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Long Term Effects of Weather Parameters on Crop Yield in Mango and Citrus under Una District of Himachal Pradesh

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ABSTRACT: The unplanned fruit plantation mostly leads to unprofitable venturing, and this has been the main reason that fruit cultivation in the subtropical region of Himachal Pradesh has not picked up despite huge potential. It is imperative to consider the micro-climatic scenario of any given niche for proper crop planning. To reap the optimum potential and achieve desired production levels in fruit production proper analysis of prevalent conditions is of utmost importance. The phenological stages of fruit crops along with changes in air temperature and rainfall are the most important factors for their production. Different fruit species are influenced differently due to varying levels of adaptability with varying climate change. Data on three weather parameters i.e. maximum temperature, minimum temperature and rainfall along with fruit production in mango and citrus pertaining to Una district of Himachal Pradesh were acquired for the period of 2004-2018. Effects of weather parameters on fruit crop production were assessed using correlation and regression models analysis whereby individual parameters were correlated with fruit crop production and the multiple linear regression equations were obtained. To compute the effect of parameters, regression coefficient of different functions considering linear, logarithmic, inverse, quadratic, cubic, compound, power, S- curve, growth and exponential functions were fitted and best fit equations were selected on the basis of R^2 and RMSE. The correlation coefficient between maximum temperature and mango production showed positive significant correlation (r = 0.703) at 1 per cent level of significance, whereas, the citrus production also showed positive significant correlation (r = 0.863). The analysis of regression models for fruit production revealed that maximum temperature on mango production was found significant with an R^2 value (0.499) and RMSE 0.38 of S-curve model, indicating further that mango production is influenced by maximum temperature. In case of citrus production, maximum temperature on the basis of R^2 value (0.769) of cubic regression equation indicated that citrus production was influenced by maximum temperature. However, the effect of weather parameters in multiple-linear regression analysis on fruit crop production was found significant with R^2 value of 0.748 for citrus and 0.522 for mango, indicating that total crop production was influenced by combinations of weather parameters for the period under study. Further, a decisive conclusion can only be drawn after proper monitorng of the temporal and spatial variations in weather for a longer time period at small multilocational pockets throughout the year. This type of data will be pivotal step in crop planning to sustain the climatic vagaries.

Keywords: Weather parameters, crop yield, correlation, regression, physiographic maps.

INTRODUCTION

Horticulture is an important sector in India which contributes 30.4 per cent GDP share to agriculture. Due to different agro ecological zones, India becomes a home for different types of horticultural crops such as fruits, vegetables, flowers, aromatic and plantation crops. Globally, India is the second largest producer of fruits and vegetables crops after China in the world. In this sector, fruit crops have also played a major role in employment generation, economy, expanding export and ensuring nutrient security (Singh *et al.* 2015). Many a times the unplanned fruit plantation by farmers in different areas of the subtropics of Himachal Pradesh has led to unprofitable venturing thereby the fruit cultivation in this subtropical region has not picked up despite huge potential. Thus, it is imperative to consider the climatic scenario of any given micro agro climatic niches for proper crop planning. Furthermore, the global warming has aggravated the variation in rainfall, temperature, relative humidity which is closely linked with crop production (Hoogenboom *et al.,* 2000).

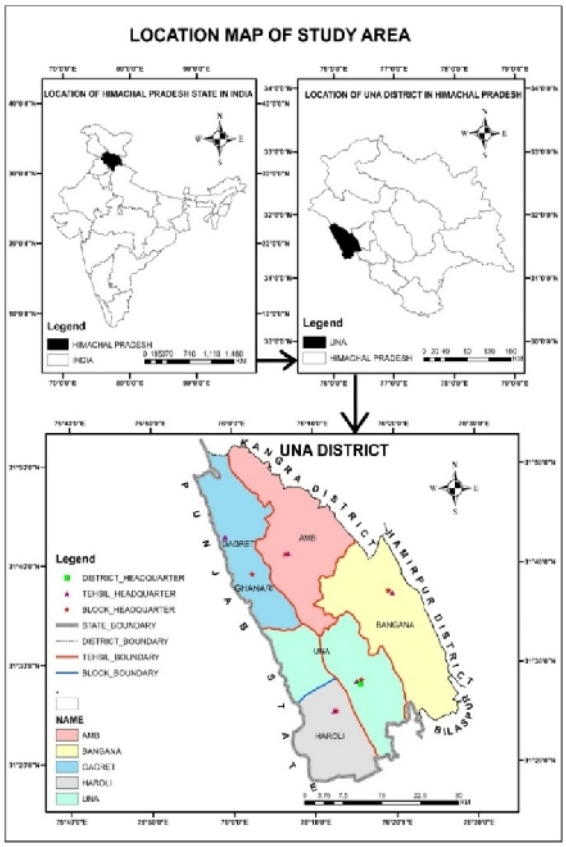
The horticulture sector is the main driver of economic growth in Himachal Pradesh. The state has favorable agro climatic regions varying from temperate to subtropical where numerous fruit crops are cultivated in upper and lower regions of the state. The mountainous tract and undulating topography plays an important role in complicating crop production due to changes in the microclimate. Agro-climatically, Himachal Pradesh is

divided into four zones with respect to altitude, rainfall, temperature, humidity and topography. Una district of Himachal Pradesh falls under Sub-Montane and Low Hills Subtropical Zone. The main fruit crops cultivated in this region are citrus, mango and litchi. The key determinants for plants are temperature, humidity, rainfall and seasonal patterns through which plant growth can be influenced directly or indirectly. Although mango is well adapted to high summer heat (Makhmale *et al.,* 2016). Weather and climate play a key role in the success or failure of fruit production. The phenological stages of fruit crops along with changes in air temperature and rainfall are the most important factors to predict the production. Different fruit species are influenced differently due to varying levels of adaptability with varying climate change. It is mostly a low hill and subtropical region and has a rich diversity of agro climate and topography in the region. The elevational differences along with healthy and well fertile soils in the district are good for fruit production.

Rainfall is the weather variable that is more associated with plant growth and production. It affects the intensity and quality of other weather variables. Heavy rainfall opens the doors for soil borne diseases and favors plant pests and disease attack. However, the shortage of rainfall causes the impact on vegetative growth of the plant and stops the transpiration process and another impact is on soil fertility and productivity (Abhinav *et al.,* 2018). High temperature and polluted air also impact fruit yield and increase the intensity of physiological disorders such as black tip of mango due to changes in the environmental system. Physical planning maps not only play an important role in the realization of land use plans, but also in the communication of information about what is and what is not allowed in geographical space or on specific land parcels (Van Elzakker, 2010). The climatic aspects of regional geography involve the relationships between natural and cultural features of the region and its climate. The local climatic features, related to the topography, occur on too small a scale to be shown on a regional map. This study was conducted to investigate the probable linkage between the fruit crop production and selected weather parameters *viz.,* maximum temperature, minimum temperature and rainfall impact on fruit production together with regression and correlated analysis.

MATERIALS AND METHODS

Study area: The current study was focused on influence of weather parameters on crop product of Mango and Citrus in Una district of Himachal Pradesh. The district has a geographical area of 1549 square kilometer situated between 31°17′52″ - 31°52′00″ north latitude to 75°58'2"- 76°28′25″ east longitude. It shares boundaries with Punjab state i.e., Hoshiarpur and Rupnagar districts of Punjab and Kangra, Hamirpur and Bilaspur districts of HP. The temperature ranges from 0^{o}C in winter to 48^{o}C peak in summer. The average annual precipitation is 1253 mm.



The analysis of study area was characterized by clipping from the toposheets of the study area. Initially, a 1:50000 – scale toposheet was geo-referenced in GIS software ArcMap 10.5.1.

Crop Statistics: The major fruit crops grown in the district are mango and citrus, these fruit crops cover an area of 6097.06 hectare with production 22237.38 metric tons. This subtropical district covers a total geographical area of 1549 Sq. Km. Among the various fruit crops cultivated in Una district are mango, citrus, guava and pear. Mango and citrus cover areas of 2203 hectare and 2048 hectare with production 12261 metric tons, and 7859 metric tons, respectively during the 2018-2019 (Anonymous, 2018).

Secondary data: The year wise secondary data of weather parameters as well as citrus and mango crop production (kg/hectare) were acquired from (2004-2018). Data were collected from the from different sources viz., Directorate of Horticulture, Shimla, Himachal Pradesh and Krishi Vigyan Kendra, Berthin, Bilaspur.

Analysis of effect of weather parameter on yield of fruit crops: Annual weather parameter and the annual crop production data were calculated to find out the impact of weather parameter on fruit production using regression study and correlated to single weather variable and all the weather parameters were combined with fruit production.

Statistical Analysis Tools and Techniques: The statistical analysis was done using SPSS (Statistical Package for Social Science) software.

Regression analysis: Thee regression analysis were carried out to find the effect of weather parameters on crop yield and checking the model adequacy on the basis of R^2 and standard error of estimation. The analysis of regression was done through fitting two types of models such as linear and non-linear models, the adequacy of the models was determined by standard error and R^2 values. Models used were:

Table: Equations of regression models.

Regression models		Equations of models
I.	Linear	$Y = \alpha + \beta x + \varepsilon$
II.	Logarithmic	$Y = \alpha + \beta \text{ in } (X) + \varepsilon$
III.	Inverse	$Y = \alpha + \frac{\beta}{X} + \varepsilon$
IV.	Quadratic	$Y = \alpha + \beta_1 X + \beta_2 X^2 + \varepsilon$
V.	Cubic	$Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \varepsilon$
VI.	Compound	$Y = \alpha \beta^X + \varepsilon$
VII.	Power	$Y = \alpha X^{\beta} + \varepsilon$
VIII.	S curve	$Y = e^{(\alpha + \frac{\beta}{X})} + \varepsilon$
IX.	Growth	$Y = e^{(\alpha + \beta X)} + \varepsilon$
X.	Exponential	$Y = \alpha \times e^{\beta X} + \varepsilon$

RESULTS AND DISCUSSION

The results of the correlation study are presented in Table 1. In citrus crops, all derived weather parameters showed a significant influence on mango and citrus crop production. The maximum temperature also showed significant, positive correlation with the temperature.

The correlation coefficient analysis between the mean maximum temperature and minimum temperature for two months (December and January) of fifteen years (2004-2018) with fruit production (citrus and mango) are presented in Table 1 and 2. It was observed that mango production showed a positive significant relationship with maximum temperature (r = 0.623) at 5 percent level of significance. Whereas, minimum temperature showed negative non-significant correlation with mango production (r = -0.266) as presented in Table 1.

The analysis of the aforementioned correlation coefficient presented in Table 2 indicated the relationship of maximum and minimum temperature with production of citrus crops. It was noticed that production of citrus crop was significantly correlated with maximum temperature (r = 0.855) at 1 percent level of significance. However, minimum temperature revealed negative non-significant correlation with production of citrus crops (-0.093).

Table 1: Correlation between temperature and mango production for winter period.

	MP	T min	T max	RF
MP	1			
T min	0.327^{NS}	1		
T max	0.703**	0.266^{NS}	1	
RF	0.082^{NS}	0.285^{NS}	0.178^{NS}	1

**Correlation is significant at the 0.01 level (2-tailed)

MP = Mango production; $\mathbf{T_{Max}}$ = Maximum temperature; $\mathbf{T_{Min}}$ = Minimum temperature

Table 2: Correlation between temperature and citrus production for winter period.

	CP	T_{min}	T_{max}	RF
CP	1			
T min	0.198^{NS}	1		
T max	0.863**	0.266^{NS}	1	
RF	0.185^{NS}	0.285^{NS}	0.178^{NS}	1

**. Correlation is significant at the 0.01 level (2-tailed)
CP = Citrus production; $\mathbf{T_{Max}}$ = Maximum temperature; $\mathbf{T_{Min}}$ = Minimum temperature

Hence, there was more influence of maximum temperature on fruit production and less influence of minimum temperature and rainfall on fruit production. Similar results were observed by Swati *et al.,* (2019) in their studies where temperature had negative correlation with mango, sapota, papaya, banana production and had positive correlation with banana productivity.

Regression models for mango and citrus production with selected weather parameters

The stepwise regression equations of weather parameters and fruit production are shown in Table 3. The regression studies among linear and nonlinear models were applied on the weather parameters *viz.,* maximum temperature, minimum temperature and rainfall in order to obtain the relationship between the weather parameter and production of citrus and mango crop. The best fitted equations along with R^2 value and coefficient standard errors have been studied.

The data pertaining to the effect of weather parameters on fruit production of mango and citrus crop were examined with the help of regression models which included fruit production as a dependent variable and weather parameters as an independent variable. The regression studies among linear (straight line) and nonlinear (logarithmic, quadratic, cubic, exponential, power, growth, compound, inverse and S-curve) models were applied on the weather parameters *viz.,* maximum temperature in order to obtain the relationship between the weather parameters and production of mango crop. The best fitted equations along with R^2 value and coefficient standard errors have been studied and shown in (Table 3, 4).

Table 3: Fitted regression equations for maximum temperature and production of Mango crop during the period 2004 to 2018.

Models	Equations	SE (βi)	R^2	RMSE
Linear	MP = -452.80 + 17.92 T max	5.23 150.87	0.494	24.67
Logarithmic	MP = -1695.91 + 523.69 T max	152.98 513.96	0.494	24.67
Inverse	MP = 594.40 – 15264.21/T max	4465.29 15.49	0.493	24.69
Quadratic	MP = -503.00 + 21.36 T max – 0.05 $T max^2$	245.62 4.19 3589.69	0.494	25.77
Cubic	MP = -489.73 + 0.00 T max – 19.82 $T max^2$	123.57 0.04 2408.08	0.494	25.77
Compound	MP = 0.01 x $1.32^{T max}$	0.109 0.039	0.495	0.38
Power	MP = 4.65 $T max^{8.27}$	2.40 0.00	0.497	0.38
S	MP = exp (12.43 – 241.86/ T max)	69.96 2.43	0.499	0.38
Growth	MP = exp (-4.12 + 0.28 T max)	0.082 2.375	0.495	0.38
Exponential	MP = 0.01 $e^{0.28 T max}$	0.08 0.03	0.495	0.38

The contents of different models revealed the relationship between production of mango crop and maximum temperature. As shown in (Table 3) the power equations were found weakly fitted for maximum temperature and production of mango crop with value of R^2 (49.9 %) along with value of RMSE (0.38).

The evidence from (Table 4) reveals that the regression model showed a relationship between maximum temperature and production of citrus crops. Among all equations, quadratic and cubic models were found more suited than other equations with value of R^2 (75.9%) along with value of RMSE (10.16)

Table 4: Fitted regression equations for maximum temperature and production of Citrus crop during the period 2004 to 2018.

Models	Equations	SE (βi)	R^2	RMSE
Linear	CP = -328.04 + 12.57 T max	2.124 61.223	0.745	10.01
Logarithmic	CP = 366.15 – 1196.08 log T max	62.66 210.51	0.740	10.10
Inverse	CP = -404.11 – 10639.34 / T max	1847.29 64.32	0.734	10.21
Quadratic	CP = 793.48 - 64.22 T max + 1.31 T max^2	96.94 1.65 1416.81	0.759	10.17
Cubic	CP = 174.24 – 0.90 T max – 0.02 T max^2	1.674 0.038 477.72	0.759	10.16
Compound	CP = 0.00 x 1.43 $^{T max}$	0.121 0.002	0.610	0.39
Power	CP = 8.39 T max $^{10.65}$	2.449 0.000	0.612	0.39
S	CP = Exp (14.18 – 310.99/T max)	71.30 2.48	0.613	0.39
Growth	CP = Exp (-7.11 – 0.36 T max)	0.084 2.42	0.610	0.39
Exponential	CP = 0.001 e $^{0.36T max}$	0.084 0.002	0.610	0.39

The relationship between the weather parameters and fruit production of citrus and mango is depicted in Table 5. Weather parameters such as rainfall (RF) exhibited a negative effect on mango production i.e. there was a significant fall in the mango production with the decrease in rainfall. However, the mango production was positively influenced with maximum temperature and minimum temperature i.e. with the increase in maximum temperature and minimum temperature then mango production was also increased. In case of citrus production, minimum temperature shows negative impact and other parameters but maximum temperature and rainfall indicate positive impact on production of citrus crop. It means maximum temperature and rainfall increases with increased citrus production.

Table 5: Multiple regression equation of weather parameters and fruit production.

Crop	Equation	SE (βi)	$\overline{R^2}$	R^2
Mango	MP = -595.55 + 13.17 T_{min} + 17.14 T_{max} – 0.01 RF	253.22 17.86 5.81 0.034	0.379	0.522
Citrus	CP = -307.37 – 1.94 T_{min} + 12.63 T_{max} + 0.004 RF	105.14 7.41 2.41 0.014	0.672	0.748

Where, **MP** = Mango Production; **CP** = Citrus Production; $\mathbf{T_{max}}$ = Maximum temperature; $\mathbf{T_{min}}$ = Minimum temperature; **RF** = Rainfall; **SE (β_i) =** Coefficient of standard error; $\mathbf{R^2}$ **=** R squared; $\overline{R^2}$ = Adj R^2

During the evaluation of the effect of weather parameters on mango and citrus production, it was observed that most of the weather parameters had no substantial impact on citrus production as seen in (Table 5). However, the multiple or composite weather parameters showed weak influence on the production of mango as shown in Table 5. The results revealed that rainfall had a negative effect on the mango crop production because of the occurrence of stress conditions due to low rainfall. On the other hand, rainfall and high temperature is also necessary for plant growth and better fruit quality. The related effects were also observed by Rachel *et al.* (2014), who observed that crop production had significant and non-significant correlation and regression with weather parameters.

Maximum temperature and minimum temperature showed a positive impact on mango crop production. Increase in temperature resulted in an increase in mango fruit production. The results indicated that temperature is a major factor in the subtropical regions for the crop growth and production. However, Una district is a subtropical warm region so temperature plays a key role in production of fruits. Similar findings were reported by Abobatta (2019) who observed that temperature plays a main role in citrus cultivation, which means citrus crop growth and yield is deeply

associated with temperature. The temperature below 10°C adversely affects the metabolism activity, reducing the new growth of citrus trees, but if temperature rises above 35°C, it may improve the fruit quality at maturity and can increase fruit production. Also, Sobrinho *et al.* (2004) estimated that mango yield was directly influenced by temperature, they observed fruit production in all four directions of mango farm, South – West direction had maximum mango production (59.11 kg per tree) while North-West direction had minimum mango production (45.41 kg per plant). Their findings revealed that the South – West direction received more sunlight and in turn the temperature remained higher than in North – West direction and the canopy of plants took less amount of temperature and solar radiation which caused reduction in the mango production and indicated that temperature is directly proportional to fruit production. On the other hand, rainfall had a weak and negative impact on mango production. The results are in accordance with the findings of Parmar *et al.* (2012) who reported that rainfall negatively correlated with mango production while temperature reduction of 2°C had influenced flowering, fruit quality and mango production.

CONCLUSION

It can be concluded that weather parameters *viz.*, maximum temperature minimum temperature and rainfall influence fruit production. The regression models fit well for weather parameters and production of mango and citrus crops. The multiple linear regression analysis revealed weakly positive significant relationship between fruit production and weather parameters in case of mango whereas, in citrus it shows positively significant value. In individual regression models as well as multiple linear regression model, equations fit in the fruit production to the optimum level. Correlation coefficient of fruit production exhibited significant correlation with maximum temperature.

Therefore, further consistent observations on changes in weather parameters and their effects on the production of horticultural as well as agricultural crops are of paramount importance.

Conflict of Interest. Nil.

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