731  | 8.1510    | 12.7824   |
| phosphorus*variety                 | v1      | 30         | v3       | 120         | -5.0667  | 0.6218         | 18 | -8.15   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -6.3731  | -3.7602  | -7.3824   | -2.7510   |
| phosphorus*variety                 | v2      | 30         | v3       | 30          | -5.1000  | 0.6218         | 18 | -8.20   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -6.4064  | -3.7936  | -7.4157   | -2.7843   |
| phosphorus*variety                 | v2      | 30         | v1       | 60          | -11.1333 | 0.6218         | 18 | -17.90  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -12.4398 | -9.8269  | -13.4490  | -8.8176   |
| phosphorus*variety                 | v2      | 30         | v2       | 60          | -0.4333  | 0.3888         | 18 | -1.12   | 0.2794  | Tukey-Kramer | 0.9896 | 0.05  | -1.2497  | 0.3830   | -1.8803   | 1.0137    |
| phosphorus*variety                 | v2      | 30         | v3       | 60          | -10.2000 | 0.6218         | 18 | -16.40  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -11.5064 | -8.8936  | -12.5157  | -7.8843   |
| phosphorus*variety                 | v2      | 30         | v1       | 120         | -9.4667  | 0.6218         | 18 | -15.22  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -10.7731 | -8.1602  | -11.7824  | -7.1510   |
| phosphorus*variety                 | v2      | 30         | v2       | 120         | 0.6000   | 0.3888         | 18 | 1.54    | 0.1400  | Tukey-Kramer | 0.9082 | 0.05  | -0.2164  | 1.4164   | -0.8470   | 2.0470    |
| phosphorus*variety                 | v2      | 30         | v3       | 120         | -14.9333 | 0.6218         | 18 | -24.01  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -16.2398 | -13.6269 | -17.2490  | -12.6176  |
| phosphorus*variety                 | v3      | 30         | v1       | 60          | -8.0333  | 0.6218         | 18 | -9.70   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -7.3398  | -4.7269  | -8.3490   | -3.7176   |
| phosphorus*variety                 | v3      | 30         | v2       | 60          | 4.6667   | 0.6218         | 18 | 7.50    | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 3.3802   | 5.9731   | 2.3510    | 6.9824    |
| phosphorus*variety                 | v3      | 30         | v3       | 60          | -5.1000  | 0.3888         | 18 | -13.13  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -5.9164  | -4.2836  | -6.5470   | -3.6530   |
| phosphorus*variety                 | v3      | 30         | v1       | 120         | -4.3667  | 0.6218         | 18 | -7.02   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -5.6731  | -3.0602  | -6.6824   | -2.0510   |
| phosphorus*variety                 | v3      | 30         | v2       | 120         | 5.7000   | 0.6218         | 18 | 9.17    | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 4.3936   | 7.0064   | 3.3843    | 8.0157    |
| phosphorus*variety                 | v3      | 30         | v3       | 120         | -9.8333  | 0.3888         | 18 | -25.31  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -10.6497 | -9.0170  | -11.2803  | -8.3863   |
| phosphorus*variety                 | v1      | 60         | v2       | 60          | 10.7000  | 0.6218         | 18 | 17.21   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 9.3936   | 12.0064  | 8.3843    | 13.0157   |
| phosphorus*variety                 | v1      | 60         | v3       | 60          | 0.9333   | 0.6218         | 18 | 1.50    | 0.1507  | Tukey-Kramer | 0.9220 | 0.05  | -0.3731  | 2.2398   | -1.3824   | 3.2490    |
| phosphorus*variety                 | v1      | 60         | v1       | 120         | 1.6667   | 0.3888         | 18 | 4.29    | 0.0004  | Tukey-Kramer | 0.0163 | 0.05  | 0.8503   | 2.4830   | 0.2197    | 3.1137    |
| phosphorus*variety                 | v1      | 60         | v2       | 120         | 11.7333  | 0.6218         | 18 | 18.87   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 10.4269  | 13.0398  | 9.4176    | 14.0490   |
| phosphorus*variety                 | v1      | 60         | v3       | 120         | -3.8000  | 0.6218         | 18 | -6.11   | <.0001  | Tukey-Kramer | 0.0004 | 0.05  | -5.1064  | -2.4936  | -6.1157   | -1.4643   |
| phosphorus*variety                 | v2      | 60         | v3       | 60          | -9.7667  | 0.6218         | 18 | -15.71  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -11.0731 | -8.4602  | -12.0824  | -7.4510   |
| phosphorus*variety                 | v2      | 60         | v1       | 120         | -9.0333  | 0.6218         | 18 | -14.53  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -10.3398 | -7.7269  | -11.3490  | -6.7176   |
| phosphorus*variety                 | v2      | 60         | v2       | 120         | 1.0333   | 0.3888         | 18 | 2.66    | 0.0160  | Tukey-Kramer | 0.3177 | 0.05  | 0.2170   | 1.8497   | -0.4137   | 2.4803    |
| phosphorus*variety                 | v2      | 60         | v3       | 120         | -14.5000 | 0.6218         | 18 | -23.32  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -15.8064 | -13.1936 | -16.8157  | -12.1843  |
| phosphorus*variety                 | v3      | 60         | v1       | 120         | 0.7333   | 0.6218         | 18 | 1.18    | 0.2536  | Tukey-Kramer | 0.9842 | 0.05  | -0.5731  | 2.0398   | -1.5824   | 3.0490    |
| phosphorus*variety                 | v3      | 60         | v2       | 120         | 10.8000  | 0.6218         | 18 | 17.37   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 9.4936   | 12.1064  | 8.4843    | 13.1157   |
| phosphorus*variety                 | v3      | 60         | v3       | 120         | -4.7333  | 0.3888         | 18 | -12.18  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -5.5497  | -3.9170  | -6.1803   | -3.2863   |
| phosphorus*variety                 | v1      | 120        | v2       | 120         | 10.0667  | 0.6218         | 18 | 16.19   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | 8.7602   | 11.3731  | 7.7510    | 12.3824   |
| phosphorus*variety                 | v1      | 120        | v3       | 120         | -5.4667  | 0.6218         | 18 | -8.79   | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -6.7731  | -4.1602  | -7.7824   | -3.1510   |
| phosphorus*variety                 | v2      | 120        | v3       | 120         | -15.5333 | 0.6218         | 18 | -24.98  | <.0001  | Tukey-Kramer | <.0001 | 0.05  | -16.8398 | -14.2269 | -17.8490  | -13.2176  |

SE Example 18.1

Split Plot  
for  
mean

$$\sum_{j=1}^b Y_{ijk}$$

$$\frac{\sigma^2_{\beta}}{b} + \frac{\sigma^2_{t\beta}}{b} + \frac{\sigma^2_{\epsilon}}{b}$$

Example 18.1

$$\frac{MS_B - MS_{AB}}{\frac{at}{b}} + \frac{MS_{AB|C} - MSE}{\frac{t}{b}} + \frac{MSE}{b}$$

$$\frac{335.9036 - 1.6407}{\frac{(3)(4)}{3}} + \frac{1.6407 - 0.2265}{\frac{4}{3}} + \frac{0.2265}{3}$$

$$= \frac{27.85824}{3} + \frac{0.35355}{3} + \frac{0.2265}{3}$$

$$= \frac{28.43829}{3}$$

$$= 9.47843$$

$$\checkmark \leftarrow$$

$$= 3.0767$$

SE  
for mean !!

## FORMULAE FOR THE STANDARD ERRORS(SPLIT PLOT DESIGN)

MSE denotes the Mean Sum of Square,

r- denotes the number of replication  $(\Rightarrow \text{# blocks})$

MSE(a) and MSE(b) denotes the main-plot error and sub-plot error respectively in split plot experiment.

S.E.(d) denotes the Estimate of Standard Error of the difference between the means of two treatments.

**NOTE:** In case of split/strip plot designs, there are more than one MSE corresponding to different splits/strips and S.E./plot of each split/strip is found by taking the square root of MSE corresponding to that split/strip.

Where p is the number of main-plot treatments and q is the number of sub-plot treatments.

(a) S.E.(d) between two main plot treatment means  $= \sqrt{\frac{2 \times \text{MSE}(a)}{r \times q}}$

(b) S.E.(d) between two sub-plot treatment means  $= \sqrt{\frac{2 \times \text{MSE}(b)}{r \times p}}$

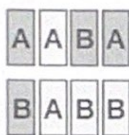
(c) S.E.(d) between two main plot treatments means at the same or different levels of sub-plot treatment means  $= \sqrt{\frac{2\{(q-1)\text{MSE}(b) + \text{MSE}(a)\}}{r \times q}}$

(d) S.E.(d) between two sub-plot treatment means at the same level of main plot treatment  $= \sqrt{\frac{2 \times \text{MSE}(b)}{r}}$

$$\sqrt{\frac{2 \left[ \frac{\text{MSE}(a) - \text{MSE}(b)}{q} + \text{MSE}(b) \right]}{r}}$$

**a**

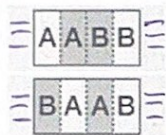
CRD



Irrigation

**b**

RCBD

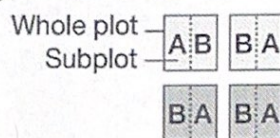


A B Fertilizer

Block

**c**

Split plot + CRD

**d**

Split plot + RCBD

