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Multiple regression analysis for prediction of anthracnose disease in mango (*Mangifera indica* L.)

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Abstract
Mango (*Mangifera indica* L.) is one of the highly demanded fruit in India. However, the crop is vulnerable to numerous diseases at all stages of its development. Among these diseases, Anthracnose disease caused by *Colletotrichum gloeosporioides* is one of the most serious and widespread disease. The purpose of this study was to carry out multiple regression analysis for prediction of anthracnose disease of mango. The experiment was conducted on 15 years old plants of twenty cultivars of mango namely Pantsinduri, Dashehari, Amarpalli, Neelum, Hathijhul, Rasgulla, Redtotapari, Langra, Nashpati, Ramkela, Gaurjeet, Golajafrani, Gulabkhas, Gorakhpurlangra, Kalahafus, Karela, Tamancha, Barahmasi, Husnara and Chausa in 2013 and 2014 at Horticulture Research Station (H.R.C.) of G. B. Pant University of Agriculture and Technology, Pantnagar, Dist. Udham Singh Nagar, Uttarakhand. Prevailing weather variables such as temperature, relative humidity and rainfall were obtained corresponding to the mango seasons for both years (2013 and 2014) from agrometeorological section of GBPUAT, Pantnagar. These data were also utilized for working out disease weather correlations. Significant correlation coefficient was used to work out multiple regressions for prediction of anthracnose in mango. The coefficient of multiple determinations (R^2) value of twenty cultivars showed that variation of disease incidence in the development of disease was maximum (94%) in Nashpati cultivar and minimum (84%) in Pantsinduri. Observing the meterological data, it was found the relative humidity and rainfall was more in 2014 (96%, 119.8 mm respectively) as compared to 2013 (97%, 105.8 mm respectively) during early stage of disease development. The minimum temperature was less in 2014 in comparison to 2013 (5.9 ^{0}C, 6.2 ^{0}C respectively) meanwhile, maximum temperature was recorded high in 2014 as compared to 2013(41.0 ^{0}C, 39.0 ^{0}C respectively). It was revealed further that free moisture/relative humidity and temperature were also very high which, contributed to the initial stage of disease development.

Keywords: Mango, powdery mildew, coefficient of multiple determinations R^2, Prediction

Introduction

Mango (*Mangifera indica* L.) is one of the most famous member of the family Anacardiaceae (Sarwar, 2015). It is called king of the fruits and is considered the most important fruit among millions of people worldwide particularly in Egypt. (El-Meslamany *et al*., 2020) [5]. It is one of the world's most important fruits of the tropical and subtropical countries and is cultivated extensively as a commercial fruit crop in India, China, Indonesia, Thailand and Mexico. The crop is grown over 87 countries in the world. Mango occupies an area of 2309 000 Ha having annual production of 21285 MT in India. (NHB, 2019-20). It is nutritionally rich in carbohydrates (11.6-24.3%), protein (0.5-1.0%), fat (0.1-8%), vitamin A and C, amino acids and fatty acids. A good mango variety contains 20 per cent of total soluble sugars. The acid content of ripe desert fruit varies from 0.2 to 0.5 percent and protein content is about 1 per cent. Among all prevailing diseases, Anthracnose caused by *Colletotrichum gloeosporioides* is one of the most important diseases of mango crop. It mainly attacks leaves, flowers, young fruits and twigs and also appears as a post-harvest disease of ripened fruits.

Yield of any crop is mainly influenced by the factors like weather parameters and the input variables. The effect of weather on crop growth varies with growth period of the crop. The influence of weather parameters on crop yield depends on the magnitude and distribution of the weather variables over crop growth period. In prediction approach for crop production, utilizing information on both weather parameters and input variables is advantageous. For accurate prediction, long term data on weather parameters and input variables are required but practically obtaining long term time series data is very difficult. Therefore to overcome this problem one can build the model with less number of parameters taking into consideration the pattern or the distribution over the entire crop growth period.

Approaches based on various weather based regression analysis which captures the effect of climate variables on crop yields was proposed by Agarwal *et al*. (1986), Yang *et al.* (1992) [17] Agarwal, Dixon *et al*. (1994) [4], Garde *et al.* (2012) [6], Rathod *et al.* (2012) [12] Kandiannan *et al.* (2002) [8]. Tannura *et al.* (2008) [16] Srinivasa *et al*., (2019) [14] observed that the explanatory power of the multiple regression models are much better and they express how weather conditions and crop yield are related to one another. The Multiple Linear Regression (MLR) models are applied when two or more independent variables are influencing the dependent variable. It uses few or all variables for prediction as necessary to get a reasonably accurate prediction.

Materials and Methods

The present investigation entitled ‘Multiple Regression Analysis for prediction of Anthracnose disease in Mango’ was carried out at Horticulture Research Center (H.R.C.), Patharchatta, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar (U.S. Nagar) during 2013 and 2014.

Experimental Material

The experiment was conducted on 15 years old plants of twenty cultivars of mango namely Pantsinduri, Dashehari, Amarpalli, Neelum, Hathijhul, Rasgulla, Redtotapari, Langra, Nashpati, Ramkela, Gaurjeet, Golajafrani, Gulabkhas, Gorakhpurlangra, Kalahafus, Karela, Tamancha, Barahmasi, Husnara and Chausa in 2013 and 2014 at Horticulture Research Station (H.R.C.) of G. B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar, Uttarakhand. Prevailing weather variables such as temperature, relative humidity and rainfall corresponding to the mango seasons for both years (2013 and 2014) were obtained from agrometeorological section of GBPUAT. These data were also utilized for working out disease weather correlations. Correlation coefficient analysis was used to work out multiple regressions.

Details of Experiment

The experiment was laid out in randomized block design with three replications. Observations were recorded for twenty cultivars at 10 days interval starting from its appearance from 23 January to 15 June during 2013 to 2014 for Anthracnose disease on a rating scale of 0 to 5 as proposed by (Suharban *et al*., 1985) [15].

Symptomatology and disease development

The disease appeared in 4th week of April in both the years. The characteristic symptoms (Figure 1) of the disease on leaves appeared as small, angular, brown to black spots that can enlarge to form extensive dead areas. While, on fruits symptoms developed as sunken, prominent, dark brown to black decay spots before or after picking. Fruit also dropped from trees prematurely (Figure 2). The characteristic symptoms observed due to the disease were compared and found to be similar to those documented by Akhtar and Alam (2002) [3], Ghosh *et al*., 2010 [7]; Onyeani *et al.*, 2012 [11]; Akem, 2006 [2]; and Nelson (2008) [10].

Fig 1: The characteristic symptoms (Figure 1) of the disease on leaves appeared as small, angular, brown to black spots that can enlarge to form extensive dead areas

Fig 2: While, on fruits symptoms developed as sunken, prominent, dark brown to black decay spots before or after picking. Fruit also dropped from trees prematurely

Based on the symptom development, following scale was devised for the assessment of disease severity/ index and were categorized as different level of resistance and susceptibility

Rating scale	Area of leaves covered (%)
0	Leaves free from anthracnose
1	1-5 per cent leaves covered by anthracnose
2	5.1-10 per cent leaves covered by anthracnose
3	10.1-20 per cent covered by leaves anthracnose
4	20.1-50 per cent covered by leaves anthracnose
5	>50.1 per cent covered by leaves anthracnose

PDI was also calculated as following

$$PDI = \frac{\sum (a+b)}{N.Z} \times 100$$

Where

$\sum(a+b)$ = Sum of infected leaves and their corresponding score scale

N = Total number of leaves examined

Z = Maximum score scale

Disease progression in relation to weather variables

To study the pre-disposing meteorological factors *viz*. average atmospheric temperature, relative humidity and rainfall on the development of anthracnose disease in field, corresponding data were obtained for these years from agrometerological section of GBPUAT. The effect of weather parameters on anthracnose disease was correlated by using SPSS version 16 software. The regression and R^2 values were also analysed by using SPSS software.

Results and Discussion

Multiple regression analysis is a set of statistical methods used for the estimation of relationships between a dependent variable and one or more independent variables. The multiple regression equation was designed based on data obtained over two years to predict the disease incidence depending upon various abiotic factors. The regression analysis of disease incidence as an independent variable with weather parameters were analyzed using SPSS 16 which was useful in the prediction of this disease. The multiple regression equations (Table 1) calculated for twenty cultivars of mango showed highly significant values of coefficient of multiple determination (R^2) which ranged from 72.6 to 99.7 per cent. Thus regression equation revealed that abiotic factors was found to be most influencing factor, which contributed 72.6 to 99.7 per cent range of variation in disease incidence of Anthracnose disease of different cultivars in mango. Maximum R^2 value (98%) was found in Ramkela and minimum R^2 value (84.1%) in Chausa. These results are in accordance with (Srinivas *et al*., 2019) [14]. The results further indicate that data needs to be generated for a longer period and the model to be tested and validated at multilocations.

Table 1: Multiple regressions analysis for prediction of Powdery mildew of mango

SI. No.	Cultivars	Multiple regression equation	R^2 (Coefficient of multiple determination)
1	Pantsinduri	$Y= -57.71 +(0.007x_1)+(3.03x_2)+(0.102x_3)+(-1.33x_4)$	0.967
2	Dashehari	$Y= -42.11+(-0.479x_1)+(3.93x_2)+(-0.106x_3)+(-1.79x_4)$	0.963
3	Amarpalli	$Y= -65.87 +(0.440x_1)+(2.31x_2)+(0.181x_3)+(-1.21x_4)$	0.955
4	Neelum X Chausa	$Y= -50.38+(0.315x_1)+(1.54x_2)+(0.205x_3)+(-0.874x_4)$	0.972
5	Hathijhul	$Y= -43.17+(-0.601x_1)+(4.602x_2)+(-0.196x_3)+(-2.00x_4)$	0.973
6	Rasgulla	$Y= -53.45+(0.474x_1)+(1.19x_2)+(0.252x_3)+(-0.635x_4)$	0.970
7	Redtotapari	$Y= 0.953+(-51.67x_1)+(0.992x_2)+(0.273x_3)+(-0.605x_4)$	0.953
8	Langra	$Y= -46.18+(-0.009x_1)+(2.40x_2)+(0.089x_3)+(-1.16x_4)$	0.958
9	Nashpati	$Y= -44.29 +(-0.134x_1)+(3.10x_2)+(-0.015x_3)+(-1.48x_4)$	0.966
10	Ramkela	$Y= -70.632+(0.696x_1)+(1.70x_2)+(0.276x_3)+(-0.788x_4)$	0.989
11	Gaurjeet	$Y= -39.06+(-0.407x_1)+(3.62x_2)+(-0.107x_3)+(-1.69x_4)$	0.963
12	Golajafrani	$Y= -47.78+(0.139x_1)+(2.30x_2)+(0.062x_3)+(-1.10x_4)$	0.966
13	Gulabkhas	$Y= -46.55+(-0.67x_1)+(4.82x_2)+(-0.171x_3)+(-2.07x_4)$	0.967
14	Gorakhpurlangra	$Y= -25.85+(-1.22x_1)+(5.52x_2)+(-0.359x_3)+(-2.38x_4)$	0.972
15	Kalahafus	$Y= -46.00+(0.025x_1)+(2.54x_2)+(0.038x_3)+(-1.22x_4)$	0.962
16	Karela	$Y= -53.59+(0.203x_1)+(2.22x_2)+(0.138x_3)+(-0.991x_4)$	0.961
17	Tamancha	$Y= -52.35+(-0.069x_1)+(3.10x_2)+(0.069x_3)+(-1.43x_4)$	0.962
18	Barahmasi	$Y= -42.03+(-0.498x_1)+(3.89x_2)+(-0.087x_3)+(-1.79x_4)$	0.966
19	Husnara	$Y= -43.22+(-0.145x_1)+(2.93x_2)+(-0.007x_3)+(-1.45x_4)$	0.972
20	Chausa	$Y= -39.66+(-0.169x_1)+(2.85x_2)+(-0.22x_3)+(-1.47x_4)$	0.938

Where, X1=Maximum Temperature (^0C), X2= Minimum Temperature (^0C), X3= Maximum Relative Humidity (%), X4= Rain Fall (mm)

Table 2: Meteorological data at Pantnagar during cropping season pooled 2013-2014

Standard weeks	Temperature (^0C)		Relative Humidity (%)	Rain fall (mm)
	Max.	Min.	Max.	
1	20.75	6.05	95.00	0.80
2	20.15	8.20	88.5	1.80
3	19.30	8.85	94.0	52.90
4	16.75	8.05	95	0.70
5	19.25	8.20	94.00	0.00
6	22.10	9.35	93.00	25.15
7	20.95	8.25	93.00	76.40
8	22.55	10.15	91.00	12.10
9	24.45	11.05	92.00	40.70
10	26.95	11.75	89.00	0.00
11	28.50	13.45	87.50	13.10
12	29.30	14.70	85.50	0.00
13	30.85	14.65	87.50	0.00
14	32.90	14.95	80.50	1.10
15	35.10	16.65	70.00	0.30
16	33.60	16.80	68.00	9.30
17	36.25	18.60	65.50	0.00
18	37.95	19.80	61.00	7.20
19	37.85	20.20	59.85	2.30
20	37.50	22.15	63.7	0.00
21	38.90	26.00	64.50	0.00

22	37.64	26.19	67.57	1.51
23	38.08	26.82	70.00	11.80
24	35.93	25.46	75.57	61.59

Conclusion
The research is very useful for the Mango growers to predict and control Anthracnose disease of Mango caused by *Colletotrichum gloeosporioides*. Very little work has been conducted on Anthracnose disease of Mango. Based on the results obtained in this study one can conclude that the multiple regression analysis for prediction of Anthracnose disease in mango, performed better. The reason for better performance of multiple regression models may be due to consideration of various weather variables. The coefficient of multiple determinations (R^2) value of twenty cultivars showed that variation of disease incidence in the development of disease was maximum (up to 98%) in Ramkela and Minimum (93%) in Chausa.

Future Scope
The research is very useful for the Mango growers to control Anthracnose of Mango caused by *Colletotrichum gloeosporioides*. Very little work has been conducted on multiple regressions for prediction of Anthracnose of Mango. More research is needed to introduce prediction using multiple regression model as it is a rational and scientific way of predicting future occurrences in agriculture the level of production effects. Its main purpose is reducing the risk in the decision1making process affecting the yield in terms of quantity and quality. It is used to provide a support to decision makers and in planning various plant disease management tactics for the future effectively and efficiently.

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