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Role of Major Weather Parameters in the Production of Black Pepper in Kerala

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The present study intends to analyse the influence of weather parameters on the production of black pepper in six major pepper producing districts of Kerala, the Indian state which contributes a considerable share to national spice exports.
Methodology: This research is based on secondary data which is limited to six major black pepper producing districts of Kerala which were chosen based on their contribution to total production of the state 2020. More than 50% of the production was from Idukki district followed by Wayanad (8%), and around 3 to 3.5% from Kannur, Kasargod, Kottayam and Kollam districts respectively. Annual precipitation, Relative humidity, Maximum and Minimum temperatures were the parameters taken into consideration along with production data of over 15 years (2005-2019) which was then subjected to regression analysis using panel data.
Results: According to the results, significant reduction in production by 2.52% and 1.88% was recorded for unit increase maximum (P= 0.047) and minimum temperature (P=0.03) respectively. Likewise, unit rise in relative humidity and rainfall was responsible for decrease
In production by 1.1%, and 0.07% respectively though they were reported to be insignificant.
Conclusion: From the present study, it could be concluded that maximum and minimum

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temperatures were found to be significant in affecting the production of black pepper. However the negative regression coefficients obtained for other factors like rainfall and relative humidity implied its negative effect on production. In order to combat these variations, there is therefore, the need to create awareness to farmers in India on the need to adopt best farming practices in order to improve yield of this important crop.

Keywords: Black pepper; panel data; regression analysis; weather parameters.

1. INTRODUCTION

Black pepper *(Piper nigrum)*, the king of spices, also referred to as "black gold" is a tropical plant that thrives in humid climate and requires sufficient amount of rainfall for its growth and optimum production. The spice had its origin in the Western Ghats of Southern India from where the production extended to different parts of the globe. It also holds immense value in trade as an essential component responsible for the pungency and its medicinal benefits is in high demand world-wide. Kerala, one among the largest producers of the crop produced nearly 20,000 metric tonnes of black pepper from 83,000 hectares following Karnataka which stand first producing, about 30,000 tonnes from 40,000 hectares in 2020. Idukki district of Kerala alone produced more than half of the state's total production while Wayanad contributed around 8%. The share of Kannur, Kasargod, Kollam and Kottayam districts in total production was 3.47%, 3.41%, 2.09% and 2.95% respectively. Being a plant of tropics, it is obvious that the microclimate surrounding it would exert a large influence on its yield. As per ecology of the crop, there are optimum ranges of temperature, rainfall and other weather parameters which it can withstand without any adverse effects.

Considering the topography, Black pepper attains good growth between 20^0N and 20^0S of the Equator which mainly covers the southern part of India and other continents like South America and South Africa. Right from sea level, it can grow well upto 1500 metres above mean sea level. In fact higher elevations favour the growth of pepper vines. Healthy plants can be noticed when grown on lateritic soils where the soil temperature stays between 26^0C and 28^0C. Black pepper vines thrive well in temperatures between 23^0C and 32^0C while 28^0C remains the favourable. The maximum temperature that could be tolerated by the crop is 40^0C while it can withstand up to a minimum of 10^0C. Higher levels of solar radiations would make the plant susceptible to many physiological disorders because partial shade remains the prime requisite of the crop ecology [1]. Inspite of that, increase in maximum and minimum temperatures adversely affect the black pepper production in Wayanad district of Kerala [2]. However, the state did not experience extreme weather variations on a regular basis during the period of 1954-2003 [3]. Being a crop of tropics, both precipitation and relative humidity revolves around larger values. As far as the production and productivity of black pepper is concerned, total rainfall and its distribution is critical. Annual rainfall of 2000 to 3000 mm with uniform distribution and a humidity of 60-95% are the optimum ranges demanded by the crop. A consistent distribution of 2000 mm rainfall in a year is desirable for the crop while any dry spells during critical periods will lead to poor yields [4]. The crop thrives well in tropical temperatures and high relative humidity, with little change in day length throughout the year. It is sensitive to extremes of heat and dryness. Flowering of vines start during May-June when slight rains occur for a minimum of 20 days. Flowering of black pepper gets hampered with delay in the onset of South West monsoon. The showers should be regular until the berries ripen. This period between flowering and ripening is reported to be critical and during the advanced stages of berry growth, strong rainfall or an extended period of drought would result in spike shedding and reduced yield which revealed that the crop is very weather sensitive. Hence there is a need to assess production behaviour of black pepper to changes in weather parameters like annual rainfall, relative humidity, maximum and minimum temperatures.

2. MATERIALS AND METHODS

The present study was conducted using secondary (panel) data collected for production of black pepper and four different weather parameters (rainfall, maximum temperature, minimum temperature and relative humidity) in six major pepper producing districts of Kerala. Districts for the study were selected on the basis of their contribution to total pepper production of the state during 2020. Analysis was carried out using 15 years of data (2005-2019). The work relied on Water Resources Information system (WRIS), Government of India for rainfall data on an annual basis [5]. The data on climatic variables were collected from NASA's data access portal on an annual frequency as production was analysed on yearly basis [6]. Finally production data was retrieved from Directorate of Economics and Statistics portal, Government of Kerala during the period of study [7].

2.1 Tools of Analysis

In this study, production of black pepper in sample districts of Kerala was taken as the dependent variable while annual precipitation, relative humidity, maximum and minimum temperatures were considered as the independent variables. In total, the dataset had 450 observations with 15 years, 6 districts and 5 variables. Analysis was done using the natural logarithmic form of variables in order to avoid wide fluctuations. Fixed Effect Model (FEM) and Random Effect models (REM) were the econometric models employed which was run using statistical package STATA and the suitable model was chosen based on the significance of Chi- squared statistic obtained from Hausman specification test. The panel data regression here assumes that production is dependent on the climatic parameters that prevailed over the previous years and it can be functionally represented as shown.

i.e, Production = f (weather parameters)

2.1.1 Fixed Effect Model

A fixed effect model examines individual differences in intercepts, assuming the sameslopes and constant variance across individual entities. Generally, within group estimation is carried out and the model can be specified as given below.

$$Y_{it} = (\alpha + u_i) + \beta X_{it} + e_{it} \text{ -------------------- [1]}$$

Where, Y_{it} = Dependent variable (Production in tonnes)
X_{it} =Independent variables (Weather parameters)
I = Number of cross-sectional units (Districts)
T = Time period (years)
A = Intercept
B = Coefficients of corresponding regressors
u_i = A fixed effect specific to a district or time period
e_{it} = Error term

2.1.2 Random Effect Model

A random effect model assumes that individual effect (heterogeneity) is not correlated with any regressor and then estimates error variances which are randomly distributed across entities or time period. Here, The intercept and slopes of regressors remain same across individual entities and the model can be specified as given below.

$$Y_{it} = \alpha + \beta X_{it} + (u_i + e_{it}) \text{ ---------------------[2]}$$

Where, Y_{it} = Dependent variable (Production in tonnes)
X_{it} = Independent variables (Weather parameters)
I = Number of cross-sectional units (Districts)
t = Time period (years)
α = Intercept
β = Coefficients of corresponding regressors
u_i = A fixed effect specific to a district or time period
e_{it} = Error term

2.1.3 Tests to differentiate Fixed and Random Effect Models

Selection of the best fit model was done based on the chi-squared statistic obtained from Hausman specification test. Modified Wald test and Wooldridge tests were conducted to check the presence of heteroskedasticity and serial correlation respectively in the fixed effect models. (Appendix)

3. RESULTS AND DISCUSSION

There are average and optimum ranges for temperature, rainfall and relative humidity which the vines could tolerate beyond which there can be substantial loss in the yields. Larger deviations from the mean was found to affect the yield adversely. The Tables 1 and 2 given below respectively shows the descriptive statistics for the initial data and data after logarithmic conversions for both dependent and independent variables for the period under study. From Table 1, it can be found that over the period of 15 years, maximum values for production and maximum temperature were found for Idukki (2006) and Wayanad (2016) districts respectively while Kasargod district showed higher values for rainfall (2006) and minimum temperatures (2019). Lowest production for the study period was for Kollam district in 2018 while minimum values for rainfall (2016), maximum and minimum temperatures (2008) was observed for Wayanad district. At the same time Kottayam district was highly humid (2005) while lowest humidity was reported in 2016 for Wayanad district.

The trend in the production as well as the weather parameters from 2005-2019 in all the sample districts are presented in the figures 1-5 given below. Fig. 1 shows the trend in production while 2, 3 and 4 shows the trend of rainfall, maximum and minimum temperatures over the time period. From Fig. 1, it is obvious that Idukki district remains exceptionally high in production, while other figures however shows similar patterns in fluctuations. A substantial dip in relative humidity was observed for Wayanad in the year 2016 as it could be seen in Fig. 5.

Table 1. Descriptive statistics for all the variables considered for the study

Sl no	Variable		Mean	Standard deviation	Minimum	Maximum	Observations
1	Production	Overall	6656.811	10170.98	836	52063	N = 90
		Between		10169.23	1302.4	27187.33	N = 6
		Within		4037.674	-5494.522	31532.48	T = 15
2	Rainfall	Overall	2640.586	953.502	926.73	4942.72	N = 90
		Between		811.819	1739.733	3818.773	N = 6
		Within		594.800	972.293	3764.534	T = 15
3	Max.temp	Overall	28.923	0.559	27.85	30.51	N = 90
		Between		0.337	28.47	29.328	N = 6
		Within		0.465	27.83	30.704	T = 15
4	Min. temp	Overall	22.964	2.714	18.73	26.92	N = 90
		Between		2.941	19.377	26.54	N = 6
		Within		0.272	22.316	23.591	T = 15
5	RH	Overall	77.739	2.455	68.97	82.23	N = 90
		Between		2.071	75.13	79.934	n = 6
		Within		1.553	71.57	82.417	T = 15

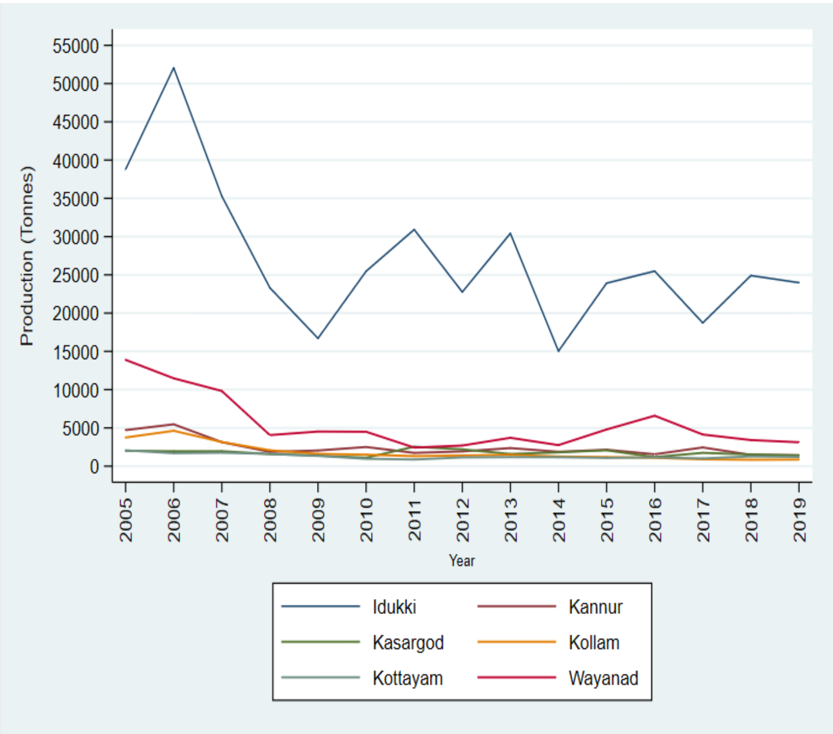

Fig. 1. Pattern of production over 2005-2019 period

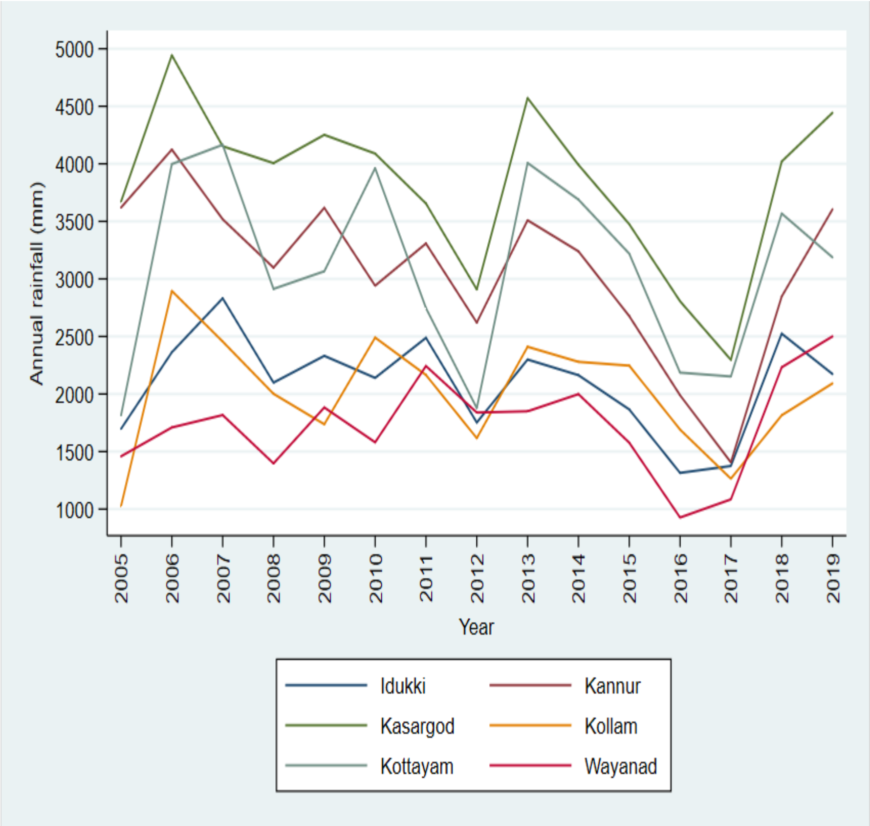

Fig. 2. Pattern of rainfall over 2005-2019 period

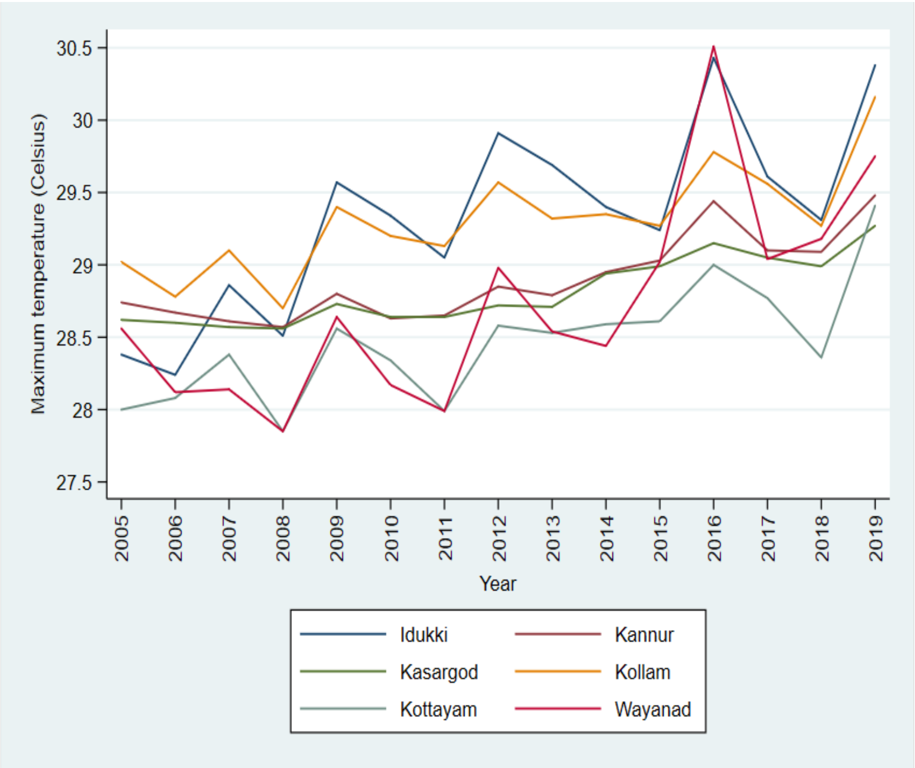

Fig. 3. Pattern of maximum temperature over 2005-2019 period

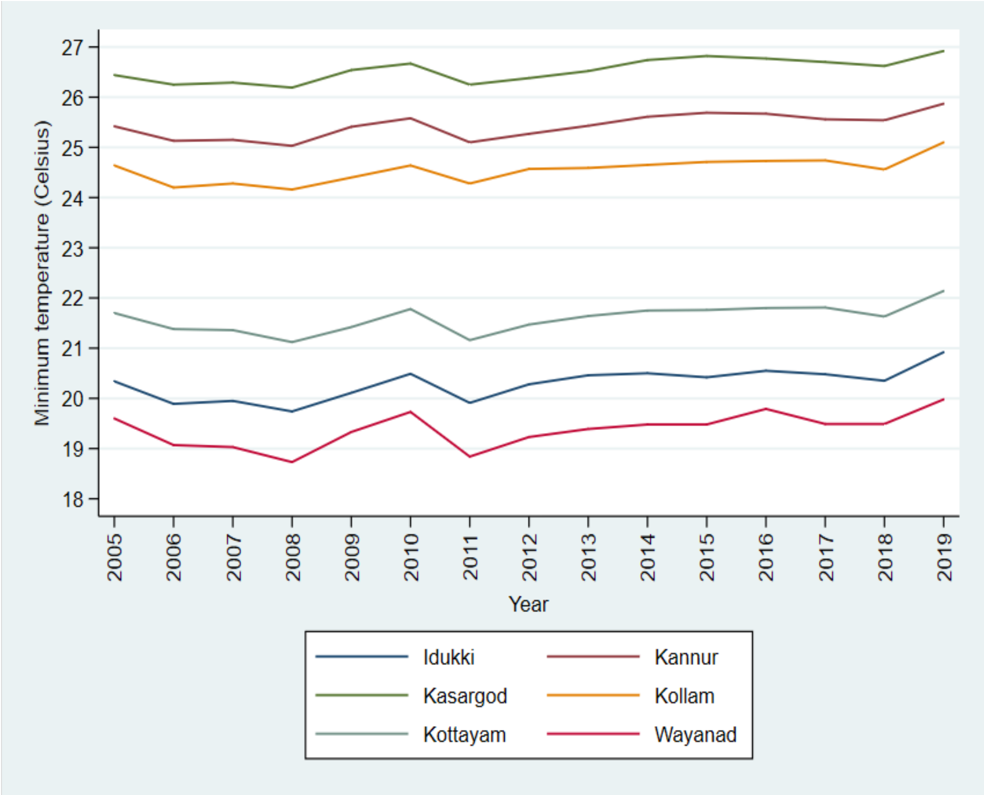

Fig. 4. Pattern of minimum temperature over 2005-2019 period

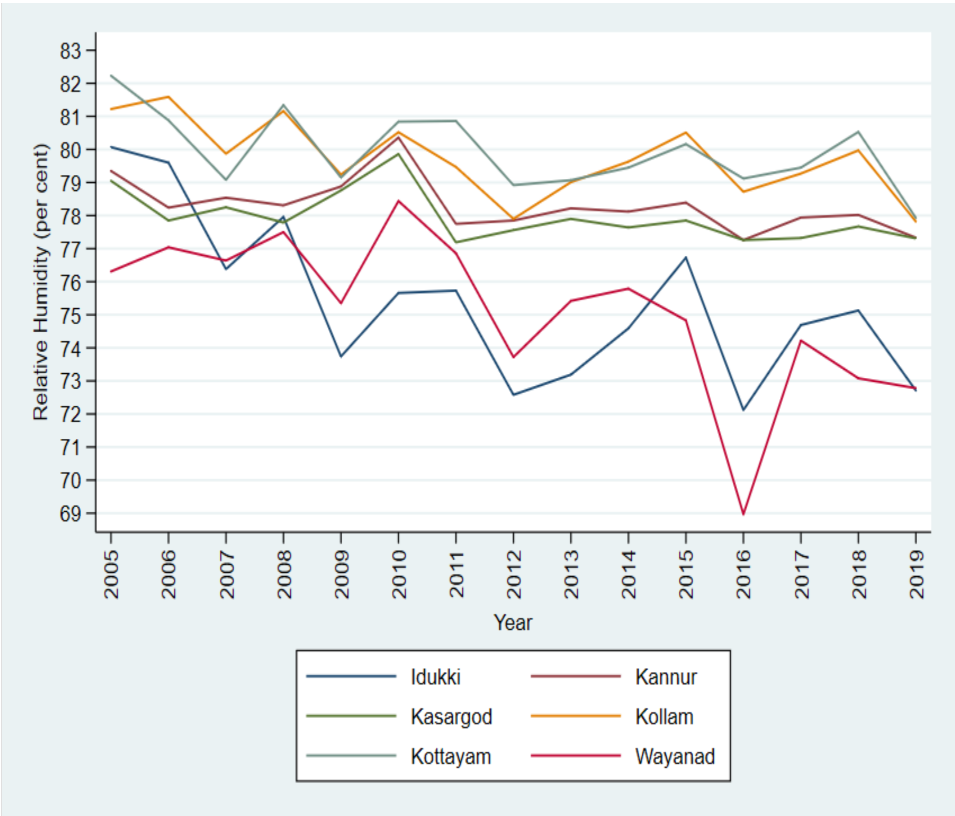

Fig. 5. Pattern of Relative Humidity over 2005-2019 period

Random Effect model was selected to analyse the results obtained from panel data regression, considering the inferences from Hausman, Wald and Wooldridge tests which was estimated and presented in Table 2. As given in the table, Wald test showed the heteroskedastic nature (*P*=0.0000) of Fixed Effect Model (FEM), which would violate the important assumption of OLS that the residuals are drawn from a population with constant variance. Likewise, Wooldridge test detected the presence of autocorrelation (*P*=0.0245) in FEM indicating that error for one time period is correlated with the error for a subsequent time period. Hence, random effects was fitted to the data for further analysis.

3.1 Role of Weather Parameters on Black Pepper Production

It could be observed from Table 2 that the probability value of 0.0693 for Chi-squared was greater than 5% which enables the selection of Random Effect Model to elucidate the influence exerted on the production of black pepper by the weather parameters. Table 3 clearly indicates that over the period of 15 years, the impact of minimum temperature on production was significant. However, among the insignificant parameters, all the three had negative coefficients which implicated an inverse relationship between dependent and independent variables as it is evident from the same table. As a considerable non significance was observed in the case of Relative humidity, REM was run again eliminating RH which turned maximum temperature to become significant and the results are as presented in Table 4. Table 5 shows the percentage change in production with reference to changes in climate based on the conversion of logarithmic coefficients.

3.1.1 Temperature and production

The present study clearly pointed out that maximum and minimum temperatures exhibited greater impact compared to annual rainfall and relative humidity. As per the crop ecology, both fairly high temperature as well as partial shade is demanded by the crop for the best growth of vines. Besides this fact, it is obvious that beyond a temperature range recommended or the growth of a crop, excess heat would increase transpiration loss causing the plants to wilt. Idukki and Wayanad districts witnessed a near eradication of black pepper cultivation due to severe summer conditions of 2003 and 2004 [8]. Adoption of good agronomic practices like proper reflective mulching and watering can offset the decline in productivity caused by high temperatures [9].

Table 2. Tests to make choice out of fixed and random effect models

Sl no	Tests	P value	Inferences
1	Hausman test	0.0693	Random effect is preferred
2	Modified Wald test	0.0000	Presence of Heteroskedasticity
3	Wooldridge test	0.0245	Presence of Autocorrelation

Table 3. Random Effect Model I (2005-2019)

Sl No	Particulars	Coefficient	Standard error	*P*-value
1	Intercept	57.071	41.559	0.170
2	Rainfall	-0.155	0.202	0.443
3	Max. temp	-6.582	7.060	0.351
4	Min. temp	-4.650**	1.579	0.003
5	RH	-2.555	4.937	0.605
6	R^2	0.319		
7	Wald Chi^2	22.36		
8	Prob> Chi^2	0.0002		
9	No. of observations	90		
10	No. of groups	6		
11	Observations per group	15		
12	Hausman t test (prob>Chi^2)	0.0693		

*(** indicates the 5 per cent level of significance)*

Table 4. Random Effect Model II (2005-2019)

Sl No	Particulars	Coefficient	Standard error	*P*-value
1	Intercept	42.727	9.552	0.000
2	Rainfall	-0.147	0.169	0.383
3	Max. temp	-5.892**	2.970	0.047
4	Min. temp	-4.381**	2.165	0.043
6	R^2	0.276		
7	Wald Chi^2	14.85		
8	Prob> Chi^2	0.002		
9	No. of observations	90		
10	No. of groups	6		
11	Observations per group	15		
12	Hausman t test (prob>Chi^2)	0.995		

*(** indicates the 5 per cent level of significance)*

Table 5. Effect of changes in weather parameters on production (2005-2019)

Sl no.	Unit rise in weather parameter (in per cent)	Corresponding decline in production (in per cent)
1	Maximum temperature	2.52
2	Minimum temperature	1.88
3	Rainfall	0.07

4. CONCLUSION

From the present study, it could be concluded that maximum and minimum temperatures were found to be significant in affecting the production of black pepper. Unit rise in maximum temperature reduced the production by 2.52% while, a decline in production by 1.88% was observed for unit rise in minimum temperature. However the negative regression coefficients obtained for other factors like rainfall and relative humidity implied its negative effect on production. It was observed from the study that the cultivation of black pepper faced a knock down in major producing areas in Kerala especially Idukki and Wayanad districts due to aberrations in weather conditions. Moreover, production plummeted down by 1.1% and 0.07% for unit rise in relative humidity and average annual precipitation respectively. Excess run off during heavy rainfall and severe infestation of pests and diseases at higher levels of atmospheric humidity would be the visible negative effects. In order to combat these variations, there is therefore, the need to create awareness to farmers in India on the need to adopt best farming practices in order to improve yield of this important crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Tests Employed to Choose between Fixed Effect and Random Effect Models

Hausman specification test

The Hausman test was employed to detect any endogenous explanatory variable if present. Such a presence would violate one of the important assumptions of Ordinary Least Squares (OLS), which assumes that the error term and predictor variable are in no way correlated. The hypotheses can be stated as follows.

H_0: The preferred model is random effects
H_1: The preferred model is fixed effects

The null hypothesis is rejected if the *P* value based on chi-squared statistic is significant and is accepted otherwise.

Modified Wald Test

This test estimates modified Wald statistic for group wise heteroskedasticity in the residuals of a Fixed Effect regression model. The null hypothesis here states that the variance remains constant for all cross sectional units. Results were inferred based on the distributed chi-squared value so as to confirm the usage or rejection of the model.

Wooldridge Test

This test was used to detect the presence of auto correlation in the data when FEM was fitted. Null hypothesis in Wooldridge test states that there exist no serial correlation among the residuals of subsequent time periods. According to the test, significance of the p value based on F statistic indicates autocorrelation.

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