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Effect of meteorological elements on Sugarcane wilt in Bihar

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Abstract
The model for forewarning of the infection of Wilt disease in Sugarcane (*Saccharum officinarum* L.) was studied and observation were recorded for each year from 2008-09 to 2017-18 for the month of September and December. Data were collected from the Sugarcane Research Institute, DRPCAU, Pusa, Bihar. The maximum disease found due to rainfall and then second due to minimum temperature. Using the original data on the response variable i.e., infection of wilt, the simple linear regression model was fitted with yearly as explanatory variable and describe severity of the infection of wilt disease during the year. The value of coefficient determination (R-Square) for this disease was 96.90% and Adjusted R-Square is 0. 907. We also include meteorological factors i.e., maximum temperature (X_1), minimum temperature (X_2), RH at 7 hrs. (X_3), RH at 14 hrs. (X_4), rainfall (X_5) and sunshine (X_6). The model provides the severity of infection of the above-mentioned disease forewarning. Meteorological factors played an important role in seasonal infection, distribution and wilt disease build-up in Sugarcane. For management purposes this model will be useful to predict the incidence of wilt disease multiple regression model for wilt is as mentioned below:
Wilt disease incidence(Y) = $-99.498 + 0.142X_1 + 0.345X_2 + 0.601X_3 - 0.05X_4 + 0.46\ X_5 + 6.25\ X_6$

Keywords: Disease incidence in sugarcane, forewarning of disease, effect of weather on disease

Introduction

Sugarcane (Saccharum *officinarum* L.) is most important cash crop of Bihar. In terms of area and production Bihar ranked 4^{th} and 5^{th} position respectively in India. Its ground area is 5284 thousand ha with production of 336900 m tone during 2015 -16 (ISMA-2017). The model for forewarning of the infection of Wilt disease in Sugarcane was studied and observation were recorded for each year from 2008-09 to 2017-18 for the month of September and December. Data were collected from the Sugarcane Research Institute, Pusa, Bihar. The maximum disease found due to rainfall and then second due to minimum temperature. Using the original data on the response variable i.e., infection of wilt, the simple linear regression model was fitted with yearly as explanatory variable and describe severity of the infection of wilt disease during the year. The value of coefficient determination (R-Square) for this disease was 96.90% and Adjusted R-Square is 0. 907. We have included meteorological factors i.e., maximum temperature (X_1), minimum temperature (X_2), RH at 7 hrs. (X_3), RH at 14 hrs. (X_4), rainfall (X_5) and sunshine (X_6). The model provides the severity of infection of the above-mentioned disease forewarning. Meteorological factors played an important role in seasonal infection, distribution and wilt disease build up in Sugarcane. For management purpose this model will be useful to predict the incidence of wilt disease and for this multiple regression model for wilt were used.

Generating forewarning models for wilt disease of sugarcane

The regression model taking pest/disease variable as dependent and independent variables such as weather variables, crop stages, population of natural enemies/predators etc., is used. These variables are used in original scale or on a suitable transformed scale such as cos, log, exponential etc., (Coakley *et al*. 1985) [2].

Prajneshu (1998) [6] developed a nonlinear statistical model for describing dynamic population growth. Solanki *et al.* (1999) [9] used correlation analysis and regression equations through multiple and stepwise regression technique to know the associations of various biological and meteorological variables with powdery mildew disease of mustard.
Reddy *et al.* (2001) [8] developed models for prediction of sheath rot epidemics based on weather parameters for crops planted at different dates. The R^2 value (coefficient of determination) of multiple regression indicated that weather parameters accounted for 44-81per cent and 46-77 per cent of variation in sheath rot epidemics.
Upadhyay *et al.* (2004) [10] used principal component analysis to find out the factors which play important roles in the population buildup of yellow stem borer. They reported that rainfall and relative humidity played a significant role in the population buildup of yellow stem borer.
Weather Based Forewarning Models such as epidemic or epidemic/low, medium or high are known. Such a situation arises quite often in pest/disease data. In such cases, the data are classified as 0 and 1 (2 categories); 0, 1 and 2 (three categories). The logistic regression is used for obtaining probabilities of different categories. Agrawal *et al.* (2004) [1].
Ramasubramanium *et al.* (2006) [11] developed statistical models for forewarning about infestation of paddy crops using step-wise regression technique and weather indices modeling technique without using transformation of data.
Gururaj *et al.* (2006) [3] used Logistic model for prediction of Groundnut caused by *Puccinia arachidis* in Northern Eastern dry Zone of Karnataka.
Henderson *et al*. (2007) [4] used logistic regression analysis for forecasting late blight in potato crops of southern Idaho.

Materials and Methods

Analysis of the model coefficient and predicted values

The predicted values of Y can also provide a measure of model validity. Unrealistic predicted values such as negative predictions of a positive quantity or predictions that fall outside the actual range of the response, indicate poorly estimated coefficients or an incorrect model form.
In this paper the methodology and the nature of data and the analytical techniques employed in the study are presented in the following heads.
1. Collection of data
2. Statistical techniques

Collection of data

To assess the impact of different weather parameters i.e., temperature, relative humidity (RH), rainfall, sunshine on the development of wilt disease infection in sugarcane crop, observations on wilt incidence were recorded through an extensive survey calculated over ten years (2008-17) on clump basis. The incidence was calculated on plot basis irrespective of number of clumps showing infection in the plot. Disease incidence data in months of September and December are averaged to get a single disease incidence value. The per cent incidence of disease was worked out by using a formula.

$$\text{Percent wilt incidence} = \frac{\text{No.of infected clumps}}{\text{Total no.of clumps}} \text{ X } 100$$

Weather data collected from department of Agro-meteorology, DRPCAU, Pusa, Samastipur was subjected to correlation and regression analysis with disease incidence.

Statistical measures

To work out the relationship between weather parameters and pest and disease incidence and to forecast the pest and diseases incidence, the data was analyzed by using the various statistical techniques presented under the following heads.

Descriptive statistics

The simple statistics *viz*. mean, standard deviation, range were used to study the behavior of weather factors along with pest and disease incidence.

Correlation Analysis

The correlation analysis was carried out to determine the degree of relationship between two variables. In the present study, the degree of relationships between pests and each of the weather parameters *viz*., minimum temperature, maximum temperature, morning relative humidity, evening relative humidity, rainfall, and sunshine were determined by using Karl Pearson's correlation coefficient.

$$R = \frac{\text{COV(XY)}}{\sqrt{\text{V(X)V(Y)}}}$$

Significance of the correlation coefficient

To test the significance of the correlation coefficient 't-test was used. Here the null hypothesis was set as $H_0: \rho = 0$ against alternative hypothesis $H_1: \rho \neq 0$

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Where,
r = Correlation coefficient
n = Number of observations

Multiple Linear Regression (MLR) model

To find out the fundamental relationship between dependent and independent variables multiple regression analysis was carried out. The following statistical model was used to assess the impact of weather factors on disease incidence.

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + e_i$$

Where
Y = Dependent variable (Disease incidence)
a= Pure constant
b_1= Regression coefficient for maximum temperature (X_1)
b_2= Regression coefficient for minimum temperature (X_2)
b_3=Regression coefficient for RH at 7 hrs. (X_3)
b_4=Regression coefficient for RH at 14 hrs. (X_4)
b_5= Regression coefficient for rainfall (X_5)
b_6=Regression coefficient for sunshine (X_6)
e_i - Random error

In disease forewarning system, the variables of interest may be maximum disease severity, pest population or disease severity at various standard weeks, weekly monitoring of pests and disease progress, occurrence or non-occurrence of pests and diseases. Depending upon the data availability, different types of models can be utilized for developing a forewarning system.

Between year models

These models are developed using previous years' data. An assumption is made that the present year is a part of the composite population of the previous years and accordingly the relationships developed on the basis of previous year's data will be applicable to the present year. The forecast for pests and diseases are obtained by substituting the current year data into the model developed in the previous years.

Coefficient of determination (R^2)

R^2 measures the goodness of fit of the regression equation; that is, it gives the proportion or the percentage of the total variation in the dependent variable Y explained by the variables X_2, X_3....X_p. It is calculated as

$$R^2 = \frac{\text{Explained sum of squares}}{\text{Total sum of squares}}$$

The measure R^2 is called coefficient of determination, $0 \leq R^2 \geq 1$.

Results and Discussion

Forewarning model of wilt on sugarcane in Bihar

The secondary data of wilt incidence on sugarcane are collected from sugarcane research institute (SRI), DRPCAU, Pusa along with the climate factors (rainfall, maximum temperature, minimum temperature, morning relative humidity, evening and relative humidity) from meteorological division, DRPCAU Pusa have been analyzed through various statistical methods as outlined in the methodologies. The results and discussion of such analyses are reported in the following heads.

1. Behavior of climate factors and wilt disease in Sugarcane
2. Correlation analysis and Multiple Linear Regression (MLR) forewarning models for wilt disease incidence of sugarcane
3. Logistic regression models and ANOVA for wilt incidence of sugarcane

Behaviour of climate factors and diseases

The data analyzed on average climatic factors from 2008 to 2017 in sugarcane growing seasons revealed that the average rainfall distribution varied greatly within sugarcane growing seasons over years (19.5 mm-78.5 mm). The average minimum temperatures (18.7 °C-26 °C), maximum temperature (30 °C -31 °C), morning relative humidity (83.7-87.6%) and evening relative humidity (51.8-85.8%) were observed. The pattern of wilt incidence on sugarcane over years is shown in Fig 1. The behaviour of climate factors and diseases have been presented in Fig 2.

Statistical analysis of climate factors with wilt of sugarcane

The data analysis on wilt incidence with the climate factors in sugarcane growing seasons revealed that the rainfall distribution varied greatly within sugarcane growing seasons and also over years. The average minimum temperature 20.67 °C, average maximum temperature 30.98 °C, morning relative humidity (83.7-87.6%) and evening relative humidity (51.8-85.8%) were observed during crop seasons over years. The Wilt severity during the years 2008, 2009, 2010 and 2013 and was low during 2016. Analysis of 10 years (2008-2017) weather data revealed that the days with RH >85per cent, temperature (26 °C - 30 °C) and rainfall are the most critical factors in the development of wilt incidence. The wilt incidence along with weather factors are presented in Fig 3

Correlation analysis of forewarning model for wilt on sugarcane

The correlation studies were undertaken to find the relationship between wilt incidences with climate factors. The multiple linear regression models (between years) were also developed for forecasting the wilt incidence subjected to the climate factors.

During the years 2008 to 2017, correlation studies revealed that there was positive association between the wilt infestation and weather factors morning relative humidity (0.23) while significant positive correlation with minimum temperature (0.89) and negative association with evening relative humidity (-0.03) while significant positive correlation is showed with maximum rainfall (0.97), maximum temperature (0.629), Table 1. The MLR model was developed with respect to these factors with R^2= 0.969 (Table 2). The influence of weather factors on wilt incidence in sugarcane is given in Table- 2. The effect of wilt incidence due to minimum temperature and effect of rainfall was shown in Fig 4 & 5 respectively. Fig -6 shows the actual incidence and predicted incidence of wilt. Fig 7 shows residuals of predicted incidence values during the years 2008-17. Logistic regression models and ANOVA for wilt incidence of sugarcane are given in Table 3. Predicted values of wilt incidence with residual during the years 2008-17 were shown in Table 4.

Table 1: Correlation matrix of weather parameter on wit disease of sugarcane

Incidence (y)	Number of observations	Weather data					
		Temperature (0c)		Relative Humidity (%)		Rainfall	Sunshine Hrs (X6)
		Maximum (X1)	Minimum (X2)	7.00 Hrs (X3)	14.00 Hrs (X4)	(X5)	
Wilt	10	0.629	0.89**	0.23	-0.03	**0.97****	0.21

**- Significant at 1% probability

Table 2: Multiple linear regression (MLR) models for weather parameters on wilt disease incidence in sugarcane

Incidence (y)	Number of observations	Pure constant	Weather data						R^2	Adjusted R^2
			Temperature (°C)		Relative Humidity (%)		Rain fall (X5)	Sun shine Hrs (X6)		
			Maximum (X1)	Minimum (X2)	7.00 Hrs (X3)	14.00 Hrs (X4)				
Wilt	10	-99.498	0.142	0.345	0.601	-0.05	0.46	6.252	0.969	0.907

Table 3: ANOVA for wilt incidence on Sugarcane

Sources of variations	DF	Sum of squares	Mean Squares	F	Sig.
Regression	6	953.948	158.991	15.619*	0.023
Residual	3	30.539	10.18		
Total	9	984.486			

***- Significant at 5% probability**

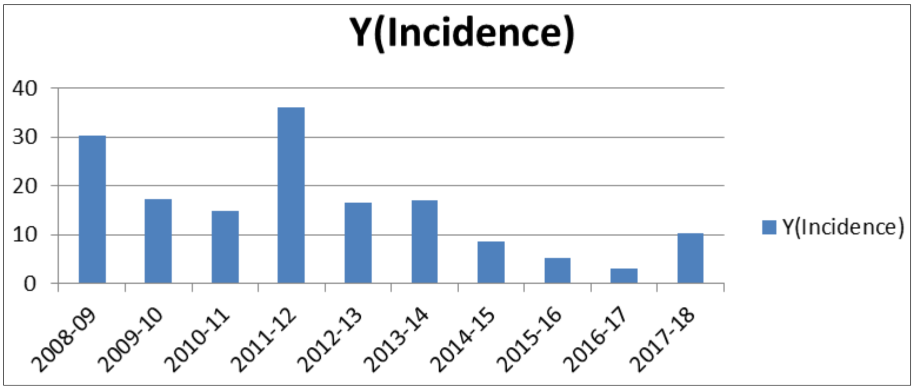

Fig 1: Wilt incidence on sugarcane during the period 2008-17

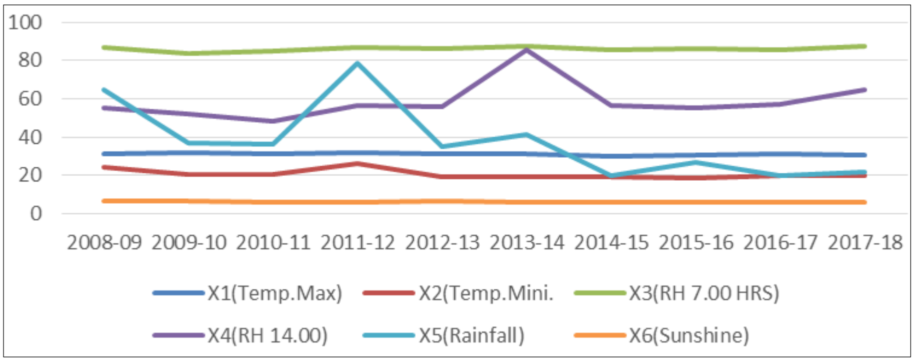

Fig 2: Pattern of climatic factors during the year 2008-17

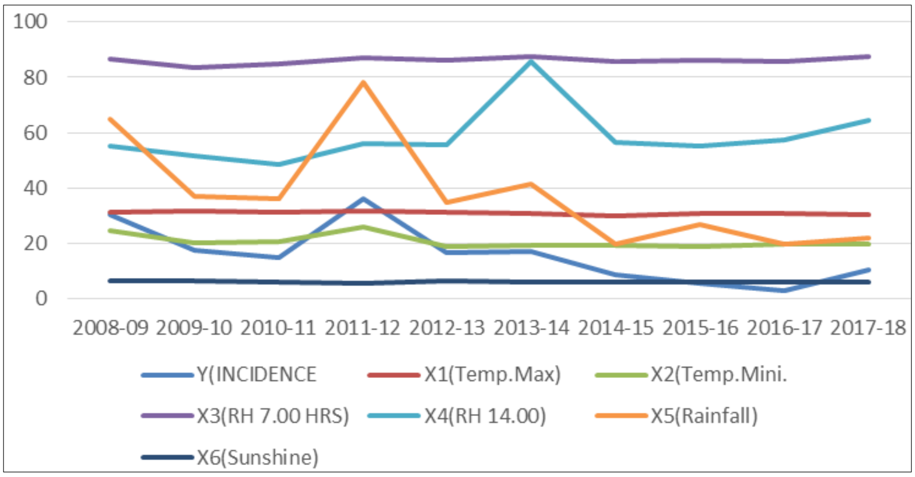

Fig 3: Effect of climatic factors on the incidence of wilt on sugarcane

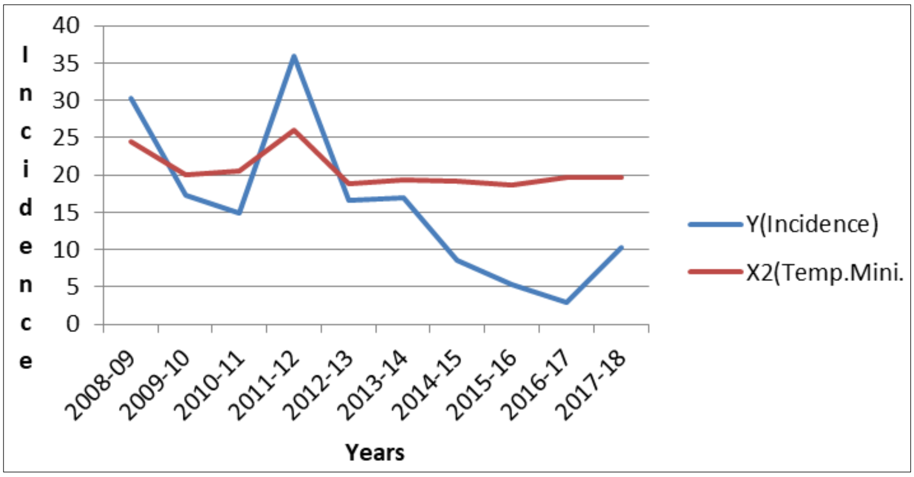

Fig 4: Effect of minimum temperature on wilt incidence in sugarcane

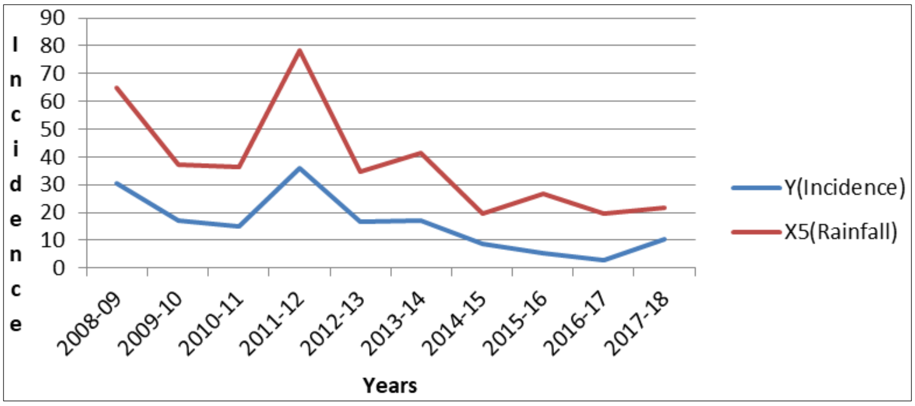

Fig 5: Effect of rainfall on wilt incidence of sugarcane

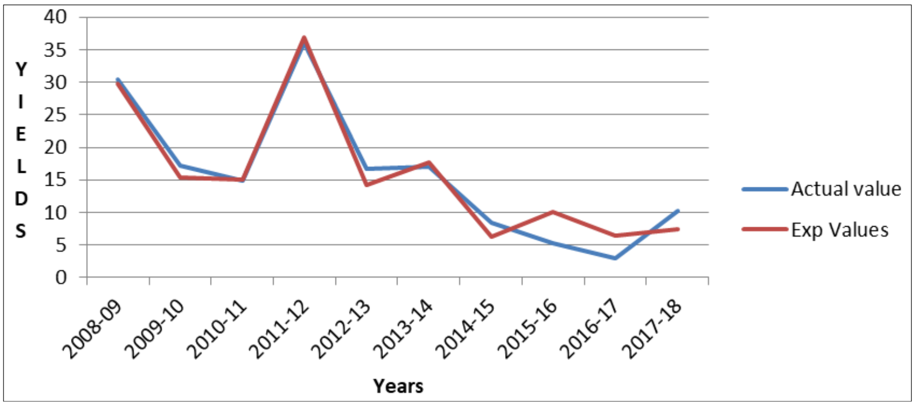

Fig 6: Line diagram of actual incidence and predicted incidence

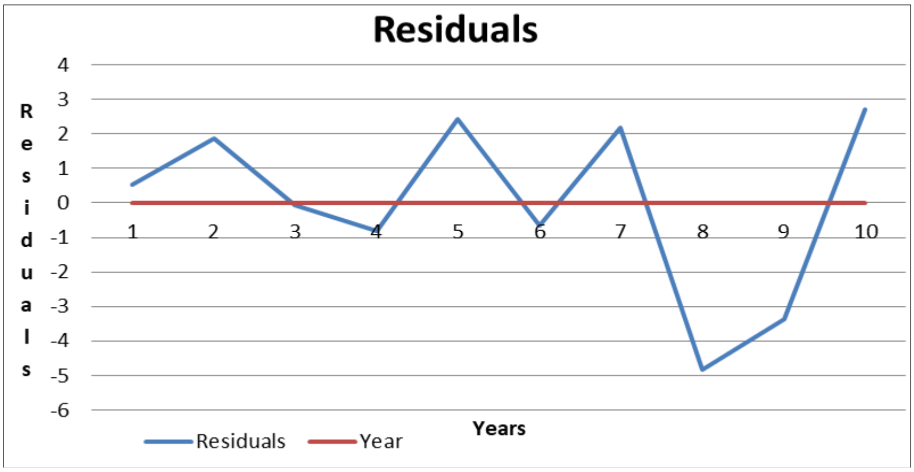

Fig 7: Residuals of predicted incidence values during the years 2008-17

Table 4: Predicted values of wilt incidence during the years 2008-17

Year	Actual value of incidence	Predicted Values of incidence	Residuals
2008-09	30.36	29.84	0.521
2009-10	17.25	15.38	1.872
2010-11	14.91	14.96	-0.054
2011-12	36.00	36.83	-0.826
2012-13	16.62	14.19	2.434
2013-14	17.00	17.66	-0.659
2014-15	8.50	6.31	2.192
2015-16	5.25	10.09	-4.841
2016-17	3.00	6.36	-3.359
2017-18	10.22	7.50	2.72

Conclusion

Forewarning models for wilt incidence on sugarcane in Bihar based on climate factors, the secondary data on wilt incidence (%) on sugarcane along with climate factors were collected for the period of 2008 to 2017 (10 years) during crop seasons, from SRI and division of meteorology, RPCAU, respectively. The correlation studies were undertaken to study the correlation between disease incidences subject to climate factors.

The Multiple Linear Regression (MLR) model was developed for the prediction of wilt incidence. Descriptive statistics were used to know the behaviour of climate factors along with wilt incidence over years during the crop seasons. Finally, ANOVA techniques applied to test the significance of the forewarning model.

Developing of forewarning model for wilt disease on sugarcane provides information on the impact of weather variables on disease incidence. Such information helps the farmers to minimize the losses in crop yield due to pest and disease. Early warnings allow timely and need-based application of pest and disease control measures and prevent application of unnecessary interventions. Increased yield and quality while reducing production costs and also reduced pesticide risks to food and environment

During the years 2008 to 2017, correlation studies revealed that there was a positive correlation between the wilt infestation and weather factors morning relative humidity (0.23) while a significant positive correlation with minimum temperature (0.89) and a negative association with evening relative humidity (-0.03) while significant positive correlation is showed with maximum rainfall (0.97), maximum temperature (0.629), (Table-1). The Multiple linear regression (MLR) model was developed with respect to these factors with (Coefficient of determination, 96.90%) i.e., R^2= 0.969 (Table 2). The influence of weather factors on wilt incidence in sugarcane is given in Table- 2. Logistic regression models and ANOVA for wilt incidence of sugarcane are given in Table 3. The predictions of wilt incidence were shown in Table 4. The pattern of wilt incidence on sugarcane over years is shown in Fig 1. The behavior of climatic factors were presented in fig 2. The wilt incidence along with weather factors are presented in Fig 3. The effect of wilt incidence due to minimum temperature and effect of rainfall was shown in Fig 4 & 5 respectively. Fig 6 shows the actual incidence and predicted incidence of wilt. Fig 7 shows residuals of predicted incidence values during the years 2008-17.

Linear regression equation model for wilt disease

Wilt incidence (Y) = $-99.498+0.142X_1+0.345X_2+0.601X_3-0.05X_4+0.46X_5+6.252X_6$

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