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A Statistical Analysis on Paddy Crop Production in Southern Punjab, Pakistan

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ABSTRACT

Background: Paddy is an important staple food crop of Pakistan and plays a vital role for the economy of Pakistan. Paddy provides more than two million tons for food requirements after wheat in Pakistan.

Objectives: The main objective of current research was to identify the factors affecting the paddy crop yield in Lodhran district, Pakistan.

Methods: The secondary data of paddy crop production of fifteen villages from 10 years (2005-2014) were collected from Crop Reporting Service, Lodhran district through simple random sampling. Multiple regression models and Durbin Watson (DW) test were used for data analysis.

Results: The results showed ten independent variables were found statistically significant and had strong impact on paddy crop production. These were seed type, seed quantity, DAP used, Urea used, other fertilizers used, number of watering, number of ploughs, number of leveling) and average humidity. These all factors were having p-value 0.000 which is highly significant ($p < 0.01$) in terms of the influence they put on the crop production. Average temperature (p-value of 0.057) was also significant at $p < 0.05$ level of significance. Whereas crop area and average rainfall were not significant statistically. Moreover, the model applied is statistically significant as various statistical checks including R^2, adjusted R^2, Durbin Watson test, mean square error, P-value and VIF were applied to test the fitness of the model and for the multicollinearity.

Conclusions: The study concluded that several factors such as seed type, seed quantity, DAP, urea and other fertilizers, number of watering, levelling, plough, average temperature and humidity have been a profound impact on the paddy crop yield of the study area. The subjective variables (average temperature and humidity) during cropping period were better in forecasting of paddy crop yield and the model is suitable to estimate the paddy crop yield in district Lodhran.

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1. INTRODUCTION

Agriculture is believed to be the key sector of the economy of Pakistan which depends mainly on its major crops. Agriculture directly affirms the masses of the country and share about its 26% of Gross Domestic Product (GDP). Some important agricultural crops of the cuntry are wheat, rice, sugarcane, cotton, fruits

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and vegetables. The agricultural sector in Pakistan is facing serious obstakles like climatic risks (Saqib et al., 2018a), resousres mismanagemnet, technological flaws, less invesment ratio, trade issuses of agriculture energy shortage, etc. (Ali et al., 2020). Paddy is an important staple food crop of Pakistan and plays a vital role for the economy of Pakistan. Paddy provides more than two million tons for food requirements after wheat in Pakistan. It is also essential tool of employment and income generation for rural areas. However, in Pakistan, the rice production is decreasing (Rehman et al., 2017). The country's majority of the populations live in the rural areas and they are mostly relying on the agriculture. The industries of agriculture provide employment and helpful in earning foreign exchange to reduce poverty. The maximum food security targets can be achieved by sound polices which are based on empirical statistics. According to Pakistan Bureau of Statistics for the period of 2013-2014, the total area of Pakistan is 79.61 million hectors only 27.72% (22.07) million hectors is cultivated, 10.38% (8.27) million hectors is culture able waste, 5.71% (4.55) million hectors is under forest and 46.28% (35.92) million hectors is uncultivable area (Bhatti, 2015). In many studies, various statistical techniques have been applied on the production of agriculture crops by different authors. Sarker et al. (2012) and Hasan et al. (2016) undertaken their studies to assess the impact of main climatic variables temperature (maximum and minimum) and rainfall on three major rice varieties which are Aus, Aman and Boroa. They obtained the data for the period of 1972-2009 at an aggregate level. They used ordinary least squares and median regression methods.

Agriculture and its production are highly prone to the serious environmental and climatic dangers (Saqib et al., 2016b; Saqib et al., 2016c), which highly influences this sector. Climatic events i.e. extreme temperature perhaps are more severe to the agricultural crops (e.g., rice) in countries like Pakistan and these crops are at risk to different natural hazards like floods, heat waves and droughts (Ashraf, 2019; Chandio et al., 2019; Chandio et al., 2020b; Rehman et al., 2019). Janjua et al. (2021) describes the loss to yield of rice due to seasonal changes of climate which is estimated to the fiscal value of PKR 27.79 billion about 222.30 thousand metric tons of rice in single rice season in the main rice growing districts (Layyah, Jhelum, Gujrat, Guranwala, Kasur, Chiniot etc) of Punjab province. He et al. (2019) found that crops like rice require particularly an explicit temperature as its nourishment gets greatly affected by the variations in temperature. Maya et al. (2019) conducted a study in Khulna, Bangladesh using Binary logistic regression to investigate the impact of climate on rice production. They concluded that 97% farmers were argued that decreasing rainfall had reduced the production of rice.

Qayyum and Pervaiz (2010) studied the rainfall impact on the wheat's yield in Punjab, Pakistan using quadratic model for the wheat crop production estimation in the province. Hamjah (2014) utilized the ARIMA model to ascertain the rice productions in Bangladesh throughout the country. Kaloo et al. (2014) found the dropping trend in production and area of paddy rice by using ordinary linear regression (OLS) analysis to interpret the impact of time on production of rice. Shah et al. (2014) verify the yield anomaly of various crops in Bahawalpur district of Punjab province by using two stages systematic sampling technique and proved it more efficient technique amongst many others. In a recent study conducted by Shah et al. (2020b) found that fertilizers like DAP and Urea and disease attack were the significant determinants of rice crop. Likewise, Shah et al. (2020a) conducted a study in District Bahawalpur to find out the different factors affecting of agricultural crops. Multiple Linear Regression models (MLRM) were applied and results revealed that factors such as the plough and rotavator number, planking, irrigation, seed type, seed treatment, DAP and urea fertilizer, farmyard manure, latest varieties, certified seed, weed spray, diseases and pests' sprays are found to be contributing factors to a higher yield of all crops. It is also evident that among various agronomic practices i.e., the fertilizer quantity of directly influence the rice production (Ali et al., 2021a). The Government of Pakistan is also keen to keep the agriculture on top priority sector (Saqib et al., 2016a) and subsidising it time by time by launching various concessional programs including interest free loan, subsidy on crops inputs, and provision of technical and monitory guidance to the farmers. Therefore, the objective of current research was to identify the factors which are affecting the yield of paddy crop in Lodhran district, Pakistan.

2. METHODS

2.1 Study design

For this cross-sectional study, a case study design was used. Using quantitative approach, both descriptive and inferential analysis methods were employed.

2.2 Setting

Pakistan is an agrarian country with agriculture as a leading sector of the economy (Saqib et al., 2016b). Paddy is amongst the largest crop of the Lodhran district. In current study, the secondary data about paddy yield of 10 years (2005-2014) from 15 villages obtained. The data mainly retrieved from the office of the Assistant Director (Statistics), Crop Reporting Service (CRS) of the district Lodhran, Punjab, Pakistan).

2.3 Data sources and measurement

Crop Reporting Service (CRS), Agriculture Department Punjab is collecting data from fields for both Rabi and Kharif season through professional field assistant/crop reporters. CRS is also estimating the area and production for all major and minor crops through acreage survey and yield estimation survey in sample villages across Punjab. Different grower's opinion and cost of production surveys for all major crops are carried out including cotton, rice and wheat in order to determine the future trend, pattern and trajectory of these crops as well as per acre cost.

It is notable that R^2 (coefficient of determination) and adjusted R^2 provide the information of data points fall within the line of the regression equation. The adjusted R^2 indicates the share of deviation or variation explicated by independent variables effective on the dependent variable (Shah et al., 2020a). If R^2 is nearer to 1, it means that the independent variables can jointly explain the variation in Y. This means Y can be accurately predicted using the independent variables (Montgomery, 2003).

2.4 Sampling

The data of paddy crop yield is taken from the 15 villages of district Lodhran. These villages randomly selected as sample areas by using simple random sampling to collect the data from field. The village selection as a sample is done with the aid of the Field Assistants of the Crop Reporting Service (CRS) of the district Lodhran those have a considerable potential of paddy crop cultivation and yield output.

2.5 Description of the model and study variables

Regression analysis is important to obtain efficient estimations for crop yield while crop yield is based on climatic factors i.e., rainfall or temperature (Konijn et al., 1988). As a result, regression analysis was utilized in this study to estimate the effects of temperature and humidity on paddy rice yield. When it comes to verifying the knowledge regarding an independent dependent variable's relationship, regression analysis is critical. The goal of regression analysis was to define the relationship between the dependent and independent variables. A model with numerous independent variables is known as a multiple regression model. The model is given by the following equation:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon, \quad (1)$$

where βo, β1, …, βn are the regression model unknown parameters (coefficients) and ε shows the error term or stochastic disturbance term or residual. The suggested model is given as in the equation (2):

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_{12} x_{12} + \varepsilon, \quad (2)$$

where dependent variable y_i is the paddy production in *mounds* (40 kg in one mound) per acre, β_0 is the intercept term, β_i is the measure of change in rice yield, and ε is the error term. The independent variables are given in Table 1.

Table 1. Description of Independent Variables

X_1	Crop area in kanals*
X_2	Seed type (0=Home and 1= Certified)
X_3	Seed quantity in kg
X_4	DAP used in kg
X_5	Urea used in kg
X_6	Other fertilizers used in kg
X_7	Number of watering
X_8	Number of plough
X_9	Number of leveling
X_{10}	Average rainfall
X_{11}	Average temperature
X_{12}	Average humidity

Note: *One kanal= 605 square yards or 20 *Marla* (1 Marla= 272 km^2)

2.6 Data analysis methods

Developing a linear regression model is just half of the work. So that be usable in practice, the model should far away from some problems of linear regression including autocorrelation, multicollinearity, etc. Over consecutive time intervals, the resemblance of time series is defined as autocorrelation problem in regression analysis. It reasoned underestimations of the standard error and can root to think independent variables are significant when they are not. The Durbin Watson (DW) test is the suitable test to measure the autocorrelation in residuals from regression analysis (Tanwar et al., 2021). The DW test indicates for a specific type of serial-correlation, the AR (1) process. Note that the lag is one time unit for a first order correlation. The DW test gives value from 0 to 4. The value 2 shows no autocorrelation; the values from 0 to 2 provides positive autocorrelation and DW>2 to 4 presents negative autocorrelation.

The variance inflation factor (VIF) shows the severity of multicollinearity in multiple regression analysis. This index is used to measure how much the variance of an estimated regression coefficient increases due to collinearity. Generally, it is inferred that if VIF exceeds 4, while VIF exceeding 10 are the indication of serious multicollinearity requiring rectification.

3. RESULTS

3.1 Paddy crop yield affecting factors

Results show that, in the model, the dependent variable was considered the yield of paddy field per acre in mounds. The histogram in Figure 1 shows the normality of the data and the linearity is explained by probability-probability (p-p) plot in Figure 2. As seen in Figure 1, the paddy data is nearly symmetric.

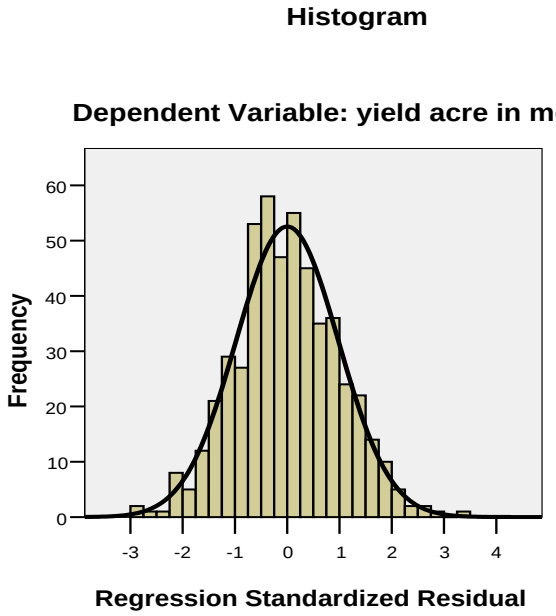

Figure 1 Histogram of the paddy production

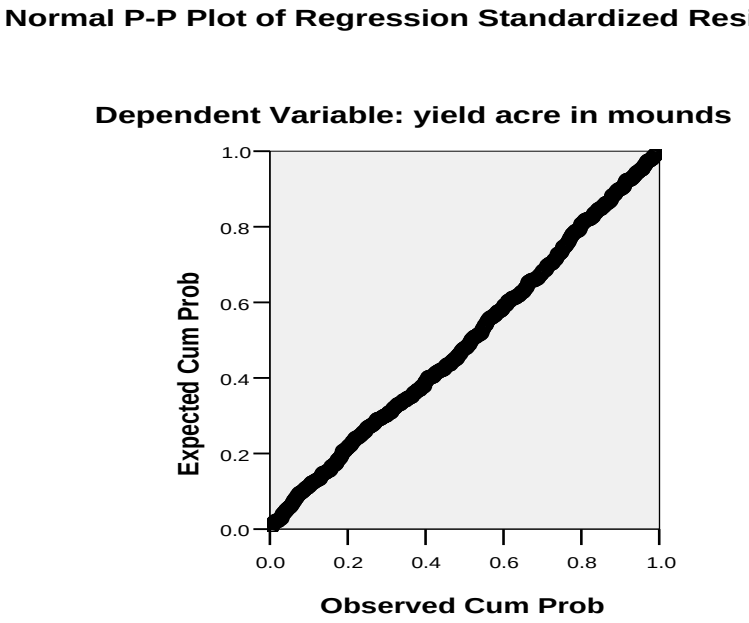

Figure 2 p-p plot for the paddy production data with normal curve

Figure 3 illustrated the dependent variable's constant behavior and shows that the paddy yield is evenly dispersed throughout the sampled data. Table 2 gives the result of multiple regression analysis for the paddy production in district Lodhran, Pakistan and shows the 10 statistically significant independent variables with a P-value at the level of 0.05. These certain factors have significantly impacted on paddy crop production. These were X2 (seed type), X3 (seed quantity), X4 (DAP used), X5 (Urea used), X6 (Other fertilizers used), X7 (number of watering), X8 (number of plough), X 9 (number of levelling) and X12 (average humidity). These all factors were having p-value 0.000 which is highly significant ($p < 0.01$) in terms of the influence they put on the crop production. X11 (average temperature) had the p-value of 0.057 which is also significant at $p < 0.05$ level of confidence. Whereas the X1 (crop area) and X10 (average rainfall) were not significant statistically with p-values of 0.925 and 0.439 respectively.

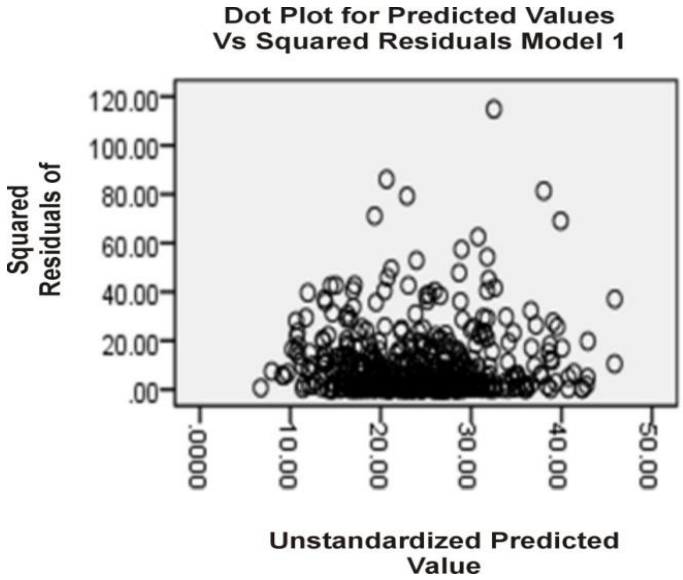

Figure 3 Predicted values versus squared residuals model for the paddy production

Further, it depicts that the standard errors of all variables are less than one and also shows the stability in the dependent variable. The VIF values with less than 10 of all variables indicate designate there is no problem of multicollinearity in the independent variables (Table 2). Then, the statistical checks were applied to test the fitness of the model including R2, adjusted R2, Durbin Watson test, Mean square error, P-value and VIF for the multicollinearity. The summary of the model is presented in Table 3. Figure 4 shows the observed and predicted yield of paddy crop in the district per acre in *mounds* (I mound is equal to 40 kg) and modelled variations over the time.

Table 2 Summary of the multiple regression model for the paddy production in Lodhran district

	Model				Collinearity Statistics	
Constant	Coefficient	Std. Error	T	Sig.	Tolerance	VIF
X_1	0.579	6.150	0.094	0.925	-	-
X_2	1.091	0.332	3.285	0.001*	0.886	1.128
X_3	0.517	0.111	4.640	0.000*	0.729	1.371
X_4	0.077	0.006	12.455	0.000*	0.769	1.301
X_5	0.068	0.006	12.285	0.000*	0.783	1.277
X_6	0.034	0.005	7.433	0.000*	0.804	1.244
X_7	0.388	0.054	7.232	0.000*	0.574	1.741
X_8	1.842	0.229	8.039	0.000*	0.587	1.703
X_9	1.425	0.296	4.806	0.000*	0.645	1.549
X_{10}	0.058	0.075	0.775	0.439	0.870	1.150
X_{11}	0.406	0.213	1.909	0.057**	0.756	1.323
X_{12}	-0.363	0.076	-4.758	0.000*	0.535	1.868

Note: ***** Significant at $p < 0.01$
****** Significant at $p < 0.05$

Table 3 Summary of model

	ANOVA					Explained Variation		Durbin-Watson
Model	Sum of Squares	Df	Mean Square	F	Sig.	R^2	Adjusted R^2	
Regression	23403.35	11	2127.58	168.83	0.000	0.786	0.781	1.955
Residual	6351.39	504	12.60	-	-	-	-	-
Total	29754.73	515	-	-	-	-	-	-

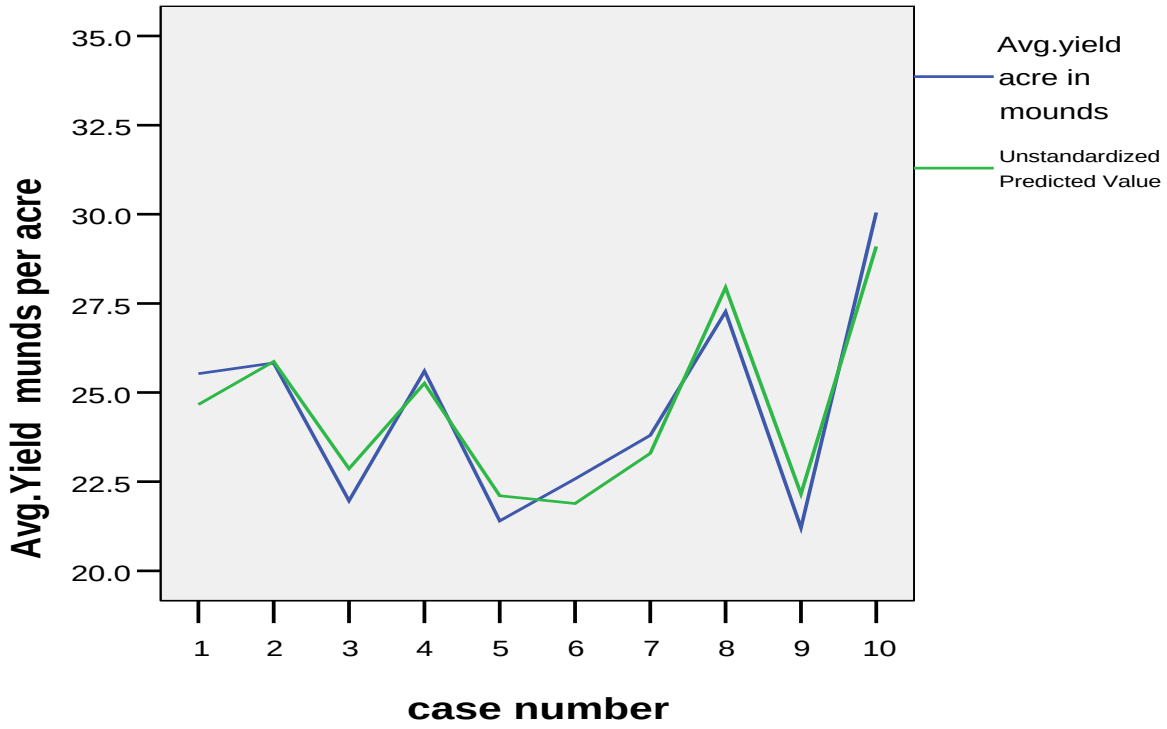

Figure 4 Observed and predicted yield of the proposed model

4. DISCUSSION

The purpose of this research was to identify the fcators affecting the paddy crop yield in Lodhran district, Pakistan. The fidnings revealed that ten (10) variables were found statistically significant and had strong impact on paddy crop production. These inlcuded seed type, seed quantity, DAP used, Urea used, other fertilizers used, number of watering, number of ploughs, number of leveling) and average humidity. Agriculture is the backbone of Pakistan's economy (Saqib et al., 2018b). Its developemnt can surely contribute in the development of economy.

Paddy crop is an important and one of the main staple crop in Pakistan and as well as in the study area district Lodhran, Pakistan. Current study used the multiple regression models for the paddy rice production in Lodhran district. Climate alone is considered a major affecting factor of paddy rice(Ali et al., 2017). Therefore, the main climatic variables i.e., the average temperature and humidity were the base of model during the crop period.

Crop area (X1) (p-value 0.000) is not found a considerable factor of paddy yield in the study area though it has an impact on yield (Ali et al., 2021a). Certified seed type (X2) and quantity (X3) (p-value 0.001 for each) can also enhance the production of crop as found by Shah et al. (2020b) and Iqbal et al. (2014) in their studies on rice and wheat. DAP (X4), Urea (X5) and other fertilizers (Manure) (X6) were also significant at (p-value 0.000) and these fertilizers significantly influenced the paddy crop production as investigated in various studies (Janjua et al., 2021; Mohsin et al., 2017; Nazir et al., 2013; Shah et al., 2020b). Though, the production of the fertilizers is not satisfactory in many developing countries including Pakistan because it is much expansive as well and less than the demand. Yet the supply of fertilizers even important for the better production (Manzoor et al., 2006). Therefore, the useful steps are being taken by the government to enhance the crop yields by directing the prices of fertilizers and pesticides (GOP, 2017). Number of watering (X7) (p-value 0.000) through irrigation is also a basic requirement for better crop production. About 70% cultivated area in Pakistan is irrigated but this sector is facing many challenges in order to provide sufficient irrigation facilities to the crops and orchards including the excessive shortage of water (Ali et al., 2021a; Chandio et al., 2020a; Javed et al., 2003). Number of plough (X8) and number of leveling

(X9) (p-value 0.000) of field are also an important factors which are essential for better yield of crop (Shah et al., 2020b). Average rainfall (X10) (p-value 0.439) was observed less significant in the yield of rice in the study area as it is found in a research that rainfall had a negative impact on agricultural production (Ali et al., 2021b). Average temperature (X11) (p-value 0.057) also significant for paddy yield as it found in a study that change in temperature can lessening the maturity time of the crop and thus ultimate reduction in yield (Ahmed et al., 2011). Average humidity (X12) (p-value 0.000) also had a profound impact on paddy yield in the study area. A recent study also reported that rising temperature during re-plantation period adversely influences paddy plant by lessening the plants number (Abbas & Mayo, 2021). Paddy crop requires a definite temperature for its growth which is greatly affected by variations in temperature (He et al., 2019).

5. CONCLUSION

The results of this descriptive study illustrate that all variables by behavior are according to specification of agriculture and ground realities of the field and past physical experience of the crops. On the basis of p-values at the level of 0.01 and 0.05 the significance of the variables and model were certified and multiple regression model was performed. The main climatic variables of the model e.g., the average temperature and humidity during the crop period were estimated using SPSS. This model is found to be significant. The diagnostic measure was applied to test the fitness of the model. All other measures (R^2, adjusted R^2, DW test, and VIF values) are also acceptable. The entire data is also probed by the projection behavior. The significant factors having a definite impact on paddy yield in study area were seed type, seed quantity, use of fertilizers like DAP, urea and other fertilizers (manure), number of watering, number of ploughs, number of levelling, average temperature and average humidity. Moreover, the suggested model which based on the subjective variables (e.g., average temperature and humidity) during cropping period is better in forecasting of paddy field. This study suggests the policymakers to prioritize the policies that could improve the paddy's cultivation in the country.

DECLARATIONS

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