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ORIGINAL RESEARCH ARTICLE



An analysis of area and production growth rate along with price forecasting of major pulses in Bangladesh

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ABSTRACT

Pulses are the most significant crops in the world, as well as in Bangladesh, for their commercial and nutritional importance. The study was carried out to determine the rate of expansion in area and production for several types of pulses such as Mosur, Mung, Mashkalai, Gram, and Khesari in Bangladesh, as well as to anticipate wholesale prices for those pulses. Secondary data from the Bangladesh Bureau of Statistics (BBS) and the Department of Agricultural Marketing were used in this study. Following a diagnostic check, such as R^2 , Adjusted R^2 , RMSE, AIC, BIC, MAE, and MAPPE, it was discovered that the Cubic growth model was the best for specified pulses. The data over the entire time revealed that total output in the area rose in the case of all pulses. Mosur and Mung had positive average production growth rates of 2.02 and 6.919 percent, respectively. Mashkalai, Gram, and Khesari experienced negative growth rates of -0.541, -8.894, and -0.854 percent, respectively. After computing the average percentage change for Area growth rate Mosur, Mung, and Mashkalai showed positive growth rates of 1.229, 4.631, and 1.152 percent, respectively. In contrast, Gram and Khesari both had negative average values of -7.719 and -1.987 percent. This study applied the ARIMA (0,1,0) (1,0,1) model for Mosur, ARIMA (0,1,2) model for Mung, ARIMA (2,1,2) model for Mashkalai, ARIMA (2,1,4) model for Gram, and ARIMA (0,1,0) model for Khesari since those models passed the diagnostic test. Forecasting findings revealed that Mosur, Gram, and Khesari wholesale prices would be marginally modified, while Mung and Mashkalai wholesale prices would be raised in 2025. Thus, analyzing the growth rates of area and output of key pulses may help farmers allocate their land more wisely and price forecasts will help farmers in identifying the best crops for their production, which will improve the output of these crops in Bangladesh.

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INTRODUCTION

Bangladesh is an agricultural-based and most densely populated country in the world. The population of Bangladesh in 2022 is 167,825,475, and the population density is 1290 per square kilometer, which was 997.29 per square kilometer in 2010

(Population, 2022). Approximately 75 percent of the population dependent on agriculture for their livelihood in Bangladesh resides in rural areas (BBS, 2020; Shahbandeh, 2020). The contribution of agriculture to Bangladesh's gross domestic product (GDP) was 12.92 percent (Neill, 2020). Crops are usually categorized into grains, spices, fibrous crops, fodder,

fruits, medicinal plants, roots, sesame and pulses, and stimulants and sugary crops (Crops, 2019). Rice, wheat, maize, potato, pulses, and oilseeds are the major food crops in Bangladesh. But pulses play an outstanding contribution to the protein requirement for rural people. Pulses are a crucial part of the daily meals of the people of Bangladesh, and the country's pulse needs are satisfied by both imports and domestic production (Das, 2016). By consuming only 56 grams of pulses, an adult can quickly fulfill his daily protein requirements. Food grains are deficient in amino acids and lysine whereas pulses are rich in both. Pulses, widely cultivated across the globe, including common bean, chickpea, lentil, cowpea, and mung bean, play a vital role in both developing and developed nations. These leguminous crops, found in Asia, Africa, and Latin America, contribute significantly to dietary diversity. Alongside their role in human nutrition, pulses also serve as a crucial element in animal feed (FAO, 2019). The collective global production of approximately 89.8 million metric tons of pulses in 2020 underscores their essential role in food security and agricultural sustainability (Sahabandeh, 2020). The dry bean production accounted for about 24 million tons, chickpea production for about 13 million tons, dry pea production for nearly 11 million tons, and cowpea production mainly was 7 million tons. The annual production of Mosur in the same triennium was estimated to be 5 million tons, while that of pigeon pea and Faba bean was about 4 million tons each (FAO, 2021). Within the Bangladeshi context, pulse cultivation is diverse, with crops such as Mosur and Khesari occupying significant areas and production volumes. The quantities of Mosur and Khesari produced in 2020 stand at 177,000 and 120,000 metric tons respectively and Mashkalai and motor are almost similar, more or less 35000 M. Tons (BBS, 2020). This landscape, however, is not static. Over the years, pulse prices have witnessed an upward trajectory. For instance, in 1986, wholesale pulse prices were below 2000 Tk per quintal. In 2021, the prices for Mosur, Mung, Mashkalai, and Khesari surpassed 10000 Tk per quintal (DAM, 2021). In the context of the growing global demand for chickpea pulses, there has been a burgeoning interest in understanding their economic importance (Merga and Haji, 2019). In India one studies revealed that all pulses showed significant growth in the case of the area, but gram and Urd showed a negative trend (Devegowda et al., 2018). A value chain analysis of Mosur in different districts of Bangladesh was conducted and researchers found that, Mosur production was profitable at the time (Hajong

et al., 2020). However, comprehensive research on price forecasting and growth rates of major pulses in Bangladesh remains limited. Although some studies have touched upon the area, production, and yield trends of pulses in the country, a comprehensive analysis is lacking (Uddin et al., 2015; Rahman and Baten, 2016). The scarcity of recent studies exploring these crucial aspects prompted the initiation of the current research. By filling this gap, the study aims to provide producers with a clearer understanding of resource allocation, potentially impacting sectoral awareness, technology utilization, and market engagement to ensure equitable benefits for producers. Therefore, the study's objective of comprehensively exploring the price forecasting and growth rates of major pulses holds significant potential to reshape the pulse production landscape in Bangladesh. By bridging the research gap, the study's outcomes can contribute to informed decision-making, optimize resource allocation, and stimulate the agricultural sector's growth, benefiting both producers and consumers.

MATERIALS AND METHODS

Selections of crops and data sources

This study was based on Secondary Data. The monthly wholesale price of Masur (lentil), Mung (green gram), Mashkalai (black gram), Khesari (Lathyrus), and Gram was collected from the Department of Agricultural Marketing (DAM). From the availability of DAM website data, researcher collected Mung and Mosur from 1986 to 2021, Mashkalai and gram from 1987 to 2021, and based on less availability in Khesari wholesale price, and researcher collected only the last seven years of data from 2015 to 2021. On the other hand, researcher took area and production data from the Yearbook of agricultural statistics of Bangladesh (BBS). This study covered the last five decades of production and area for Mung, Mosur, Mashkalai, and Gram and the previous three decades of production and area for Khesari.

Model selection criteria

Several contemporary model that exists to measure the best-fitted model, such as R^2 , adjusted R^2 , RMSE, AIC, BIC, MAE, and MAPPE (Gujarati, 2003). To get the best model, the researcher has to pass the diagnostic checks by considering the maximum value of R^2 , adjusted R^2 , and minimum value of RMSE, AIC, BIC, MAE, and MAPPE (Bhuiyan, 2019), which is given in Table 1.

Table 1. Diagnostic measures for the selection of best fitted model.

Notation	Equations	Meaning
Coefficient of determination (R^2)	$R^2 = 1 - \frac{ESS}{TSS}$	ESS= Error sum of a square and TSS = Total sum of square
Adjusted Coefficient of determination (adjusted R^2)	Adjusted $R^2 = 1 - ((1-R^2)*(n-1))/(n-k)$	R^2 = sample R^2 , n= Total sample number, k= number of the independent variable.
Root Mean Square Error (RMSE)	$RMSE = \sqrt{\frac{1}{n-k} \sum e^2}$	k is the number of estimated parameters in the model, MSE is the mean square error
Akaike Information Criterion (AIC)	AIC= $2k+n \log(MSE)$	
Bayesian information criterion (BIC)	BIC= $k \log(n)+n \log(MSE)$	
Mean Absolute Error (MAE)	MAE= $1/n \sum \text{absolute error}$	
Mean Absolute Percent Prediction Error (MAPPE)	MAPE= $(100\%)/n \sum (\text{real value}-\text{forecast value})/(\text{real value})$	

Cubic growth model

There are many ways to calculate growth rates in area and production for different products. Such as linear, log-linear, compound, cubic, exponential, and so on. Percentages of simple growth rate at different points of time are being calculated by this formula:

$$R = ((P_t - P_0) / P_0) \times 100$$

Where R= Percentages simple growth rate at different points of time; P_t = Area or production at time t; P_0 = Area or production at the base year (Dhakre and Sharma, 2010).

The growth rates of production as well as area were calculated by following the cubic function.

$$Y = \alpha + \beta t + \gamma t^2 + \delta t^3 + \epsilon$$

After differencing we got $((\beta + 2\gamma t + 3\delta t^2) / y) \times 100$

here, y is the production; t represents time taking integers values starting from 1; β , γ , δ = coefficient of the model:

Price forecasting by using ARIMA model

The auto-Regressive Integrated Moving Average model is short-ly called ARIMA. This model is mainly used for analyzing and forecasting time series data. An ARIMA model is characterized by three-term that is p , d , and q , where p is for the AR term, which is also called lag order, q is for the MA term, which is called the order of moving average, and d is the degree of differencing (Tularam and Saeed, 2016) the expressions for MA, AR and ARMA are:

$$\text{AR}(p) \text{ model: } Y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \beta_3 y_{t-3} + \dots + \beta_k y_{t-k}$$

$$\text{MA}(q) \text{ model: } Y_t = \alpha_1 \epsilon_{t-1} + \alpha_2 \epsilon_{t-2} + \alpha_3 \epsilon_{t-3} + \dots + \alpha_k \epsilon_{t-k}$$

$$\text{ARMA}(p,q) \text{ model: } Y_t = \beta_1 y_{t-1} + \alpha_1 \epsilon_{t-1} + \beta_2 y_{t-2} + \alpha_2 \epsilon_{t-2} + \beta_3 y_{t-3} + \alpha_3 \epsilon_{t-3} + \dots + \beta_k y_{t-k} + \alpha_k \epsilon_{t-k}$$

The estimation and forecasting of the univariate time series model is carried out by using the BOX- Jenkins (B-J) methodology. This two-scientist used three steps for forecasting:

- I. Identification of appropriate model
- II. Estimation of the model
- III. Diagnostic test and Forecasting

Table 2. Best estimated models for pulses production in Bangladesh.

Pulses	The name of the best model	The functional form of the model
Mosur	Cubic	$Y = 40.925 + 20.373t - 0.921 t^2 + 0.011 t^3$
Mung	Cubic	$Y = -0.780 + 2.700t - 0.083 t^2 + 0.010 t^3$
Khesari	Cubic	$Y = 167.508 + 8.175t - 1.105 t^2 + 0.026 t^3$
Mashkalai	Cubic	$Y = 29.304 + 3.172t - 0.165 t^2 + 0.002 t^3$
Gram	Cubic	$Y = 23.724 + 6.249t - 0.288 t^2 + 0.003 t^3$

The p , d , and q values were determined by using the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). For any ARIMA (p , d , q) process, the theoretical PACF has nonzero partial autocorrelations at lags 1,2... n and has zero partial autocorrelations at all lags, while the theoretical ACF has non zero autocorrelation at lags 1,2... n and zero autocorrelations at all lags. The nonzero lags of the sample PACF and ACF are tentatively accepted as the p and q parameters. For a non-stationary series, the data are differenced to make the series stationary. For using the ARIMA model, the researcher had to transform data from non-stationary to stationary by using the differencing method (Peixeiro, 2019).

The number of times the series is differenced determines the order of d . Thus, for stationary data, $d = 0$ and ARIMA (p , d , q) can be written as ARMA (p , q) (Rahman and Baten, 2016).

Dickey-Fuller unit root test has to test the following hypothesis

Null hypothesis: The time series data of prices of major pulses is non-stationary.

Alternative hypothesis: The time series data of prices of major pulses is stationary.

The augmented Dickey-Fuller test was calculated by using R software and STATA software. If the computed Tau is greater or equal to the DF critical value, then the researcher rejects the null hypothesis; otherwise, accept. But it is clearly said that only stationary variables are applicable to this methodology. By using the autocorrelation function (ACF), researcher have to identify in the relation has or not in the same series of data set. It will help to determine the parameter p . Another factor, the partial autocorrelation function (PACF), is used to measure the degree of association between variables when the effects at other time lags are removed (Box and Jenkins, 1976).

RESULTS AND DISCUSSION

In this study, we calculated R^2 , Adjusted R^2 , RMSE, AIC, BIC, MAE, and MAPPE for identifying the cubic model was best-fitted model for estimating Mosur, Mung, Khesari, Mashkalai, and Gram production growth rate. The calculation recommends that the best model for Mosur, Mung, Khesari, Mashkalai, and Gram was shown in Table 2.

Table 3. Suggested models for Mung wholesale price.

Model	Model Fit statistics			Ljung Box Q(18)		
	R ²	RMSE	BIC	Statistics	DF	Sig.
ARIMA (0,1,2)	0.985	450.078	12.275	9.356	16	.898
ARIMA (1,1,1)	0.985	455.767	12.300	21.562	16	.158
ARIMA (1,1,0)	.984	465.430	12.328	37.410	17	.003

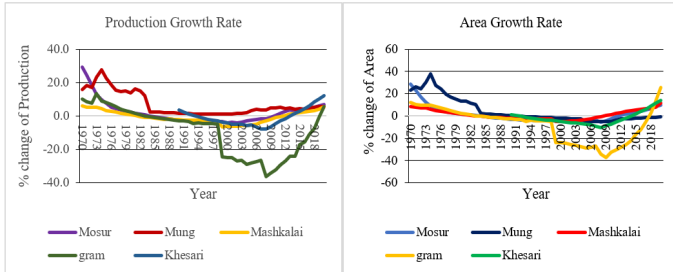


Figure 1. Trend line for production and area growth rate.

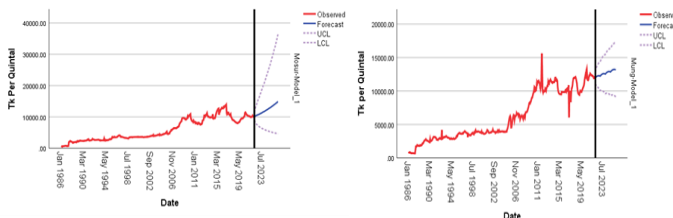


Figure 2. Forecasting trend for Mosur and Mung wholesale price.

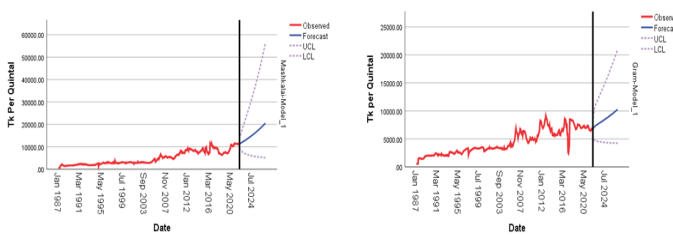


Figure 3. Forecasting trend of the wholesale price of Mashkalai and Gram.

Growth rate in area and production of major pulses

Figure 1 demonstrated that all of these pulses production growth rate trends are currently increasing. In contrast, all of the selected pulses production were reduced in the middle of the time frame. However, Mung's growth rate had always been in the upper 0 percent range, although gram production has been steadily declining since 1998, and has continued to do so until 2014. After 1998, when gram demand decreased possibly due to shifting farmer preferences or market dynamics, that's why gram growth rate became negative and more erratic than that of other pulses. According to the calculation of the average percentage change for production growth rate, Mosur and Mung has a positive value, whereas Mashkalai, Gram, and Khesari has a negative value. It means that on average, Mosur and Mung's production is better than Mashkalai, Gram, and Khesari's production. This suggests that Mosur and Mung's production performances were comparatively better than the other pulses. The trend line for area percentage change over the previous 5 decades is shown in Figure 1. Mosur, gram, and

Mashkalai areas were reduced in the 1970s until 1984, after which, with the exception of gram, all four areas remained nearly the same until 2009. The area cultivated for pulses has increased in the last ten years. Gram had a higher percentage of 25.9 percent in 2020 than during the entire span of time. These findings are in line with Devegowda et al. (2018), who reported the production of different pulses in India.

Wholesale price forecasting of major pulses in Bangladesh

By using ARIMA (0,1,0) (1,0,1) three years ahead wholesale price is estimated for Mosur in Bangladesh. On the other hand, Figure 2 Explained that the trend line of Mosur wholesale price from 1986 to 2021 was increased year over year but finally my forecasting result shows that an almost stable trend will be in the future. By using ARIMA (0,1,2) researcher made the Figure 2 and it explained that Mung wholesale price is increasing from the beginning year of 1986 to till now. From 2006 to 2021 prices become fluctuated surprisingly. My predicted future data clearly said that wholesale prices will be steadily increase in the future. From Table 4 the researcher may take a clear decision on which model is the best for Mashkalai wholesale price forecasting. It was ARIMA (2,1,2) because the value of this model is quite more appropriate than another model. Figure 3 declared that the wholesale price of Mashkalai price was slowly increased between 1987 and 2007. After that, positive change with a huge fluctuation occurred in the last 14 years. But from this current observation researcher can be said that the wholesale price of Mashkalai will be 18015.84 taka per metric ton at the end of 2025 which is too higher than the current price. So, it may predict that, Mashkalai wholesale price will be increase in recent years. ARIMA (2,1,4) is the best fit model for Gram wholesale price forecasting. Here the researcher uses the transform log function with one differencing to calculate R², RMSE, and BIC. From Table 5 ARIMA (2,1,4) has a maximum value of R² and minimum value of RMSE and AIC than others. The Figure 3 shows that Gram's wholesale price will be sharply increased in the future. But in the last 5 years researcher found a dramatically decreased gram price and the curve is steadily upward-moving in the future. The R², RMSE, BIC, which is given in Table 6, and ARIMA (0,1,0) is the best model for forecasting by comparing with others. The predicted values of respective study variables are computed by using ARIMA (0,1,0) model. Similarly, Uddin et al. (2015) also carried out the modeling studies of pulses production in Bangladesh.

Table 4. Suggested models for Mashkalai wholesale price.

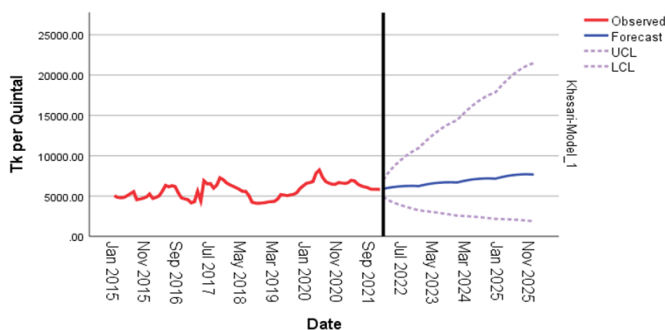
Model	Model Fit statistics			Ljung Box Q(18)		
	R ²	RMSE	BIC	Statistics	DF	Sig.
ARIMA (2,1,6)	0.984	372.514	11.985	7.907	10	.638
ARIMA (2,1,2)	0.984	372.939	11.929	13.574	14	.482
ARIMA (6,1,6)	0.984	375.731	12.059	8.170	6	.226

Table 5. Suggested models for Gram wholesale price.

Model	Model Fit statistics			Ljung Box Q(18)		
	R ²	RMSE	BIC	Statistics	DF	Sig.
ARIMA (2,1,4)	0.972	353.820	11.853	6.473	12	.890
ARIMA (1,1,1)	0.967	380.533	11.941	34.416	16	.005
ARIMA (4,1,4)	0.972	355.836	11.893	6.691	10	.754
ARIMA (3,1,2)	0.970	367.349	11.913	19.678	13	.104
ARIMA (1,1,0)	0.967	380.733	11.927	35.440	17	.005

Table 6. Suggested models for Khesari wholesale price.

Model	Model Fit statistics			Ljung Box Q(18)		
	R ²	RMSE	BIC	Statistics	DF	Sig.
ARIMA (0,2,2)	.736	512.226	12.692	12.586	16	.703
ARIMA (1,2,3)	.736	519.054	12.826	10.427	14	.730
ARIMA (1,2,1)	.737	511.506	12.690	12.224	16	.656
ARIMA (0,1,0)	.748	493.198	12.508	13.688	18	.749

**Figure 4.** Forecasting trend of the wholesale price of Khesari.

In that case ARIMA (0,1,0) has higher value of R², lower value of RMSE and BIC. By using this ARIMA this study predicted future value which indicates that the Khesari wholesale price will be minimally increase in the future, which is shown in Figure 4. The cubic model is the best model for measuring the growth rate in area and production for Mosur, Mung, Mashkalai, Gram, and Khesari in Bangladesh. During the study period the area and production under Mosur, Mung, Mashkalai, Gram, and Khesari has no actual growth trend. In the whole period, the minimum production growth rate for Mosur, Mung, Mashkalai, Gram, and Khesari is -3.9, 1.2, -6.6, -36.1, and -7.9 percent and the maximum growth rate is 29.5, 27.8, 6.3, 13.6, 12.2 percent respectively. Overall, the mean value of Mosur and Mung is 2.02 and 6.919 percent, which is positive. Apart, Mashkalai, Gram, and Khesari have a negative growth rate of -0.541, -8.894, and -0.854 percent. For area growth rate, the minimum value for Mosur, Mung, Mashkalai, Gram, and Khesari area is -5.4, -5.2, -5.1, -37, and -10.463 percent, and the maximum growth rate is 28.4, 38, 11.4, 25.9, and 13.87 percent respectively. After calculating the average percentage change for area growth rate, this study found that Mosur,

Mung, and Mashkalai have positive values of 1.229, 4.631, and 1.152 percent respectively. Conversely, Gram and Khesari have a negative average value of -7.719 and -1.987 percent. This study used ARIMA modeling for forecasting the wholesale prices of different pulses. After completing all the procedures this study decided that, ARIMA (0,1,0) (1,0,1) for Mosur, ARIMA (0,1,2) for Mung, ARIMA (2,1,2) for Mashkalai, ARIMA (2,1,4) for Gram and ARIMA (0,1,0) for Khesari are the best model for forecasting wholesale price in Bangladesh. For Mosur ARIMA (0,1,0) (1,0,1) the R² value is .993, RMSE value is 286.718, and BIC is 11.345. For Mung ARIMA (0,1,2) the R² value is 0.985, RMSE value is 450.078, and BIC is 12.275. For Mashkalai ARIMA (2,1,2) has R² value 0.984, RMSE value is 372.939, and BIC is 11.929. For Gram ARIMA (2,1,4) has R² value 0.972, RMSE value is 353.820, and BIC is 11.853 and finally for Khesari ARIMA (0,1,0) the R² value is .748, RMSE value is 493.198, and BIC is 12.508. The wholesale prices of Mosur, Gram, and Khesari would be slightly changed in the future, that is a minor change. Apart from that, mung shows somewhat increased, and Mashkalai shows a rapid rise in the future. So, the overall result is that the wholesale prices will increase in the following year. The study presented in this summary aimed to forecast the production growth rate and wholesale prices of major pulses in Bangladesh using ARIMA modeling. These models were selected based on their ability to accurately predict future prices and were validated using metrics such as R², RMSE, and BIC. The results of the forecasts provided valuable insights into the potential price trends for each pulse. which provided valuable insights into the trends, patterns, and potential future scenarios of pulse production and prices in the region. Hajong et al. (2020) also reported the value chain analysis of certain lentil crops in Bangladesh.

Conclusion and recommendations

The study's findings shed light on the current state of major pulse crops in Bangladesh and offer a roadmap for policymakers to address challenges and optimize production to meet the nation's dietary needs. Pulses, often referred to as the "poor's protein," hold immense significance for the middle-class population, making it imperative to enhance their production and availability through effective strategies. However, the challenges stemming from inadequate management practices, limited knowledge dissemination, and suboptimal land utilization have resulted in an inability to satisfy domestic demand. Recognizing the nutritional value of pulses, it's crucial for both the government and stakeholders to collaboratively overcome these hurdles and promote sustainable pulse cultivation. The study's examination of price trends for selected pulses unveiled an upward trajectory. However, the growth rates in both production area and output displayed fluctuations due to weather patterns and soil characteristics impacting pulse cultivation. Encouragingly, recent decades have seen positive growth trends, largely attributed to advancements in pulse variety development tailored to challenging environmental conditions. Nevertheless, the overall growth rates for most pulses remained negative, except for Mung. ARIMA modeling, suggest a strategic shift in cultivation preferences. Given the fluctuating prices of Gram, the study advocates for considering Mung and Mosur as priority crops, as their projected prices indicate potential benefits. Moreover, the anticipated price volatility for Mashkalai and the stable pricing of Khesari present opportunities for producers to explore these crops. So, this study may be helpful for the policymakers, researchers, and farmers to deal with the problems of production of major pulses crops in Bangladesh. To solve all these problems, effective measures should be taken by the government immediately.

- For improving the production of major pulses farmers need to use High Yield Variety (HYV) seeds as well as proper knowledge about pulse farming.
- Bangladesh requires minimum support for better prices, improved management methods, and other incentives for better output.
- Recognizing the appropriate quantity and quality of seeds should be one of the key elements for increasing agricultural productivity. Therefore, it is important for the government and non-governmental groups to guarantee that farmers have access to high quality seeds.
- Extension services and their linkage with farmers should be increased to make available knowledge to the farmers.
- A crop insurance scheme for major pulse crops should be introduced as an incentive.

Therefore, this study looked at the area and production growth rates, as well as wholesale price projections for Bangladesh's major pulses. Not only can price forecasting assist producers in making decisions, but it also aid policymakers and producers in better allocating their resources. As a result, both producers and consumers, as well as Bangladesh's economy, may benefits from the productions.

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