Journal of the University of Ruhuna
Volume 13 No 1, June 2025. Pp 42-51
DOI: https://doi.org/10.4038/jur.v13i1.8048
ISSN: 2659-2053

RESEARCH ARTICLE

Towards Sustainable Consumption: Fostering the Use of Bangladeshi Grown Onions over Imports

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Abstract: This study examines the intricacies of onion production in Bangladesh, with the goal of offering valuable insights into methods for encouraging domestic cultivation and decreasing reliance on imports. By employing time series analysis, ARIMA (Autoregressive Integrated Moving Average) modelling, and qualitative methodologies such as fishbone diagrams and Pareto charts, this study utilizes data from 1989 to 2020 to anticipate onion production patterns and identify the important elements that influence customer preferences. The results demonstrate a steady rise in domestic onion output, indicating a favourable prospect for satisfying local demand. The ARIMA (1,1,0) with drift model predicts a consistent increase in production until 2040, assisting policymakers in managing the trade-off between import dependence and initiatives to strengthen domestic production. Furthermore, the fishbone diagram and Pareto chart serve to emphasize pivotal elements, including market demand, financial backing, and policy interventions, which have the potential to influence consumer inclination towards locally cultivated onions. By taking into consideration these various elements, Bangladesh has the potential to augment its economic growth and attain a higher level of self-sufficiency in the production of onions.

Keywords: *Fishbone diagram, Import substitution, Pareto chart, Policy interventions, Self-sufficiency, Time series analysis.*

Introduction

Onion (*Allium cepa* L.) is botanically included in the family of Liliaceae (Tripathi, 2016), can be found in various latitudes and altitudes throughout the globe, including Europe, Asia, North America, and Africa. Onions have historically been traded more than other types of vegetables due to their ability to be preserved for extended periods of time and withstand shipping (Griffiths *et al.*, 2002). It is known as the kitchen queen due to its cherished flavor, enticing aroma, and distinct taste. Furthermore, its flavor compounds are not only noteworthy for their culinary value, but also their health benefits (Selvaraj, 1976). In 2020, Bangladesh produced 22.68 million metric tons (MT) of onion from 4.80 million acres of land, followed by 19.53 million MT from 4.57 million acres of land in 2019 and 18.02 million MT from 4.26 million acres of land in 2018 (BBS, 2020). It indicates a significant increase in onion production in Bangladesh. Similarly, the average amount of onion imports from 2010 to 2018 was 0.327 million MT, which is greater than the average amount imported from 2001 to 2010 (0.302 million MT) (Rana *et al.*, 2021). In recent years, the total cost of onion imports was 239.60 million US dollars for 0.64 million MT in 2019-20 and 235.64 billion US dollars for 0.78 million MT in 2020-21 (Bangladesh Bureau of Statistics, 2021). This enormous sum can be saved by encouraging local farmers to cultivate onions. In Kushtia, Jhenaidah, and Pabna, the benefit-cost ratios (BCR) for onion production were 2.02, 1.83, and 1.74, respectively (Bapari *et al.*, 2016, Anjum and Kumar Barmon, 2018). As exemplified by the crop's profitability and BCR values, these findings demonstrate that growing

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onions in Bangladesh is a lucrative endeavor. The retail price of locally grown onion is 90 taka per kilogram, which is frequently higher than the price of imported onions (80 taka per kg) (Department of Agricultural Marketing, 2023). Even though local onion production is on the rise, onion prices remain unstable due to a disorganized or congested supply chain in the onion market (Mila *et al.*, 2022). By ingesting locally grown onions, consumers can contribute to the sustenance of Bangladeshi farmers. In turn, this can stimulate the local economy by creating employment and promoting sustainable agricultural practices. Currently, Bangladesh imports a substantial quantity of onions, which can have negative economic effects. In this regard, strategies should be taken to encourage consumers for the consumption of national products as well as onions rather than foreign products. It is necessary to mention the elements that influence domestic onion consumption more than that of imports.

Forecasting is a key tool for crop production planning, enabling timely estimates of production quantities. Timely forecasts made before crop harvest are valuable for shaping policies on storage, distribution, pricing, marketing, and import-export activities (Agarawal, 2004). In addition, agricultural production is a function of nature. Risk and uncertainty are distinctive features of agricultural cultivation (Adnan *et al.*, 2021). Thus, there is always some degree of uncertainty in achieving the target production level. Forecasting is a management tool for decision-making, involving the estimation of future uncertainties. Forecasting models allow policymakers and agricultural planners to make informed decisions based on expected production trends, aiding in resource allocation and supply chain management. Various techniques have been employed in time series prediction to determine the most effective approach for forecasting. Among these methods, implementing the ARIMA (Autoregressive Integrated Moving Average) model has proven to be highly valuable because it can effectively handle time series data sets (Saleem. *et al.*, 2023). This model is particularly suitable for agricultural data, where seasonal and external factors, including climate and market fluctuations, influence production trends. The ARIMA model's capability to analyze past data patterns and project future trends makes it a robust tool for forecasting the production of onions in Bangladesh. By identifying the ARIMA model for onion, this study aims to provide accurate forecasts that can guide national efforts in ensuring food security and managing production and export-import.

This study aims to promote sustainable onion consumption by encouraging the use of locally grown over imports. The objective of this study is to forecast the domestic production trends, identify the challenges faced by farmers, prioritized factors affecting onion production and propose target strategies to enhance domestic production. To achieve this objective, we employed time series modeling to predict future production and a fishbone diagram to identify the root cause of the affecting onion production as well as Pareto analysis is applied to identify the key factors requiring immediate take account. This study seeks to furnish actionable insights to policymakers by merging time series forecasting with fishbone and Pareto analyses, thereby promoting sustainable agriculture practices and advocating for the consumption of locally grown onions instead of imports.

Materials and Methods

Data Sources

The data on onion production value from 1989 to 2011 were gathered from the Yearbook of Agricultural Statistics of Bangladesh. Data from 2012 to 2021 were obtained from the official website of the Bangladesh Government. The website can be accessed through http://www.bbs.gov.bd/site/page/3e838eb6-30a24709-be85-40484b0c16c6/Yearbook-of-Agricultural-Statistics. Additionally, 200 primary data were collected for Pareto analysis using a pretested questionnaire administered through Google Forms. Microsoft Excel was utilized to accumulate a time series database.

ARIMA Model

Various techniques have been employed in time series prediction to determine the most effective approach for forecasting. Among these methods, the implementation of the ARIMA model has proven to be highly valuable because it can effectively handle time series data sets (Saleem. *et al.*, 2023). ARIMA stands for Autoregressive Integrated Moving Average. It emerged as one of the prominent models extensively in the econometric and statistical analysis of time-series data when George Box and Gwilym Jenkins introduces the concept of “Forecasting and Control”, where they elucidated techniques for transforming non-stationary data into stationary form (Makala and Li, 2021). The ARIMA model is also known as the Box-Jenkins time series method (Syahrini *et al.*, 2023). When additional time series are included as input variables in the ARIMA model, it is commonly referred to as an ARIMAX model (Mondal *et al.*, 2014). An ARIMA model is labeled as an ARIMA model (p,d,q) wherein:

- p is the number of autoregressive terms.
- d is the number of non-seasonal differences needed for stationarity; and
- q is the number of moving averages.

Following Devi *et al.*, (2023) the general formula of ARIMA model is as follows:

$$\boldsymbol{Y_t = \varphi_0 + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \cdots \varphi_p Y_{t-p} + \mu + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \cdots \theta_q \epsilon_{t-q} + \epsilon_t}$$

where, $\boldsymbol{Y_t}$ is the response variable at time t, $\boldsymbol{Y_{t-1}}$, $\boldsymbol{Y_{t-2}}$, $\boldsymbol{Y_{t-p}}$ are the response variable at lag t-1, t-2 and t-p respectively, $\boldsymbol{\varphi_0, \varphi_1, \varphi_2, \varphi_p}$ are the coefficients to be estimated, $\boldsymbol{\mu}$ is the constant mean of the process, $\boldsymbol{\theta_1, \theta_2}$, $\boldsymbol{\theta_q}$ are the coefficients to be estimated, $\boldsymbol{\epsilon_t}$ is the error term at time t, $\boldsymbol{\epsilon_{t-1}, \epsilon_{t-2}, \epsilon_{t-q}}$ are the error in the previous time. The rationale behind employing the ARIMA model lies in its capability to effectively capture and forecast temporal patterns in onion production data.

ARIMA model fitting procedure

The ARIMA model was applied to forecast onion production trends using time series data from 1989 to 2020. The analysis was conducted using R statistical software, following these steps:

1. **Data Preparation**: Time series data were tested for stationarity using the Augmented Dickey-Fuller (ADF) test. Non-stationary data were different until stationarity was achieved.

2. **Model Identification**: Various ARIMA models were fitted to the data using the auto.arima function in R, which evaluates model performance based on the Akaike Information Criterion (AIC).

3. **Model Comparison**: A set of candidate models was compared using AIC, Mean Error (ME), and Root Mean Square Error (RMSE) to assess model accuracy and fitness.

4. **Model Selection**: The model with the lowest AIC and acceptable error metrics was selected as the best fit for forecasting onion production.

Fishbone Diagram

This study employed the fishbone diagram (Ishikawa diagram) to discover the root causes of inefficiencies in onion production. Data obtained from interviews with farmers, agricultural specialists, and stakeholders, together with secondary sources, were analyzed and classified into six primary categories: Manpower, Methods, Machines, Materials, Measurements, and Environment. Challenges regarding manpower include a deficiency of trained farmers and restricted access to agricultural training. In Methods, factors such as ineffective irrigation methods and minimal adoption of contemporary agricultural technologies led to output inefficiency. Machines were limited by insufficient technological equipment and inadequate maintenance expertise. Resources were constrained due to inadequate access to quality seeds and elevated expenses for fertilizers and insecticides. Measurement problems encompassed erratic quality control and inadequate market research. Environmental considerations, including variable government policies, climate change, and unfavorable weather conditions, were recognized as substantial impediments. This systematic method facilitated the identification of essential production bottlenecks, establishing the foundation for later prioritization and focused interventions (Ilie and Ciocoiu, 2010, Li and Lee, 2011, Coccia, 2018).

Pareto Chart Analysis

A Pareto chart was developed to prioritize the issues highlighted in the fishbone study. Primary data from 200 respondents, gathered through a validated Google Forms questionnaire, was utilized to measure the relative influence of each factor. The graphic indicated that critical factors, including restricted availability to quality seeds, insufficient irrigation systems, and elevated input costs, were the principal causes of inefficiency in onion production. This corresponds with the Pareto principle, which posits that 80% of outcomes derive from 20% of sources (Radson and and Boyd, 1997, Šarkoćević and Lazarević, 2015). The Pareto chart facilitated the visualization of these significant concerns, offering insights for targeted interventions to enhance production efficiency and foster sustainable behaviors.

Results and Discussion

Onion production

The production of onions in earlier years, particularly before the late 1990s, was relatively low and stable (Fig. 1), requiring imports to meet domestic demand.

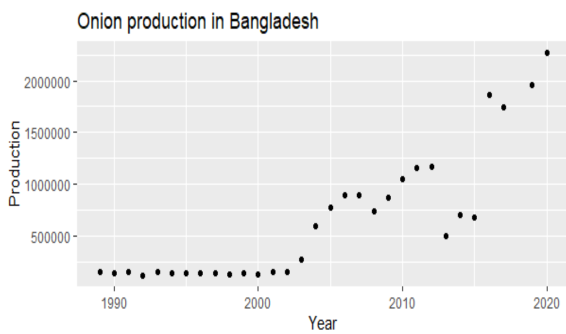

Figure 1. Time series plot of onion production (Metric tons) in Bangladesh

However, production has significantly increased over time, with notable peaks in years like 2010-11, 2011-12, 2012-13, and 2016-17, where production exceeded one million MT. By 2020, production surpassed two million MT, reflecting substantial growth (Fig. 1). Despite fluctuations, the overall trend is upward, indicating that domestic production has been steadily improving and contributing to meeting the country's onion demand.

This consistent growth in production highlights a shift toward self-sufficiency, reducing reliance on imports and stabilizing the domestic market. The upward trend provides a positive outlook for farmers, as increasing demand for locally grown onions creates opportunities for expanded cultivation and profitability. This progress not only boosts production capacity but also strengthens the nation’s ability to sustain its agricultural needs internally.

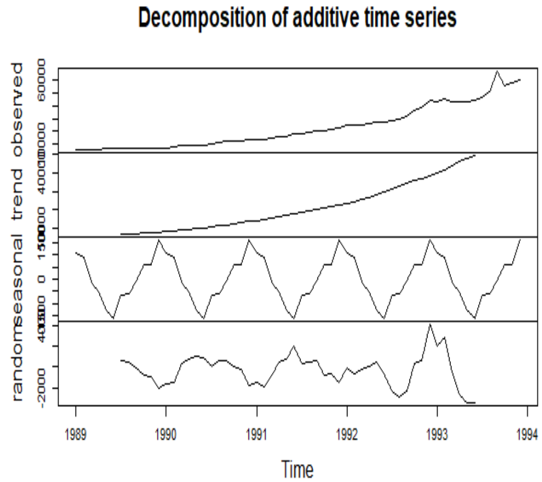

Figure 2. Decomposition of additive time series for onion production in Bangladesh

Decomposition of Additive Time Series

Fig. 2 illustrates four distinct types of plots. The initial plot presents the raw observed data, showcasing the actual fluctuations and patterns in production over the years. The second plot highlights the overall trend, revealing the long-term movement in onion production, while the third plot isolates seasonal variations, uncovering repetitive patterns linked to seasonal factors.

Lastly, the fourth plot displays random or unpredictable data points, representing irregular fluctuations in production. In this graph, it is evident that the production of onions steadily rises over time. It's a straightforward story of growth and progress, illustrating a clear and positive trend in onion cultivation.

Forecasting Onion Production

The present study employed the auto.arima function in R to effectively forecast the onion production conditions in Bangladesh.

Table 1 displays the results of various ARIMA models. Among all the models, ARIMA (1,1,0) with drift was identified as the best fitted model, as it exhibited the lowest AIC value. This model was used to predict the onion production of Bangladesh up to the year 2040.

Table 1. ARIMA models and AIC (Akaike Information Criterion) values

Models	AIC
ARIMA (2,1,2) with drift	Inf
ARIMA (0,1,0) with drift	1106.27
ARIMA (1,1,0) with drift	1103.99
ARIMA (0,1,1) with drift	1104.19
ARIMA (0,1,0)	1110.13
ARIMA (2,1,0) with drift	1106.29
ARIMA (1,1,1) with drift	1106.29
ARIMA (2,1,1) with drift	Inf
ARIMA (1,1,0)	1110.93

Table 2. Fitted Values of ARIMA (1,1,0) with Drift Model

ARIMA Model	Fitted Values	
	AR 1	Drift
Coefficients	-0.27	901.40
Standard Error (SE)	0.12	272.69
sigma^2	7260385	
log likelihood	-548.78	
AIC	1103.55	
AICc	11033.99	
BIC	1109.79	

Table 2 presents a clear observation: the AIC and BIC values correspond to the ARIMA (1,1,0) with drift model with parameters (p=1, d=1, and q=0). Therefore, based on these criteria, it can be concluded that this particular model represents the most suitable choice for accurately predicting future values of this time series data.

Table 3. Coefficient values of ARIMA (1,1,0) with drift model (z test of coefficients)

	coefficient	standard error	z value	Pr(>|z|)
AR 1	-0.27	0.12	-2.17	0.03*
Drift	901.40	272.69	3.31	0.00***

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

Therefore, the AR1 coefficient is statistically significant at the 5% significance level, while the drift coefficient is highly significant (Table 3). The significant AR1 suggests the presence of autocorrelation, while the significant drift suggests the presence of a significant trend or drift component in time series data.

Table 4. Model performance of ARIMA (1,1,0) with drift model

ME	RMSE	MAE	MPE	MAPE	MASE
-3.01	2626.28	1328.84	-0.36	6.43	0.96

These metrics collectively assess the performance of the ARIMA (1,1,0) with drift model in forecasting onion consumption in Bangladesh, providing valuable insights for strategies to promote local onion consumption over imports. ME (Mean Error) means the average difference between the actual values and forecasted values. Negative value indicates that, on average, the forecasted values are 3.01 units lower than the actual values. The RMSE (Root Mean Square Error) value of 2626.28 units indicates the model's prediction accuracy, where lower values indicate better performance. Considering a forecasted onion production exceeding 75000 MT in 2040, which is substantially higher than the RMSE value. So, the model demonstrates strong performance. MAE (Mean Absolute Error) represents the average magnitude of errors without considering the direction of the error, further confirming the model's accuracy. In this case it is 1328.84 units. MPE (Mean Percentage Error), the average percentage difference between the actual and forecasted values, expressed as a percentage of the actual values. A positive value indicates overestimation, while a negative value indicates underestimation. Here, it is -0.36, suggesting a minor underestimation bias in the forecasts. MAPE (Mean Absolute Percentage Error) is a measure of the model's accuracy in terms of percentage errors where low percentage error indicates high forecasting precision. Here, it is 6.43%. MASE (Mean Absolute Scaled Error) compares the accuracy of different forecasting methods. A value less than 1 indicates better performance compared to the simple forecasting method. Here, it is 0.96, suggesting that the model performs slightly better than the simple forecast method.

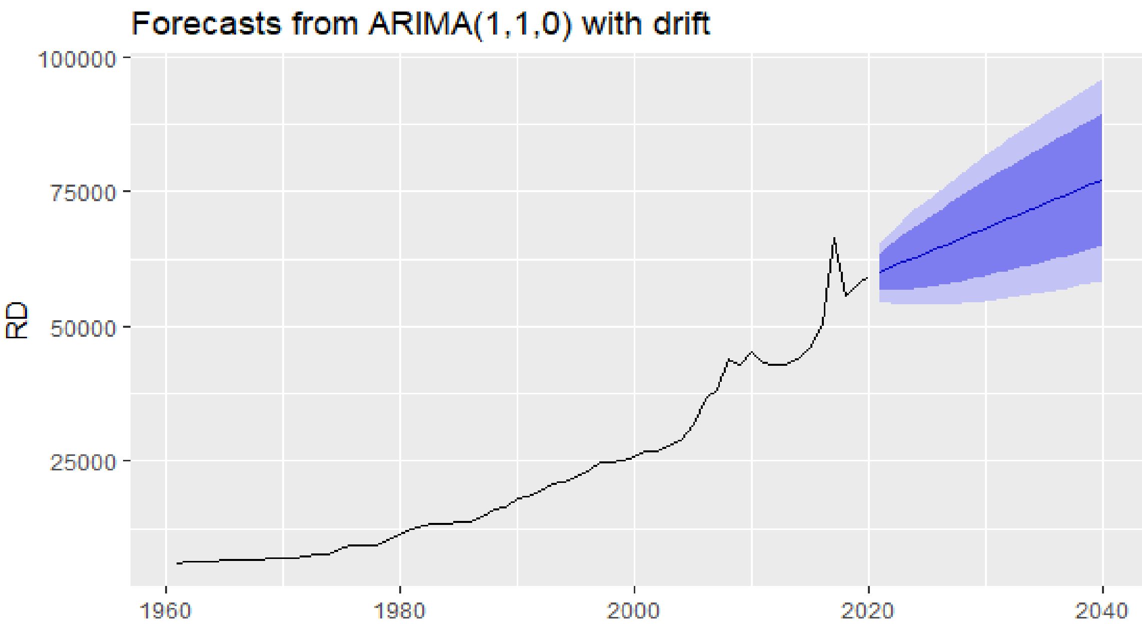

Figure 3. Forecasting Onion Production Trends in Bangladesh Using the ARIMA Model. RD focuses on Production

Fig. 3 illustrates the forecasting prediction of locally produced onions, represented by the blue straight line. Upon careful observations, it becomes apparent that, in previous years, onion production exhibited significant fluctuations. However, the future projection indicates a steady increase in production, with a reduced level of volatility. Additionally, the figure depicts the confidence intervals (CI) represented by the light blue and deep blue lines. The deep blue line represents an 80% CI, while the light blue line corresponds to a wider 95% CI. These intervals provide a measure of uncertainty in the predictions. Based on forecasting analysis, it can be estimated that the onion production for the year 2040 will be approximately more than 75 million MT of onion, with a 95% CI (Fig. 3). This prediction indicates a level of reliability in the forecasted value and range within which it is expected to fall.

The findings from this study provide encouraging news for farmers who are considering increasing their onion production in the near future. The analysis reveals a stable upward trend in onion production, indicating a positive market outlook. The predictions show that onion production is expected to grow steadily, with reduced fluctuations. This means that farmers can have more confidence in the future demand for onions.

Fishbone Diagram

The fishbone diagram provides an initial framework for understanding the potential factors contributing the preference for imported onions over locally produced onions. It can be used as a starting point for further analysis and discussion, helping identify specific causes and develop strategies to encourage the consumption and production of local onions.

From the diagram (Fig. 4), it presents the specific challenges faced by Bangladeshi farmers in encouraging the production of locally grown onions. It can serve as a foundation for further exploration, analysis, and strategic decision-making aimed at promoting locally produced onions in the country.

Pareto Chart Factors

1. Market demand and price stability (MDPS)
2. Access to quality seeds and inputs (AQSI)
3. Technical knowledge and training (TKT)
4. Financial support and credit facilities (FSCF)
5. Infrastructure development (ID)
6. Government policy support (GPS)
7. Well-developed market linkages (WDML)
8. Research on climate resilient varieties (RCRV)

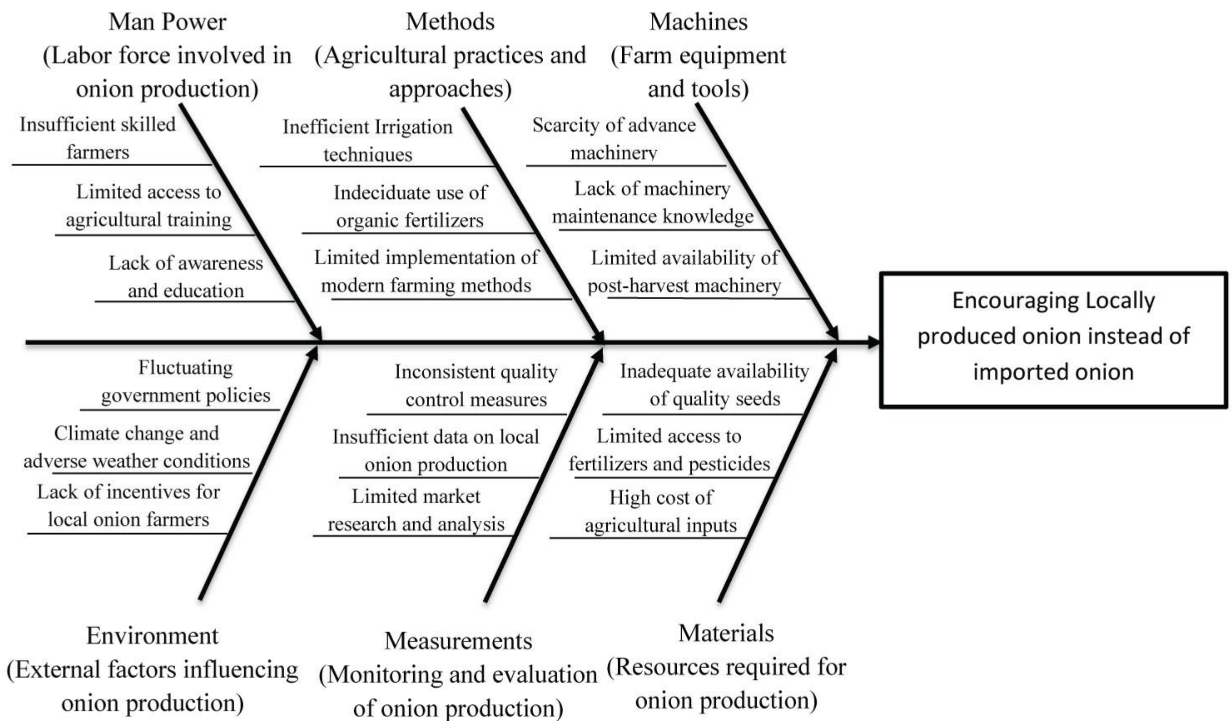

Figure 4. Fishbone Diagram for analysing the Challenges and Solutions to Encouraging Consumption of Domestic Onion in Bangladesh

Table 5. Pareto Table of Key Factors Affecting Onion Production Efficiency in Bangladesh

Factors	No. of occurrences	Percentage (%)	Cumulative percentage
Market demand and price stability	77	38.5	38.5
Financial support and credit facilities	27	13.5	52
Government policy support	24	12	64
Well-developed market linkages	21	10.5	74.5
Technical knowledge and training	19	9.5	84
Research on climate resilient varieties	17	8.5	92.5
Access to quality seeds and inputs	11	5.5	98
Infrastructure development	4	2	100
Total	200	100	

Table 5 presents a pareto analysis of important factors influencing onion production efficiency in Bangladesh, ranked by their frequency of occurrence and cumulative impact. Market demand and price stability emerged as the most critical factor (38.5%) followed by financial support (13.5%) and government policy support (12%). The findings highlight the importance of market stability, financial and institutional support in encouraging local onion producers to enhance onion production.

The Pareto chart (Fig. 5) is about encouraging Bangladeshi onion producers to produce more onions and reduce imports. The Pareto rule suggests that 80% of the effects come from 20% of the causes. The chart shows eight factors that play a role in encouraging local producers. Applying this rule, it can focus on the top 20% of these factors that contribute to 80% of the occurrences. The top four factors are- market demand and price stability (38.5% of the total occurrences), financial support and credit facilities (13.5% of the total occurrences), government policy and support (12% of the total), and well-developed market linkages (10.5% of the total occurrences). These top four factors collectively represent around 74.5% of the total occurrences. Therefore, to promote local onion production and reduce imports, prioritize these four factors as they have the most significant impact.

From the time series plot of onion production, it shows that the production of onions has been consistently increasing over the years. According to Mila and Parvin, (2019), despite a rising trend in onion production, the country falls short of meeting the yearly demand of 2177.24 thousand metric tons.

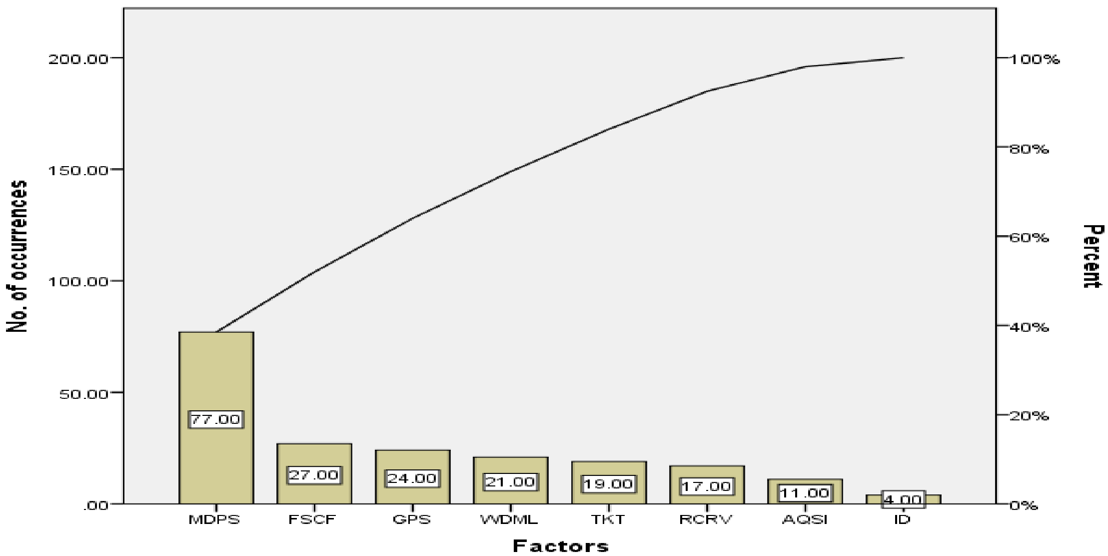

Figure 5. Pareto Chart of Key Factors Affecting Onion Production Efficiency in Bangladesh

To fill the gap, it imports 700 to 800 thousand MT annually, mainly from India, the second-largest onion producer globally. In this research, utilizing the ARIMA (1,1,0) with drift model, forecasts onion production until 2040. The insights gained can assist policymakers in determining the optimal balance between importing and relying on local production to meet our onion needs. Haque *et al.*, (2011) found that onion cultivation yielded greater profitability compared to competing crops such as mustard, groundnut, and cabbage. They also highlighted various challenges encountered by local onion farmers, including non-availability of HYV onion seed at the proper time, lack of technical knowledge, high price, and non-availability of fertilizer in time etc. In this study it breaks new ground by using fishbone diagram and Pareto chart to encourage local onion farmers, filling a notable gap in existing literature. Surprisingly, there is a lack of prior studies utilizing these tools for agricultural encouragement.

Additionally, this research contributes to the literature by incorporating fishbone diagrams and Pareto charts to systematically identify and address obstacles in onion production. Onion farmers worldwide encounter significant challenges, including input shortage, high cost, labour issues, shortage of knowledge gaps, transportation cost, marketing process, and fluctuation in raw material procurement (Kumar *et al.*, 2020, Zegeye *et al.*, 2024). A similar pattern is evident in Bangladesh, where this study identified critical factors such as a lack of skilled farmers, limited access to advanced machinery, and inadequate availability of quality seeds. To mitigate these challenges, it is essential to address the factors affecting onion production and implement policies that emphasize them. Mulatu and and Gemechu, (2023) noted that onion production influenced by education level, access to market information, family size and access to credit services. Our study revealed that market demand and price stability, financial support and credit facilities, government policy support, and well-developed market linkages are the most dominant factors affecting onion production in Bangladesh. To promote local onion production, these challenges and influencing factors must be prioritized. This study introduces a novel approach by combining a fishbone diagram and Pareto chart within the context of agricultural development in Bangladesh, addressing a significant gap in the existing literature.

Conclusion

This study includes a comprehensive analysis of onion production in Bangladesh, including historical patterns, future projections, and innovative approaches for supporting local producers. The ARIMA (1,1,0) with drift model predicts a favourable trend in domestic onion output until 2040, providing policymakers with insights into balancing imports and boosting local growth. The use of a fishbone diagram and a Pareto chart fills a gap in the current literature by identifying important criteria critical to supporting local production. This paper supports self-sufficient onion production by resolving problems and prioritizing issues such as market demand and financial assistance, therefore contributing to Bangladesh's economic growth and sustainable agriculture.

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