Research Article

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Crop weather relationship in arecanut

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Abstract

Weather plays an important role in the crop development and yield of any agricultural crops. Even though, arecanut (*Areca catechu* L.) grows in a wide range of climatic conditions, its performance is greatly influenced by the weather. The effect of weather variables such as maximum temperature, minimum temperature, relative humidity and rainfall at different stages of crop development on the annual yield of arecanut is studied. The study showed that the maximum temperature positively influences the flowering and fruit set in arecanut. Also, high rainfall and relative humidity during the flowering and fruit setting period adversely affect the arecanut yield. The stepwise regression model fitted using the significant weather variables could explain 97 per cent of the yield variation in arecanut.

Keywords: Arecanut, rainfall, temperature, weather, yield

Introduction

Weather is an important factor for crop development and yield in both annual and perennial crops. It affects the crop differently in various crop/yield development stages. The response of crops to the different weather variables is quite complex and difficult to explain. Weather changes at critical periods of a crop's development influence the crop yield. Therefore, a model based on weather parameters can explain the variation in yield to a great extent and it also provides a reliable forecast in advance for crop yield.

Arecanut (*Areca catechu* L.) is a perennial plantation crop that is grown in varied climatic conditions in humid tropics, sub-humid regions, and plains. It is sensitive to extreme climatic conditions (Bhat and Abdul Khader, 1982). Weather variables like rainfall, relative humidity, and temperature influence the yield of arecanut (Vijayakumar *et al*., 1991; Sunil *et al*., 2011). Data-driven technique is more adequate to study the input response relationship when the form of the relationship is unknown (Jose and Ravi Bhat, 2008; Jose *et al.,* 2008).

The effect of weather variables at different stages of crop development on the annual yield of arecanut was studied in this paper. A statistical model was developed to forecast/predict the annual yield of arecanut based on weather variables. The weather variables considered for the study were maximum temperature, minimum temperature, rainfall, rainy days, humidity forenoon and humidity after noon. Twelve years of average annual yield data of 850 arecanut palms at ICAR-CPCRI Regional Station, Vittal was used for the study. Monthly averages of maximum temperature, minimum temperature, relative humidity forenoon, relative humidity after noon, total monthly rainfall and rainy days for the current and one year lag periods were considered for working out the effect of weather variables on the yield of arecanut.

Material and Methods

Twelve years of annual yield data (Number of nuts) of 850 arecanut palms from spacing cum nutritional experiments at CPCRI Regional Station, Vittal, Karnataka have been considered for the study. The yield data were collected from the 9th year of planting as arecanut yield generally

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stabilizes by the 9th year of planting. Annual (July to June) average yield of 850 arecanut palms for 12 years from the 9th year of planting was taken as the response variable. Monthly averages of maximum temperature, minimum temperature, relative humidity forenoon and afternoon, monthly total rainfall and number of rainy days for the current year and one year lag were considered as independent variables. If the total rainfall in a day is greater than or equal to 2.5mm, we consider it as a rainy day. Linear correlations between the annual yield of arecanut and monthly weather variables for the current and previous years were worked out to understand any linear relationship. To study any deviation from the linearity, a data-driven technique (spline smoothing technique) was used to fit a smooth curve for the variables having a significant correlation with the annual yield of arecanut. The software SAS 9.3 was used for the data analysis. The weather variables, having a significant correlation ($P<0.05$) with the annual arecanut yield were, selected for fitting the regression model using the step-up regression procedure.

Results and Discussion

To study the yield weather relationship in arecanut, 12 years annual arecanut yield (July to June) and the weather variables such as maximum temperature, minimum temperature, relative humidity (forenoon and afternoon), number of rainy days and the total rainfall during the period were considered. The linear correlation coefficient between the yield (number of nuts) and monthly weather data are shown in Table 1. The range of monthly weather variables during the period under study are given in Table 2.

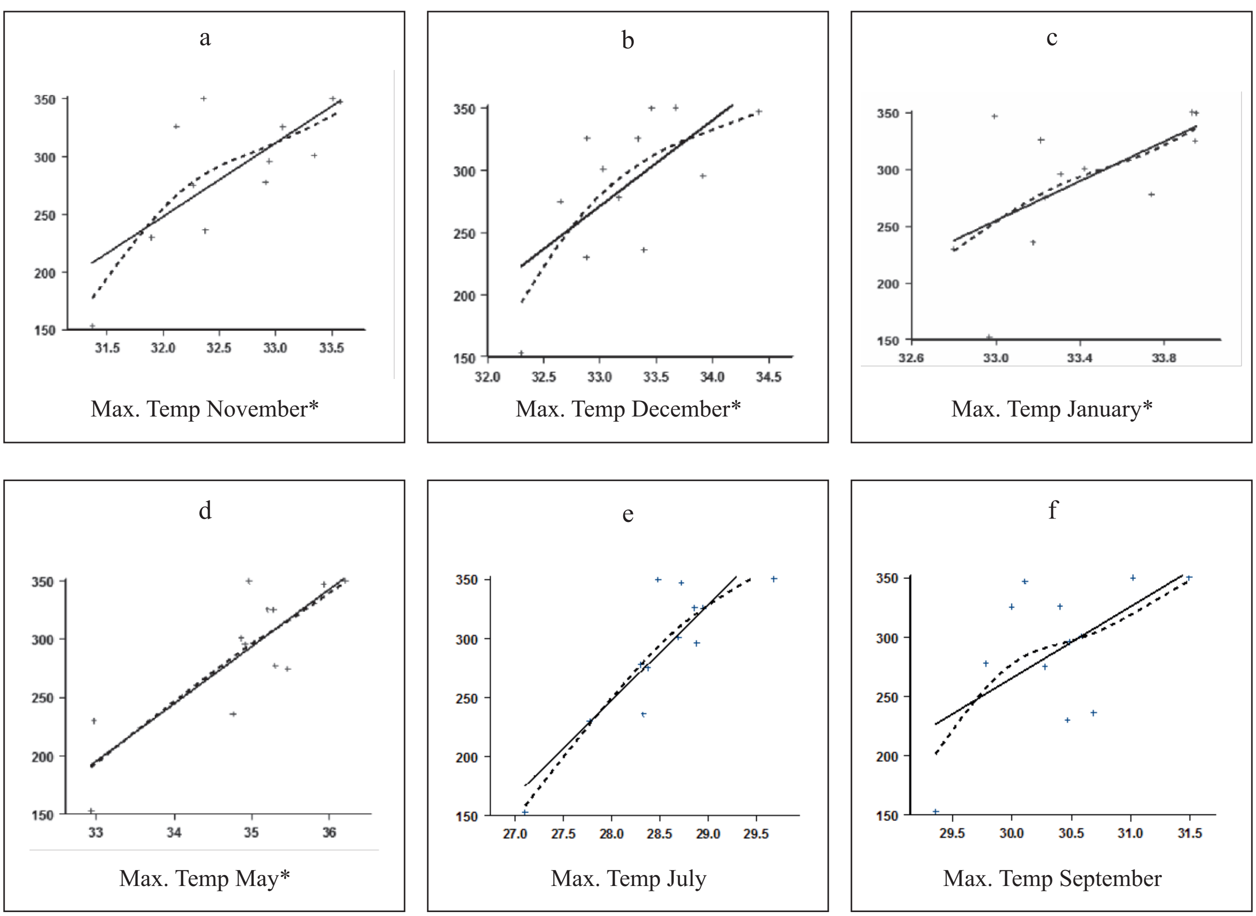
Table 1. Linear correlation coefficient between monthly weather variables and annual yield (no. of nuts) of arecanut (July-June)

Month	T Max. (⁰C)	T Min. (⁰C)	Total rainfall (mm)	No. of rainy days	Humidity (FN)	Humidity (AN)
July*	0.46	0.26	-0.48	-0.25	-0.40	-0.22
August*	-0.36	-0.46	0.54	0.25	-0.32	0.40
September*	0.16	-0.36	-0.21	-0.01	**-0.75**	0.29
October*	-0.23	-0.16	-0.16	**-0.67**	-0.36	0.31
November*	**0.73**	-0.53	**-0.91**	**-0.88**	**-0.75**	**-0.62**
December*	**0.67**	0.03	-0.40	-0.30	0.33	0.29
January*	**0.60**	0.10	0.06	0.06	-0.15	0.31
February*	0.38	0.00	-0.31	0.00	**-0.79**	0.46
March*	0.35	0.38	-0.03	-0.12	**-0.77**	0.55
April*	0.39	0.03	-0.36	-0.31	**-0.73**	-0.16
May*	**0.83**	**0.66**	**-0.66**	**-0.64**	**-0.65**	**-0.70**
June*	0.48	0.37	-0.50	-0.25	-0.42	-0.44
July	**0.87**	0.52	**-0.69**	-0.58	**-0.85**	**-0.72**
August	0.35	-0.01	0.07	-0.30	-0.56	-0.02
September	**0.57**	0.34	-0.10	0.05	**-0.68**	0.21
October	-0.15	-0.05	-0.32	-0.25	-0.59	0.19
November	0.24	-0.29	-0.55	-0.38	-0.38	-0.16
December	0.23	-0.13	-0.31	-0.03	0.08	0.14
January	0.45	-0.29	0.19	0.19	-0.54	0.24
February	0.33	-0.13	0.00	0.00	-0.47	0.26
March	0.13	-0.04	0.38	0.32	-0.23	0.45
April	0.17	-0.27	0.06	0.01	-0.40	0.11
May	0.11	0.32	-0.02	-0.15	-0.04	0.02
June	0.04	0.13	-0.23	-0.11	-0.27	-0.15

*Previous year; values in bold indicate correlation coefficient is significant at P=0.05

Table 2. Range of monthly weather variables during the period under study

Month	T Max. (^{0}C)	T Min. (^{0}C)	Total rainfall (mm)	No. of rainy days	Humidity (FN)	Humidity (AN)
Jan	32.80-33.95	17.28-21.10	0-18	0-2	90.97-95.16	35.35-55.74
Feb	33.19-35.36	18.78-22.52	0-1	0-0	91.39-95.89	39.93-55.71
Mar	34.84-36.27	21.51-24.30	0-97	0-4	88.90-95.13	46.00-58.29
Apr	34.76-36.23	23.02-24.56	0-15	10-8	87.13-94.63	48.50-57.40
May	32.93-36.20	23.56-25.61	0-377	0-16	85.90-95.65	48.97-66.52
Jun	26.96-32.47	22.26-24.33	477-1537	17-30	89.43-97.63	64.40-88.40
Jul	27.10-29.68	22.45-23.62	539-1617	21-31	94.48-97.84	76.35-89.03
Aug	27.51-30.89	22.35-23.71	373-1619	17-31	93.84-97.13	70.39-88.16
Sep	29.36-31.49	22.36-23.65	101-674	8-27	94.13-96.60	67.13-81.53
Oct	30.68-32.59	22.21-23.49	90-3077	7-17	93.68-96.32	57.26-71.77
Nov	31.37-34.08	20.39-23.26	31-262	3-13	91.43-97.10	47.77-65.13
Dec	32.30-34.41	18.54-21.75	0-35	0-3	84.71-94.26	39.16-55.32



* indicates the previous year

Fig. 1. Scatter plot with linear fit and spline curve of average monthly maximum temperature (x-axis) and arecanut yield (y-axis)

Average monthly maximum temperature

The linear correlation coefficient between annual arecanut yield and monthly average maximum temperature (Table 1) shows that there is a significant positive effect of monthly average maximum temperatures during November, December, January, and May of the previous year and July and September of the current year with the annual yield of arecanut. The above months are the major flowering and fruit setting period in arecanut and the result shows that maximum temperature positively influences the flowering and fruit set in arecanut. The average monthly maximum temperature of November during the period of study varied between 31^{0}C and 34^{0}C and in this range; the temperature positively influenced the arecanut yield of next year (Fig. 1a). Even though the relationship is almost linear, the spline curve shows that the rate of yield reduction is more when the temperature is below 32.5^{0}C. Similarly, the average monthly maximum temperature of December during the period of study varied between 32.3^{0}C and 34.4^{0}C and in this range; the temperature positively influenced the arecanut yield of next year (Fig. 1b). The spline curve shows that the rate of yield reduction is more when the temperature is below 33.5^{0}C. The average maximum temperature of January and May during the period of study varied between32.8^{0}C to 34^{0}C and 32.9^{0}C to 36.2^{0}C respectively and in these ranges, the maximum temperature linearly and positively influenced the arecanut yield of next year (Fig.1c & d). The average monthly maximum temperature of July and September during the period of study varied between 27^{0}C to 30^{0}C and 29^{0}C to 32^{0}C respectively and in these ranges; the maximum temperature linearly and positively influenced the arecanut yield of the current year (Fig. 1 e & f).

Average monthly minimum temperature

The results of the correlation study (Table 1) showed that there was a significant positive correlation between average monthly minimum temperature during May and the next year's arecanut yield. The spline curve indicated that up to 25^{0}C, the minimum temperature during May positively influenced the arecanut yield and the yield declined once the minimum temperature was more than 25^{0}C (Fig.2).

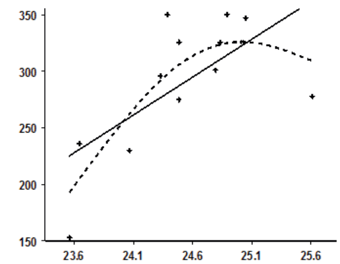


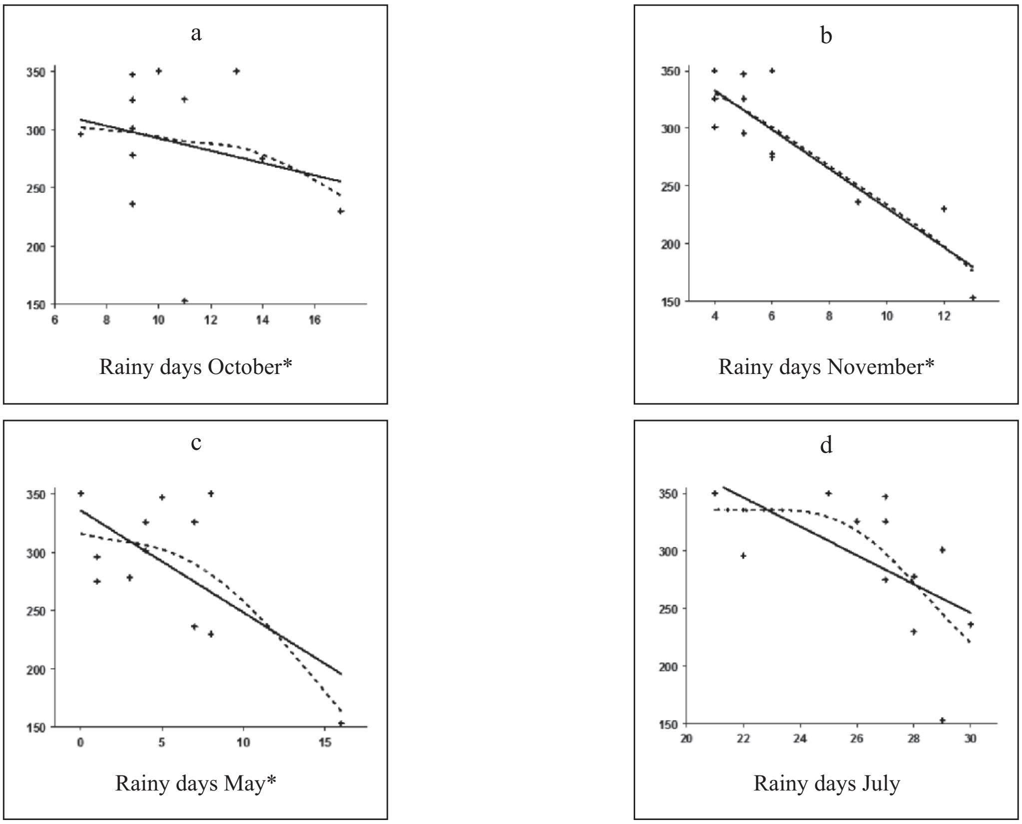
Fig. 2. Scatter plot with linear fit and spline curve of the minimum temperature of May* (x-axis) and arecanut yield (y-axis)

* indicates the previous year

Total rainfall and number of rainy days

Correlation study showed that there was a significant negative correlation between annual arecanut yield and total monthly rainfall during November of the previous year which was the main flowering period for the next year's yield. Also high rainfall during May and July which is the fruit setting period of arecanut adversely affects the yield of arecanut (Fig. 3). For the given range of rainfall (31- 262mm) observed during the month of November (previous year), the arecanut yield showed an increasing trend as the total rainfall during the month decreases. Even though the relationship is almost linear, the spline curve showed that the rate of yield reduction was more when the rainfall was more than 175mm. Similarly, arecanut yield showed an increasing trend as the total rainfall during the month of May (previous year) and July decreases. The spline curve showed that the rate of yield reduction was high when the total rainfall during May (previous year) and July are more than 200 mm and 1100 mm respectively.

Correlation study showed that there was a significant negative correlation between annual arecanut yield and number of rainy days during October and November of the previous year which is the main flowering period (Fig. 4a & b). Spline curve confirmed that the relationship of annual arecanut yield with the number of rainy days during October and November of the previous year was almost linear. Also, there was a significant negative correlation between annual arecanut yield and number of rainy days during the month of May (previous year) and July which is the fruit setting period (Fig. 4 c & d). The spline curve showed that the rate of yield reduction was high when the number of rainy days during May (previous year) and July were more than 7 and 26 respectively.



* indicates the previous year

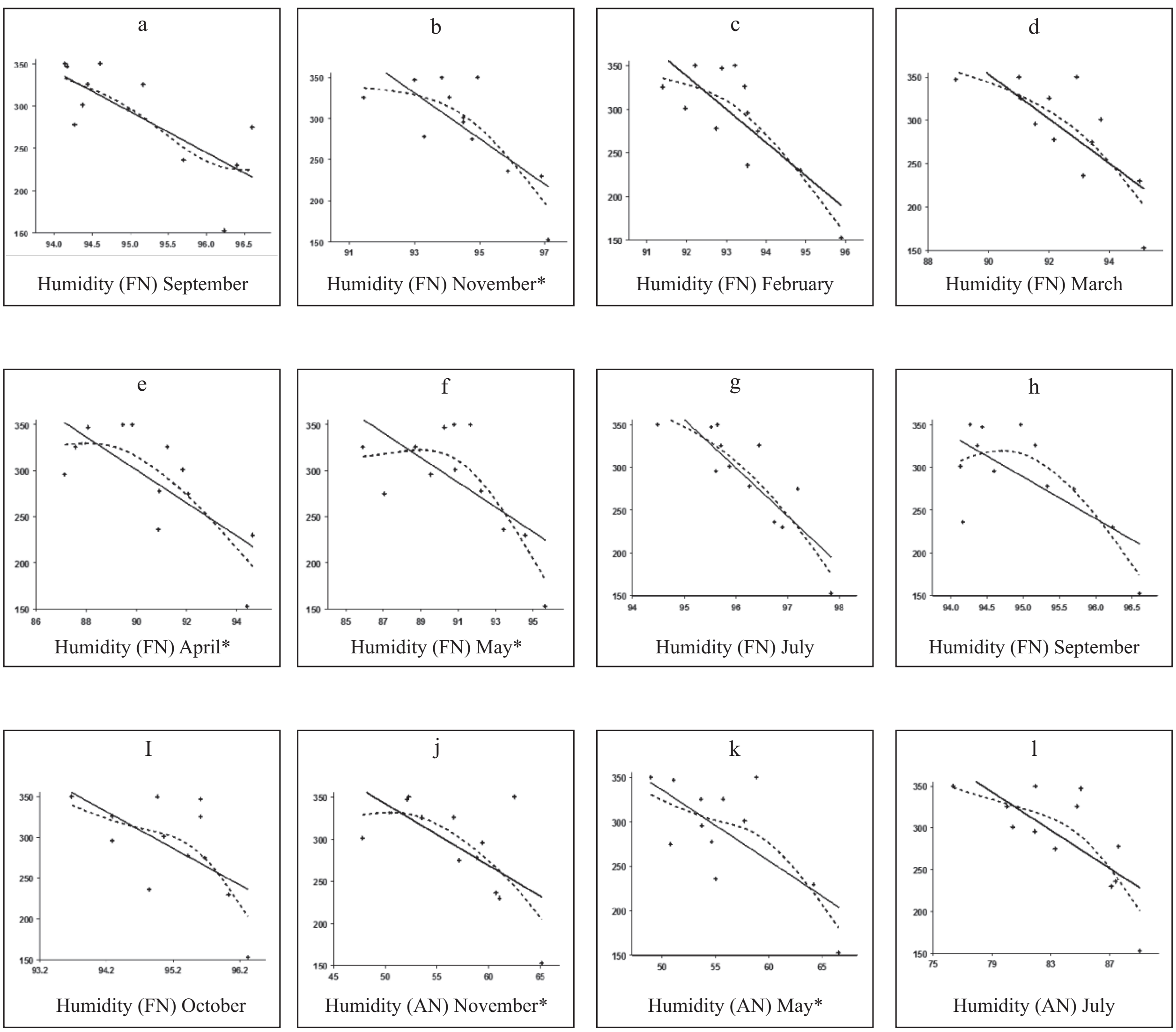
Fig. 4. Scatter plot with linear fit and spline curve of number of rainy days (monthly) (in x-axis) and arecanut yield (y-axis)

Humidity

The correlation study shows that high relative humidity (FN) during September, November and the summer months from February to May during the previous year adversely affected next year's arecanut yield. The high relative humidity during July, September, and October of the current year also had a negative impact on yield (Fig. 5). Also, the high relative humidity (AN) during November (previous year), May (previous year) and July adversely affected the arecanut yield. The above results indicated that the high relative humidity during the flowering and fruit setting period adversely affected the arecanut yield.

The average monthly RH (FN) in September during the period under study varied between 94 per cent and 97 per cent. As the humidity during September decreased from 97 per cent to 94 per cent, the arecanut yield for the next year showed an increasing trend (Fig. 5). The spline curve also confirmed that the relationship between annual arecanut yield and the RH (FN) in September (previous year) was linear. The monthly average RH (FN) in November varied between 91 per cent and 97 per cent and the next year's arecanut yield showed an increasing trend as the RH decreases. The spline curve showed that the rate of yield reduction was high when the RH (FN) during November (previous year) was more than 95 per cent. Similarly, the next year's arecanut yield showed an increasing trend as the Humidity (FN) during the summer months, February, March, April, and May of the previous year decrease. The spline curve showed that the rate of yield reduction was high when the RH (FN) during February, March, April, and May of the previous year is more than 93 per cent, 92 per cent, 90 per cent and 91 per cent respectively. The annual arecanut yield shows an increase as the humidity (FN) during July, September and October decreases. The spline curve showed that the rate of yield reduction was high when the RH (FN) during September and October is more than 95.3 per cent and 95.7 per cent respectively.

The relative humidity (AN) of November and May during the period of study varied between 47 per cent to 65 per cent and 49 per cent to 67 per cent respectively and in these ranges of relative humidity (AN) during November and May negatively influenced the arecanut yield of next year (Fig. 5). The spline curve showed that the rate of yield reduction was high when the RH (AN) during November and May of the previous year was more than 57 per cent and 60 per cent respectively. The relative humidity (AN) during July varied from 76 per cent to 89 per cent and in this range, it negatively influenced the arecanut yield. The spline curve showed that the rate of yield reduction was high when the RH (AN) during July was more than 85 per cent.



* indicates the previous year

Fig. 5. Scatter plot with a linear fit of average monthly humidity (FN & AN) (in x-axis) and arecanut yield (y-axis)

Yield prediction model

Monthly weather variables that are significantly correlated with annual arecanut yield (Table 1) were selected to predict the annual yield of arecanut. Stepwise regression (forward) with annual yield as the response variable and the selected monthly weather variables as independent variables were used to predict the annual yield of arecanut and the resultant regression function with (R^2=0.97) is given below

$$Y=261.97-0.3944X_1+37.6792X_2-11.6254X_3$$

Where, Y is the annual arecanut yield (number of nuts), X_1: Total rainfall during November (previous year), X_2: maximum temperature during September and X_3: Humidity (FN) March (previous year). The estimated value using the above regression model is almost near to the observed value and about 97per cent of the yield variation could be explained using the regression model (Fig.6). Since most of the 16 weather variables (independent variables) which are significantly correlated with the response variable are correlated with each other, only 3 variables were selected in the regression model through stepwise regression. The model can also be used for pre-harvest yield prediction in arecanut.

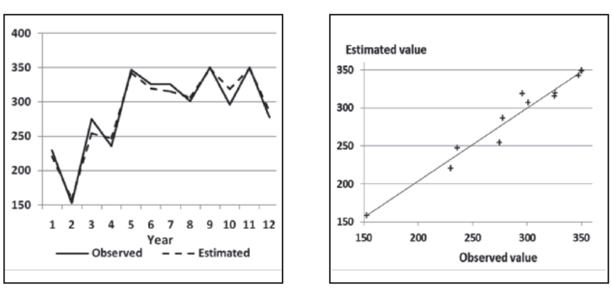


Fig. 6. Observed and estimated values of arecanut yield (y-axis) Vs year (x-axis)

Conclusion

The present study showed that the arecanut yield was highly influenced by the weather conditions during the current and previous year. The weather parameters such as maximum temperature, minimum temperature, rainfall, and relative humidity influenced the arecanut yield. The stepwise regression fitted using the significant weather variable could explain about 97 per cent of the yield variation in arecanut. Also, the model can be used to undertake a pre-harvest forecast of arecanut yield. Information on yield-weather association in the farmer's field and corresponding yield variations could help in decisions on compensating farmers accordingly. Advance information on yield variations could further give a clue on price variations so as the producers can plan the sale of their produce.

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