*Journal of Crop and Weed, **9**(1):27-31(2013)*

# Regression analysis for biological yield and harvest index in rice and wheat crops under rice-wheat cropping system

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***Received: 07-06-2012, Revised: 25-04-2013, Accepted: 30-05-2013***

**ABSTRACT**

*Using an experiment on integrated nutrient management in rice-wheat cropping system at Jabalpur (MP), a regression analysis for biological yield and harvest index of both the crops has been worked out to evaluate the contribution of various vegetative and reproductive attributes. Two years data on both the crops revealed that plant height, number of tillers at harvest, LAI, panicle length and grains per panicle are determinants for biological yield and harvest index.*

***Keywords:*** Biological yield, harvest index, rice, wheat

Integrated nutrient management system is an important component of sustainable agricultural intensification. The goal of INM is to integrate the use of all natural and man-made sources of plant nutrients, so as to increase crop productivity in an efficient and environmentally benign manner without diminishing the capacity of the soil to be productive for present and future generations. It seeks to maintain or improve soil fertility for sustaining the desired level of crop production and crop productivity through optimization of the benefit from all possible sources of plant nutrients in an integrated manner.

Nearly 500 cropping systems exist in different parts of the country depending on their suitability to agro–climatic conditions, infra-structural facilities, socio-economic status of the farmers and availability of technology as well as extension services. Out of them, 10 cropping systems have much concern in agriculture by covering sizeable area and significant production. Amongst them rice-wheat system is the most dominating double cropping system in India and has become mainstay of cereal production. In the traditional areas, particularly those endowed with rich natural resources, rice made its niche by replacing low yielding high-risk crops such as maize, sorghum pulses etc. and wheat replaced barley, pulses and mustard. Over the years, rice became a major crop of non-traditional areas such as Punjab, Haryana and western Utter Pradesh also by replacing maize, pearl millet, cotton and pulses. Similarly, in West Bengal wheat area spread remarkably, making it most widely grown crop during winter season. Rice and wheat both the crops requires high quantity of nutrients to harness their potential yield. However, it is unaffordable to poor and subsistence farmers of the country. Application of inadequate and unbalanced quantity of fertilizers to rice and wheat crops results in low crop yield as well as unsustainable productivity. Therefore, a long-term experiment has been initiated on integrated nutrient management in rice-wheat system at Jabalpur (MP) since *kharif* season 1987-88 to maintain the sustainable and high grain yields of both the crops rice and wheat without degradation of soil health under irrigated production system. The present paper deals with the studies during the year 2002-03 and 2003-04.

## MATERIALS AND METHODS

The soil of the experimental field was neutral in reaction (soil pH 7.7) and normal in EC (0.38 dS $m^{-1}$) with medium organic carbon content (6.9 g $kg^{-1}$) and analyzing medium in available N (260 kg $ha^{-1}$), P (16 kg $ha^{-1}$) and high in available K (448 kg $ha^{-1}$) contents. The rainfall was 1266 and 1756 mm during the two consecutive years *i.e.* 2002-03 and 2003-04. There were 12 treatments (Table 1). Different organic manures *viz.*, FYM (1.22-0.55-0.90% and 1.18, 0.48, 1.02% N, P, K in 2002-03 and 2003-04 respectively), wheat straw (0.49-0.09-1.80% and 0.50, 0.10, 1.68% N, P, K in 2002-03 and 2003-04 respectively) and green leaf manure of sunnhemp (2.21-0.48-1.77% and 2.30, 0.51, 1.79% N, P, K in 2002-03 and 2003-04 respectively) were analyzed and their quantities required to substitute a specified amount of N as per the treatments was calculated. Recommended 100% NPK for both crops was 120 kg N + 60 kg $P_2O_5$ + 40 kg $K_2O$ $ha^{-1}$ applied as per the treatment through urea, single super phosphate and muriate of potash respectively. The experiments were laid out in Randomized Block Design with 4 replications. Rice cv. Kranti was grown by using 40 kg seeds $ha^{-1}$ under transplanting with 20 cm × 15 cm planting geometry. Wheat cv. Lok-1 was grown by using seeds 100 kg $ha^{-1}$ in rows 20 cm apart. Other cultural practices *viz*. weed management and plant protection measures were followed as per recommendation in the state. Data recorded during the course of experimentation were analyzed statistically as per the procedure suggested by Panse and Sukhatme (1967).

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**Table 1: Details of treatments under integrated nutrient management programme**

| Treatments | *Kharif* (Rice cv. Kranti) | *Rabi* (Wheat cv.Lok-1) |
|---|---|---|
| $T_1$ | No fertilizers, no organic manures(Control) | No fertilizers, no organic manures (Control) |
| $T_2$ | 50% recommended NPK through fertilizers | 50% recommended NPK through fertilizers |
| $T_3$ | 50% recommended NPK through fertilizers | 100% recommended NPK through fertilizers |
| $T_4$ | 75% recommended NPK through fertilizers | 75% recommended NPK through fertilizers |
| $T_5$ | 100% recommended NPK through fertilizers | 100% recommended NPK through fertilizers |
| $T_6$ | 50% recommended NPK throughfertilizers + 50% N through FYM | 100% recommended NPK through fertilizers |
| $T_7$ | 75% recommended NPK through fertilizers + 25% N through FYM | 75% recommended NPK through fertilizers |
| $T_8$ | 50% recommended NPK through fertilizer + 50% N through wheat straw | 100% recommended NPK through fertilizers |
| $T_9$ | 75% recommended NPK through fertilizers+ 25% N through wheat straw | 75% recommended NPK through fertilizers |
| $T_{10}$ | 50% recommended NPK through fertilizers + 50% N through green leaf manuring (Sunhemp) | 100% recommended NPK through fertilizers |
| $T_{11}$ | 75% recommended NPK through fertilizers + 25% N through green leaf manuring (Sunhemp) | 75% recommended NPK through fertilizers |
| $T_{12}$ | Farmer's practice (40kg N + 20kg $P_2O_5$ + 3t FYM $ha^{-1}$) | Farmer's practice (40kg N + 20 kg $P_2O_5$ $ha^{-1}$) |

*Note: Recommended 100% NPK for both crops was 120 kg N + 60 kg $P_2O_5$ + 40 kg $K_2O$/ha through urea, single super phosphate and muriate of potash, respectively.*

## RESULTS AND DISCUSSION

### Rice

Let $Y_1$, $Y_2$ and $Y_3$ denote the grain yield, straw yield and harvest index of rice crop respectively. Also, let $X_1$ be plant height at 30 days after transplanting (DAT); $X_2$ , plant height at 60 DAT; $X_3$ , plant height at harvest; $X_4$ , number of tillers at 30 DAT; $X_5$ , number of tillers at 60 DAT; $X_6$ , number of tillers at harvest; $X_7$ , Leaf Area Index; $X_8$ , effective tillers per $m^2$; $X_9$ , panicle length and $X_{10}$ , number of grains per panicle respectively. The multiple regression analysis of biological yield (grain and straw yield) and harvest index on the characters of the plants was performed having all the variables first and then other three variables ($X_8$,$X_9$ and $X_{10}$) looking to the importance of the variables.

The regression line of grain yield for the year 2002-03 is as under

$$Y_1= -83.505 + 0.123\ X_1 + 0.309\ X_2 + 4.839\ X_3 - 3.672\ X_4 - 0.126\ X_5 + 0.251\ X_6 + 3.837\ X_7$$
$$(0.172)\quad (0.076)\quad (10.532)\quad (2.040)\quad (0.414)\quad (0.698)\quad (2.257)$$

The value of $R^2$ was found to be 0.99 and F-ratio was also significant (Table 2).

$$Y_1= -0.126 + 0.249\ X_8 - 0.596\ X_9 + 0.262\ X_{10}$$
$$(0.182)\quad (0.306)\quad (0.149)$$

The value of $R^2$ was 99.30% for this model and F-ratio was also significant (Table 2).

The regression line of grain yield for the year 2003-04 is as under

$$Y_1 = 11.701 + 0.476\ X_1 - 0.169\ X_2 + 0.481\ X_3 – 0.467\ X_4 + 0.817\ X_5 - 0.471\ X_6 – 0.0641\ X_7$$
$$(0.259)\quad (0.072)\quad (9.632)\quad (1.638)\quad (0.242)\quad (1.128)\quad (2.130)$$

In this case the value of $R^2$ was 98.80% and F-ratio was also significant (Table 3).

$$Y_1= -2.9 + 0.241\ X_8 – 0.0659\ X_9 + 0.219\ X_{10}$$
$$(0.286)\quad (0.568)\quad (0.211)$$

The value of $R^2$ was 97.50% for this model and F-ratio was also significant (Table 3).

The regression line of straw yield for the year 2002-03 is as under

$$Y_2= -39.566 + 0.266\ X_1 + 0.621\ X_2 + 21.177\ X_3 – 8.182\ X_4 - 0.708\ X_5 + 1.004\ X_6 + 3.367\ X_7$$
$$(0.467)\quad (0.207)\quad (28.653)\quad (5.549)\quad (1.127)\quad (1.899)\quad (6.142)$$

The value of $R^2$ was 99.0% for this model and F-ratio was also significant (Table 4).

$$Y_2= -5.131 + 0.578\ X_8 - 0.886\ X_9 + 0.459\ X_{10}$$
$$(0.179)\quad (0.302)\quad (0.147)$$

The F-ratio was also significant and the value of $R^2$ was found to be 0.99 (Table 4).

The regression line of straw yield for the year 2003-04 is as under

$Y_2 = 112.609 + 1.49 X_1 - 0.444 X_2 + 14.331 X_3 – 3.110 X_4 + 0.763 X_5 - 3.143 X_6 - 0.562 X_7$

(0.846) (0.235) (31.424) (5.343) (0.79) (3.682) (6.95)

The value of $R^2$ was 96.80% for this model and F-ratio was also significant (Table 5).

$Y_2= -5.169 + 0.657 X_8 - 0.786 X_9 + 0.559 X_{10}$

(0.165) (0.298) (0.139)

The value of $R^2$ was 99.40% for this model and F-ratio was also significant (Table 5).

The regression line of harvest index for the year 2002-03 is as under

$Y_3 = 11.542– 0.0140 X_1 -0.0134 X_2 – 1.859 X_3 + 0.237 X_4 + 0.0747 X_5 – 0.429 X_6 + 0.680 X_7$

(0.027) (0.012) (1.64) (0.318) (0.065) (0.109) (0.351)

F-ratio was also significant and the value of $R^2$ was found to be 0.90 significant (Table 6).

$Y_3 = 34.310 – 0.0154 X_8 – 0.0655 X_9 + 0.0134 X_{10}$

(0.059) (0.10) (0.049)

The F-ratio was also significant and the value of $R^2$ was found to be 0.51 (Table 6).

The regression line of harvest index for the year 2003-04 is as under

$Y_3 = 9.671 – 0.134 X_1 + 0.0217 X_2 – 1.871 X_3 + 0.466 X_4 + 0.172 X_5 + 0.468 X_6 + 0.197 X_7$

(0.084) (0.023) (3.136) (0.533) (0.079) (0.367) (0.694)

The value of $R^2$ was 78.20% for this model and F-ratio was also significant (Table 7).

$Y_3 = 32.502 + 0.0364 X_8 + 0.124 X_9 – 0.0449 X_{10}$

(0.118) (0.235) (0.087)

The F-ratio was also significant and the value of $R^2$ was found to be 0.249 (Table 7).

**Table 2: ANOVA for yield attributing characters of rice during 2002-03**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 971.9 | 138.9 | 88.1 |
| Residual | 4 | 7.3 | 1.6 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 971.9 | 324.0 | 354.6 |
| Residual | 8 | 7.3 | 0.9 | $R^2 = 0.99$ |
| **Total** | **11** | **979.2** | | |

**Table 3: ANOVA for yield attributing characters of rice during 2003-04**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 568.1 | 81.2 | 48.2 |
| Residual | 4 | 6.7 | 1.7 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 560.5 | 186.8 | 104.1 |
| Residual | 8 | 14.4 | 1.8 | $R^2 = 0.98$ |
| **Total** | **11** | **574.8** | | |

**Table 4: ANOVA for yield attributing characters in rice straw yield during 2002-03**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 4403.9 | 629.1 | 53.9 |
| Residual | 4 | 46.7 | 11.7 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 4443.5 | 1481.2 | 1667.7 |
| Residual | 8 | 7.1 | 0.9 | $R^2 = 0.99$ |
| **Total** | **11** | **4450.6** | | |

**Table 5: ANOVA for yield attributing characters in rice straw yield during 2003-04**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 2195.4 | 309.4 | 17.1 |
| Residual | 4 | 13.8 | 17.9 | $R^2 = 0.97$ |
| $X_8, X_9, X_{10}$ | 3 | 2195.4 | 731.8 | 424.8 |
| Residual | 8 | 13.8 | 1.7 | $R^2 = 0.99$ |
| **Total** | **11** | **2209.1** | | |

**Table 6: ANOVA for yield attributing characters in rice harvest index during 2002-03**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 1.44 | 0.21 | 5.36 |
| Residual | 4 | 0.15 | 3.82 | $R^2 = 0.90$ |
| $X_8, X_9, X_{10}$ | 3 | 0.81 | 0.27 | 2.78 |
| Residual | 8 | 0.78 | 0.10 | $R^2 = 0.51$ |
| **Total** | **11** | **1.59** | | |

**Table 7: ANOVA for yield attributing characters in rice harvest index during 2003-04**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 2.55 | 0.37 | 2.04 |
| Residual | 4 | 0.71 | 0.18 | $R^2 = 0.78$ |
| $X_8, X_9, X_{10}$ | 3 | 0.82 | 0.27 | 0.89 |
| Residual | 8 | 2.45 | 0.31 | $R^2 = 0.25$ |
| **Total** | **11** | **3.27** | | |

**Wheat**

Let $Y_1$, $Y_2$ and $Y_3$ denote the grain yield, straw yield and harvest index of rice crop respectively. Also, let $X_1$ be plant height at 30 days after transplanting (DAT); $X_2$ , plant height at 60 DAT; $X_3$ , plant height at harvest; $X_4$ , number of tillers at 30 DAT; $X_5$ , number of tillers at 60 DAT; $X_6$ , number of tillers at harvest; $X_7$ , Leaf Area Index; $X_8$ , effective tillers per $m^2$; $X_9$ , panicle length and $X_{10}$ , number of grains per panicle respectively. The multiple regression analysis of biological yield (grain and straw yield) and harvest index on the characters of the plants was performed having all the variables first and then other three variables ($X_8$,$X_9$ and $X_{10}$) looking to the importance of the variables.

The regression line of grain yield for the year 2002-03 is as under

$$Y_1 = -335.778 + \underset{(0.282)}{0.0361\ X_1} - \underset{(0.123)}{0.0631\ X_2} + \underset{(4.953)}{6.38\ X_3} + \underset{(0.050)}{0.101\ X_4} - \underset{(2.914)}{1.036\ X_5} + \underset{(5.58)}{6.901\ X_6} + \underset{(0.178)}{0.193\ X_7}$$

The F-ratio was also significant and the value of $R^2$ was found to be 0.99 (Table 8)

$$Y_1 = -0.0286 + \underset{(0.266)}{0.337\ X_8} - \underset{(1.215)}{0.511\ X_9} + \underset{(0.142)}{0.270\ X_{10}}$$

The value of $R^2$ was 98.20% for this model and F-ratio was also significant (Table 8)

The regression line of grain yield for the year 2003-04 is as under

$$Y_1 = -65.285 + \underset{(0.184)}{0.0751\ X_1} + \underset{(0.058)}{0.0117\ X_2} + \underset{(3.253)}{7.058\ X_3} - \underset{(0.045)}{0.0113\ X_4} - \underset{(1.317)}{1.545\ X_5} + \underset{(4.263)}{1.424\ X_6} + \underset{(0.090)}{0.229\ X_7}$$

The value of $R^2$ was found to be 0.993 and F-ratio was also significant (Table 9).

$$Y_1 = -0.321 + \underset{(0.166)}{0.180\ X_8} + \underset{(0.805)}{0.246\ X_9} + \underset{(0.129)}{0.260\ X_{10}}$$

The value of $R^2$ was 98.20% for this model and F-ratio was also significant (Table 9).

The regression line of straw yield for the year 2002-03 is as under

$$Y_2 = -327.043 + \underset{(0.294)}{0.213\ X_1} - \underset{(0.128)}{0.135\ X_2} + \underset{(5.170)}{8.513\ X_3} + \underset{(0.053)}{0.161\ X_4} - \underset{(3.042)}{1.865\ X_5} + \underset{(5.825)}{6.838\ X_6} + \underset{(0.186)}{0.319\ X_7}$$

The value of $R^2$ was 99.50% for this model and F-ratio was also significant (Table 10).

$$Y_2 = -1.170 + \underset{(0.387)}{0.240\ X_8} + \underset{(1.767)}{0.207\ X_9} + \underset{(0.206)}{0.481\ X_{10}}$$

The F-ratio was also significant and the value of $R^2$ was found to be 0.983 (Table 10).

The regression line of straw yield for the year 2003-04 is as under

$$Y_2 = -4.868 - \underset{(0.289)}{0.0544\ X_1} + \underset{(0.092)}{0.0509\ X_2} + \underset{(5.117)}{11.278\ X_3} + \underset{(0.072)}{0.0169\ X_4} - \underset{(2.071)}{2.667\ X_5} + \underset{(6.705)}{0.306\ X_6} + \underset{(0.142)}{0.357\ X_7}$$

The value of $R^2$ was 99.30% for this model and F-ratio was also significant (Table 11).

$$Y_2 = -0.993 + \underset{(0.218)}{0.309\ X_8} + \underset{(1.061)}{0.148\ X_9} + \underset{(0.170)}{0.404\ X_{10}}$$

The F-ratio was also significant and the value of $R^2$ was found to be 0.986 (Table 11).

The regression line of harvest index for the year 2002-03 is as under

$$Y_3 = -43.453 - \underset{(0.051)}{0.0876\ X_1} + \underset{(0.022)}{0.0224\ X_2} + \underset{(0.905)}{0.451\ X_3} - \underset{(0.009)}{0.0953 X_4} + \underset{(0.532)}{0.223\ X_5} + \underset{(1.019)}{1.657\ X_6} - \underset{(0.032)}{0.0205 X_7}$$

The value of $R^2$ was 82.60% for this model and F-ratio was also significant (Table 12).

$$Y_3 = 41.159 + \underset{(0.048)}{0.128\ X_8} - \underset{(0.221)}{0.474\ X_9} - \underset{(0.026)}{0.0455\ X_{10}}$$

The F-ratio was also significant and the value of $R^2$ was found to be 0.675 (Table 12).

The regression line of harvest index for the year 2003-04 is as under

$$Y_3 = -62.821 + \underset{(0.107)}{0.0633\ X_1} - \underset{(0.034)}{0.0580\ X_2} - \underset{(1.891)}{0.775\ X_3} - \underset{(0.026)}{0.0120\ X_4} + \underset{(0.766)}{0.351\ X_5} + \underset{(2.479)}{2.030\ X_6} - \underset{(0.052)}{0.0165\ X_7}$$

The value of $R^2$ was 37.30% for this model and F-ratio was also significant (Table 13).

$$Y_3 = 41.047 + \underset{(0.069)}{0.0292\ X_8} - \underset{(0.333)}{0.0574\ X_9} - \underset{(0.053)}{0.0329\ X_{10}}$$

The F-ratio was also significant and the value of $R^2$ was found to be 0.130 (Table 13).

**Table 8: ANOVA for yield attributing characters in wheat grain yield (2002-03)**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 788.8 | 112.7 | 59.3 |
| Residual | 4 | 7.6 | 1.970 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 782.0 | 260.7 | 145.2 |
| Residual | 8 | 14.4 | 1.8 | $R^2 = 0.98$ |
| **Total** | **11** | **796.4** | | |

**Table 9: ANOVA for yield attributing characters in wheat grain yield (2003-04)**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 570.5 | 81.5 | 84.9 |
| Residual | 4 | 3.8 | 1.0 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 563.9 | 188.0 | 143.0 |
| Residual | 8 | 10.5 | 1.3 | $R^2 = 0.98$ |
| **Total** | **11** | **574.4** | | |

**Table 10: ANOVA for yield attributing characters in wheat straw yield (2002-03)**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 1818.7 | 259.8 | 125.5 |
| Residual | 4 | 8. 3 | 2.1 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 1796.6 | 598.9 | 157.7 |
| Residual | 8 | 30.4 | 3. 8 | $R^2 = 0.98$ |
| **Total** | **11** | **1827.0** | | |

In case of rice and wheat crop, the grain yield, straw yield and harvest index may be described by plant height, number of tillers at harvest, LAI, panicle or earhead length and grains per panicle or earhead which have been shown by above mentioned regression lines and ANOVA tables. These findings are consistent with the findings of Rao and Saxena (1999) on the experiment conducted in rice at Jagdalpur, Madhya Pradesh and Nakishima *et al.* (1990) in Japan. Rajeswari and Nadarajan (1996) and Mahajan *et al.* (1986) also found the similar kinds of results in both rice and wheat crops.

**Table 11: ANOVA for yield attributing characters in wheat straw yield (2003-04)**

| Source of variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 1279.1 | 182.7 | 77.0 |
| Residual | 4 | 9.5 | 2.4 | $R^2 = 0.99$ |
| $X_8, X_9, X_{10}$ | 3 | 1270.3 | 423.5 | 185.5 |
| Residual | 8 | 18.3 | 2.3 | $R^2 = 0.99$ |
| **Total** | **11** | **1288.6** | | |

**Table 12: ANOVA for yield attributing characters in wheat harvest index (2002-03)**

| Source of Variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 1.21 | 0.17 | 2.71 |
| Residual | 4 | 0.25 | 3.82 | $R^2 = 0.83$ |
| $X_8, X_9, X_{10}$ | 3 | 0.99 | 0.33 | 5.54 |
| Residual | 8 | 0.47 | 0.059 | $R^2 = 0.68$ |
| **Total** | **11** | **1.46** | | |

**Table 13: ANOVA for yield attributing characters in wheat harvest index (2003-04)**

| Source of Variation | df | SS | MS | F-ratio |
|---|---|---|---|---|
| $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ | 7 | 0.77 | 0.11 | 0.34 |
| Residual | 4 | 1.30 | 0.33 | $R^2 = 0.37$ |
| $X_8, X_9, X_{10}$ | 3 | 0.27 | 8.95 | 0.40 |
| Residual | 8 | 1.80 | 0.23 | $R^2 = 0.13$ |
| **Total** | **11** | **2.07** | | |

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