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*Research Article*

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# Forecasting Model for Mango (*Mangifera indica*) Malformation in New Delhi and Lucknow

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**ABSTRACT**

*Data related to intensity of mango malformation and weather variables at New Delhi and Lucknow were collected. They were analyzed for their relation and for developing and validation of MLR prediction models. The resultant correlation matrix found less than 0.1 was considered not having relation to malformation intensity with that particular weather variable and was excluded in further multiple linear regression analysis. Data from 1993 to 2000 was used for developing prediction models and are validated by using data from 2001 to 2006 for both FBD (flower bud differentiation) and flowering stages. The percent deviation was calculated which gave good forecasting of disease intensity for all selected malformation prone areas. For Delhi the wind speed, RH2, minimum and maximum temperatures were positively correlated with mango malformation and the MLR models under predicted the disease intensity for both FBD and flowering stages. Lucknow, at flowering stage maximum temperature and minimum temperature showed significant relation with the mango malformation and the MLR model at FBD stage showed a very good estimate whereas for flowering stage it gave reasonable estimate. The model under predicted the disease during FBD stage whereas it was over predicted at flowering stage.*

***Keywords:*** *Mango, Malformation, Forecasting, Weather variables.*

## INTRODUCTION

Malformation of mango (*Mangifera indica* L.) induced by *Fusarium mangiferae* (*Fusarium moniliformae var. subglutinans*) is considered as plant disease of international importance. Maksoud and Haggag et al. (1994;1995) suggested predictin models to estimate percentage malformation in mango trees and prediction equation was proposed by regression analysis. Aguilera et al. (2003). correlated mango malformation with density of Fusarium spp., relative humidity and temperature. The pattern of changes in incidence of vegetative and floral malformation of mango with host age was expressed mathematically by Pandey et al. (2003). Relative humidity and temperature may influence malformation incidence in mango, which have direct relationship with fruit-set and yield and lower temperature usually favour the development of malformed panicle (2001).

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Chakrabarti et al. (2003) made an attempt to identify predictors for forecasting incidence of floral malformation. Very little is known about the epidemiology of the disease because of the lack of uniformity in its occurrence and variation in the severity of disease from season to season. However no information is available regarding malformation intensity with different weather variables at FBD and flowering stages. Hence the studies were undertaken to know the correlation between mango malformation and different weather variables, and obtaining the forecasting models for New Delhi and Lucknow.

## MATERIALS AND METHODS

The experiment was conducted at Division of Fruits and Horticulture technology, IARI, New Delhi during 2004 – 2007. Historical weather data of fourteen years from 1993 to 2006 for the New Delhi and Lucknow are collected, which were used for correlation and multiple linear regression analysis (MLR). The weather parameters included monthly average of maximum temperature, minimum temperature, $RH_1$, $RH_2$, rainfall, sun shine hours, evaporation and wind speed. Intensity of mango malformation disease data of New Delhi and Lucknow for fourteen years (1993 - 2006) were collected from secondary sources (journals and published articles and AICRP STF (All India Co-ordinate Research Project on Sub Tropical Fruits) annual reports) and used for analysis. The relationship between weather variables and mango malformation disease intensity per cent were analyzed by using the correlation analysis for their degree of association in development of disease for both flower bud differentiation (FBD) and flowering stages. If the resultant correlation matrix is less than 0.1 means no relation between malformation intensity with that particular weather variable and was excluded in further multiple linear regression analysis. Monthly mean values of weather variables along with disease intensity of mango malformation for both FBD and flowering stages were analyzed for eight years (1993 - 2000) of New Delhi and Lucknow. However for FBD stage also used the same malformation disease intensity per cent i.e. flowering period malformation intensity for both correlation and MLR analysis. The relationship between the weather variables and mango malformation intensity per cent were represented as in the following formulae.

$$Y = a + b_1X_1 + b_2X_2 + \ldots\ldots + b_nX_n$$

Where, Y = Mango malformation intensity per cent

a = Intercept

$b_1$ = Regression coefficient for $X_1$

$b_2$ = Regression coefficient for $X_2$

The mango malformation intensity is predicted by substituting the monthly mean weather variables of six years (2001 - 2006) in regression model for New Delhi and Lucknow. The percent of deviation were calculated by using the following formulae.

$$\text{Per cent deviation} = \frac{\text{PDI} - \text{ODI}}{\text{ODI}} \times 100$$

Where,

PDI = Predicted malformation disease intensity per cent

ODI = Observed malformation disease intensity per cent

## RESULTS AND DISCUSSION

For New Delhi, the weather data for 8 years (1993-2000) was averaged for two stages *i.e.*, FBD stage (October-December) and flowering stage (February- March) separately based on the time of occurrence. The correlation analysis between weather variables and the mango malformation during the FBD stage revealed that the weather variables significantly differed with mango malformation intensity. The bright sunshine hours (-0.43), evaporation (-0.06) and rainfall (-0.03) had showed negative association with mango malformation intensity in ascending order. These are presented in Table 1. The wind speed, $RH_2$, minimum and maximum temperatures were positively correlated with mango malformation. The highest degree of association was noticed with wind speed (0.47) and bright sunshine hours (-0.43). The lower bright sunshine hours, low evaporation demand and less rainfall led to cloudy weather with low light intensity, which led to an increase in $RH_2$ values and minimum temperature. These conditions favoured the disease development. High wind speed during this period helped in spread of mango malformation.

The correlation analysis between the weather variables and mango malformation during the flowering stage showed that except rainfall and evaporation, all other variables had significant with mango malformation intensity. The wind speed (0.57) and $RH_1$ (0.12) are positively correlated, which is presented in Table 1. Among the negatively correlated variables highest degree of association was observed with minimum temperature (-0.56) followed by maximum temperature (-0.54). The correlation analysis between the weather variables and mango malformation during the flowering stage showed that high wind speed, $RH_1$ values along with lower temperatures and sunshine hours increased the disease intensity. Similar results were obtained by Noriega – Cantu et al. (1999).

Multiple regression models of mango malformation intensity and weather variables at New Delhi at different growth stages revealed that during the FBD stage, coefficient of determination was $R^2$=0.79, whereas for the flowering stage it was of 0.99 (Table 2).

Multiple regression model developed between the weather variables and mango malformation intensity for Delhi was further used for prediction of disease intensity of mango malformation from 2001-2006. The model developed for predicting the mango malformation at FBD stage showed a per cent deviation range from 6.0 to 17.9 (Fig.1), whereas these values for flowering stage ranged from 13.2 to 27.1, which are presented in Fig.2.

Similarly for Lucknow the weather data for 8 years (1993-2000) was averaged for two stages *i.e.*, FBD stage (October-December) and flowering stage (February-March) separately based on the time of occurrence. The correlation analysis between the weather variables as independent variables and disease intensity of mango malformation as dependent variable is presented in Table. 1. Weather variables significantly differed for their relationship with mango malformation intensity at FBD stage and the high degree of positive association was shown by rainfall (0.53), followed by wind speed (0.36), $RH_1$ (0.29), maximum temperature (0.2), $RH_2$ (0.18) and evaporation (0.05). The correlation analysis between the weather variables and disease intensity of mango malformation at FBD showed that the high amount of rainfall along with wind speed, moderate high $RH_1$ and lower minimum temperatures favors disease development. These results are incongruent with Aguilera et al. (2003) and Youssef et al. (2006). Whereas, at flowering stage, maximum temperature, minimum temperature and rainfall showed significant association with the mango malformation intensity. Only $RH_2$ showed negative correlation with mango malformation while all other variables were positively correlated (Table 1). During the flowering stage higher temperatures with higher amount of rainfall and lower $RH_2$ favour the disease development. These conditions might favor high moisture formation on panicle surfaces.

The multiple regression equation developed between the weather variables and mango malformation by using the data of 1993-2000 crop seasons at FBD stage showed a very good estimate with coefficient of determination of

0.94, whereas for flowering stage it gave reasonable estimate ($R^2$ = 0.73) , which is presented in Table. 2.

Multiple regression model developed between the weather variables and mango malformation for Lucknow was further used for prediction of disease intensity of mango malformation from 2001-2006. The model developed for predicting the mango malformation at FBD stage showed a per cent deviation range from 1.3 to 20.3, which is presented in Fig.3, whereas deviations for flowering stage ranged from 0.9 to 27.0 (Fig 4).

Multiple regression models developed between the weather variables and mango malformation at FBD stage under predicted the disease intensity at New Delhi and Lucknow. At flowering stage the disease was over predicted at Lucknow whereas for New Delhi the model under predicted the incidence of malformation.

**Table 1: Correlation matrix of mango malformation intensity and weather variables for New Delhi and Lucknow at flower bud differentiation and flowering stages from 1993-2000.**

| **Period** | **location** | **T. max** | **T.min** | **$RH_1$** | **$RH_2$** | **WS** | **RF** | **SSH** | **EVP** |
|---|---|---|---|---|---|---|---|---|---|
| flower bud differentiation | **Delhi** | 0.25 | 0.18 | 0.12 | 0.21 | 0.47 | -0.03* | -0.43 | -0.06* |
| | **Lucknow** | 0.199 | -0.255 | 0.294 | 0.179 | 0.357 | 0.525 | -0.065* | 0.054* |
| **Flowering** | **Delhi** | -0.54 | -0.56 | 0.12 | -0.32 | 0.57 | -0.03* | -0.43 | -0.08* |
| | **Lucknow** | 0.522 | 0.610 | 0.073* | -0.267 | 0.184 | 0.567 | 0.226 | 0.207 |

* Correlation matrix less than 0.1 are considered as no relation with mango malformation intensity and were excluded for further multiple linear regression analysis

T. max - maximum temperature
T. min - minimum temperature
$RH_1$ - relative humidity maximum
$RH_2$ - relative humidity minimum
WS - wind speed
RF - rainfall
SSH - sunshine hours
EVP - evapotranspiration

**Table2. Multiple regression models for New Delhi and Lucknow at flower bud differentiation and flowering stage**

| Period | location | Multiple regression model | R2 |
|---|---|---|---|
| flower bud differentiation | Delhi | $Y = 67.6 - 6.3X_1 -20.8X_2+7.7X_3 - 3.5X_4+0.9X_5 - 47.5X_7$ | 0.79 |
| | Lucknow | $Y = -348.6+0.4X_1-5.0X_2+4.0X_3+0.5X_4+34.8X_5+0.4X_6$ | 0.9 4 |
| Flowering | Delhi | $Y = 28.1 + 14.3X_1 - 25.2X_2 +1.4X_3- 0.7X_4 - 0.8X_5 - 28.5X_7$ | 0.99 |
| | Lucknow | $Y = -175.1+7.9X_1-2.3X_2+0.2X_4-12.1X_5+2.4X_6+10.9X_7-6.1X_8$ | 0.73 |

$X_1$ - maximum temperature
$X_2$ - minimum temperature
$X_3$ - relative humidity maximum
$X_4$ - relative humidity minimum
$X_5$ - wind speed
$X_6$ - rainfall
$X_7$ - sunshine hours
$X_8$ - evapotranspiration

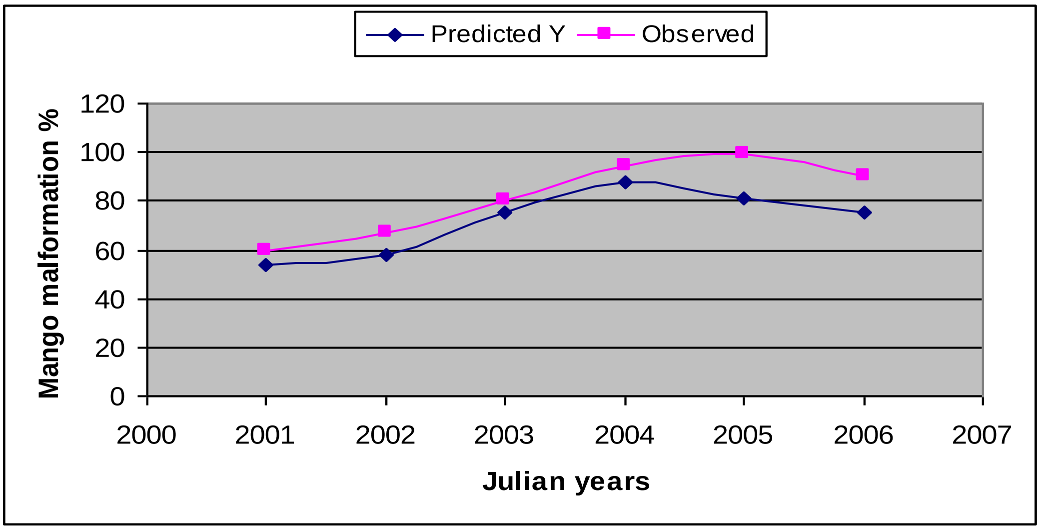


**Fig. 1: Predicted and observed values of mango malformation intensity for Delhi at F.B.D stage (Oct-Dec) by using weather variables from 2001-2006**

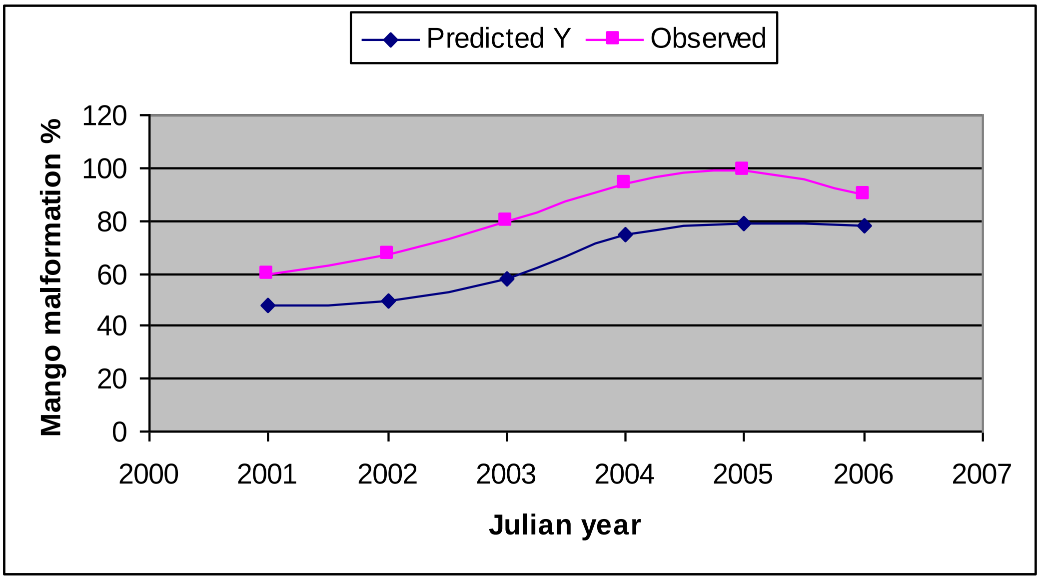


**Fig. 2: Predicted and observed values of mango malformation intensity for Delhi at flowering stage ((Feb - Mar) by using weather variables from 2001-2006**

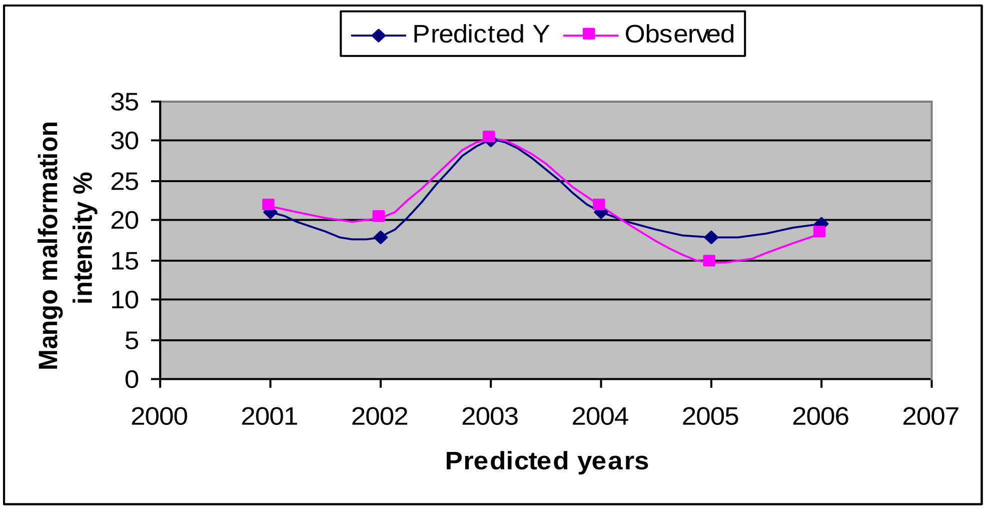


**Fig. 3: Predicted and observed values of mango malformation disease intensity for Lucknow at F.B.D stage (Oct-Dec) by using weather variables from 2001-2006**

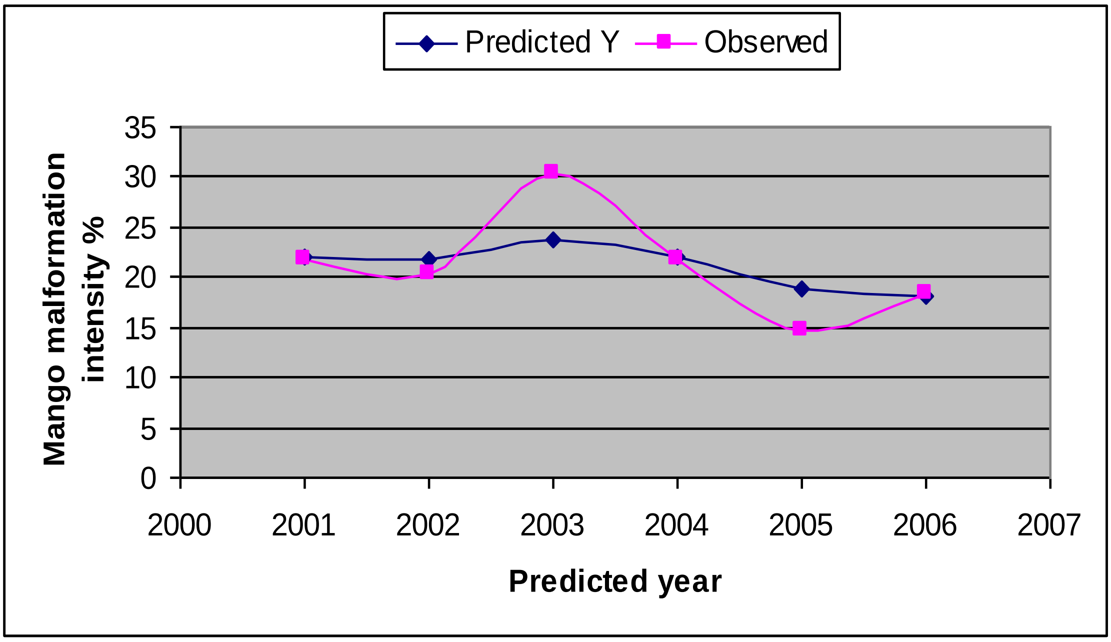


**Fig. 4: Predicted and observed values of mango malformation disease intensity for Lucknow at flowering stage (Feb - Mar) by using weather variables from 2001-2006**

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