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GROWTH AND INSTABILITY ANALYSIS OF BLACK GRAM (*Vigna mungo* L.) IN BANGLADESH

J. K. Prioty*, K. S. Rahman and M. A. M. Miah

Agricultural Statistics and Information and Communication Technology (ASICT) Division, Bangladesh Agricultural Research Institute (BARI), Gazipur. Bangladesh

Abstract

Growth and instability of crops are two crucial aspects that significantly impact the contributions to enhance agricultural resilience, food security, economic development, risk management, income volatility, and sustainable practices to meet increasing demands. Black gram is one of the high-value pulse crops in Bangladesh, and is essential for human and animal nutrition, and also contributes to soil health improvement through adding nitrogen, carbon and organic matter. This study presents the growth and instability in area, production, and productivity of black gram along with the contributory factors affecting the growth and instability production based on secondary data for the last 40 years (1981-2020). The entire period was divided into four sub-periods: 1981-1990, 1991-2000, 2001-2010 and 2011-2020 for analysis through different statistical tools. Growth rates were calculated by fitting an exponential growth function, and instability was analyzed by generating the Cuddy-Della Valle index. The analysis presented highlights with a significant decrease in the area of black gram cultivation and production, even though there has been a notable increase in productivity. However, this increase in yield is not sufficient to meet the overall demand for black gram in the country. The study also points out that the growth rate of yield is low compared to the increase in demand. Throughout the study period, the contribution of the area was -3.29%, while the yield contribution was 142.25% in the average growth of black gram production at the national level. The analysis underscores the lack of stability in black gram cultivation, production, and yield during this period. Notably, there were instabilities of 4.37%, 4.89%, and -25.7% in area, production, and productivity of black gram at the national level, respectively. Hence, researchers, policymakers, and farmers must prioritize advancing improved technologies to boost black gram production in the country. This enhancement holds the promise of improving food and nutritional security in Bangladesh. Encouragingly, there are signs that the Bangladesh Agriculture Research Institute (BARI) has strengthened its varietal development research, and the government has recently implemented incentives to support the cultivation of pulse crops including black gram.

Keywords: Black gram, Cuddy-Della Valle index, Growth decomposition, Instability

* Corresponding author: jamilaprioty@gmail.com

Introduction

Pulses are important food crops in Bangladesh. They are an important source of essential nutrients in the human diet (Das 2016.), provide feed for animals, and generate good profits for farmers (Miah *et al.*, 2009). Pulses contribute to agricultural and environmental sustainability through adding nitrogen, carbon, and organic matter in soil (Senanayake *et al.*, 1987; Zapata *et al.*, 1987; Sarker and Kumar, 2011). A favorable climatic condition exists in Bangladesh for growing different types of pulses all over the country. Because of the high protein content and low-price, pulses are called *poor man's meat*. So, most of the low-income people use these nutritious crops in daily diet. However, per capita consumption of pulses in our country is only 17.1 g/day (HIES, 2022) which is much lower than the desirable intake of 50 g/day (DDP, 2013). The local production of pulses almost remained static in the last couple of years, causing a rise in imports to meet the increasing demand (Miah *et al.*, 2022). Bangladesh had to import a huge quantity of pulses to meet the demand. Bangladesh imported 1363.39 thousand tons of pulses valuing USD 707.172 million in 2021 (FAOSTAT, 2021). According to Bangladesh Bank's statistics, Bangladesh spent Tk. 6,185 crores to import pulses in the last fiscal year of 2021-22, an increase of 11% year-on-year.

Black gram (locally called *Mashhkalai* is a leguminous plant under the *Vigna mungo* species. It is a drought-tolerant crop predominantly grown during Kharif-II season. Its seed is generally eaten as whole seed, flour for various snacks or after splitting cooked as *Dal*. Protein, fiber, vitamins, and minerals like calcium and iron are abundant in whole black grams (Reddy *et al.*, 1982 and Salunkhe *et al.*, 1985). The composition of black gram residue is approximately as follows: cellulose (26.8% ± 2.3%), hemicellulose (32.48% ± 3.0%), lignin (23.14% ± 2.1%), crude protein (16% ± 0.8%), and ash content (5.1% ± 1.2%) (Ilyas *et al.*, 2012). Black gram is also used as a green manure and cover crop or fodder crop and as a short-lived forage. In 2021-22, it was cultivated in about 41.3 thousand hectares of land producing 39.00 thousand MT with an average yield of 0.94 t/ha (BBS, 2022), the demand for black gram was 1.3 lakh MT in 2021 (Bokhtiar *et al.*, 2022). Therefore, decent growth in black gram is also necessary to contribute to the overall GDP of Bangladesh. However, instability in agricultural production is on the rise due to several factors, such as erratic rainfall patterns, low irrigation coverage, and an increase in the frequency and severity of natural disasters, among others. Instability also exists in the area regarding the production and yield of black gram. This instability has also had adverse effects on food management and macroeconomic stability in the country. There has been some economic and agronomic study in Bangladesh focusing on aspects other than the growth and instability of black gram, and therefore, we have focused on these areas. In this context, this paper attempts to analyze these two aspects, as balancing these is essential for building resilient and productive agricultural systems. The specific objectives of this study are to determine the growth rates of area, production, and yield of black gram in Bangladesh; and to measure the change and instability in area, production, and yield of black gram.

Materials and Methods

Data and its sources

The study was based on secondary data collected from various published sources. Times series data on the area, production, and yield of black gram for the last 40 years from 1981-82 to 2019-20 were collected from different issues of the Yearbook of Agricultural Statistics of Bangladesh.

Analytical procedures

Various statistical tools were used to analyze the data to examine the nature of change, instability, and degree of relationship in area, production, and yield of black gram in Bangladesh.

Trend analysis

Trend analysis aims to find out the extent and causes of instability of area and production of black gram over time. This information may lead researchers as well as policymakers to prepare appropriate policy documents and priority research areas for the improvement of black gram in the country. A simple line graph and bar diagram were used to show the trends in area, production, and yield of black gram in Bangladesh.

Index number

The relative changes in area, production, and yield of black gram that occur within a specified timeframe can be quantified using an index number. At first, the entire study period is divided into four sub-periods such as 1981-1990, 1991-2000, 2001-2010, and 2011-2020. The reason for the division was to know the changes that occurred in the area, production, and yield of black gram in every decade. The average value of area, production, and yield of the first 10 years sub-period (e.g. 1981-1990) provided the base information.

Annual growth rates

Growth rates are the percent change of a variable over time. It is important because it can help researchers and policymakers to predict future production growth. For simplicity and widely used even in the recent past (Rahman *et al.*, 2011; Das and Mishra 2020; Chaudhary *et al., 2016*) the compound growth rates of area, production, yield, and price of black gram were worked out by fitting an exponential function of the following type:

$$Y = ae^{bt} \text{ or } LnY = Lna + bt \text{----------(1)}$$

Where Y is the area/production/yield of black gram, 't' is the time in a year, and 'a' is the constant, e^b -1 is the compound growth rate which is expressed in percentage. The component analysis model has been used to measure the relative contributions of area and yield toward the overall output change with regard to individual crops. The growth performance of the crops has been studied using this model by numerous researchers (Gupta and Saraswat, 1997; Singh and Ranjan, 1998; Siju and Kombairaju, 2001; Kakali and Basu, 2006).

$\Delta P = A.\Delta Y + Y.\Delta A + \Delta A.\Delta Y$---------- (2)

Change in production = Yield effect + Area effect + Interaction effect

Thus, the total change in production is attributed to area and yield that can be decomposed into three effects viz; yield, area and interaction effects.

Instability index

Instability means the quality or state of being unstable or lack of stability. Agricultural instability can be measured by different methods, such as the coefficient of variation (CV), dispersion, Cuddy Della Valle Index (CDI), Coppock Instability index, etc. The present study applied the Cuddy and Valle (1978) Index to examine the nature and degree of instability in the area, production, and yield of black grams in Bangladesh. The use of CV as a measure to show the instability in any time series data has some limitations. It does not explain properly the trend component inherent in the time series data. If the time series data exhibit any trend, the variation measured by CV can be overestimated, i.e. the region which has growing production at a constant rate will score high in instability of production if the CV is applied for measuring instability. As against that, CDI first attempts to de-trend the CV by using the coefficient of determination (R^2). Thus, it is a better measure to capture instability in agricultural production. A low value of this index indicates low instability in production and vice-versa. The estimable form of the equation is as follows:

$CV_t = (CV) \times \sqrt{1 - R^2}$ ---------- *(3)*

Where, CV_t is the coefficient of variation around the trend; CV is the coefficient of variation around the mean in percent; and R^2 is the coefficient of determination from time trend regression adjusted by the number of degrees of freedom.

$$CV = \frac{Standard\ deviation}{Mean} \times 100$$

$$R^2 = 1 - \frac{Unexplained\ variation}{Total\ variation}$$

Results and Discussion

Trends of area, production and yield of black gram in Bangladesh

The trends in the area, production and yield of black gram in Bangladesh have shown fluctuations over the decades. The cultivated area and production of black gram in the first decade initially showed a declining trend until 1985-86, after which there was an increasing trend from 1986-87 to 1989-90. This increase in area during the second decade, up to 1998, was driven by the black gram's resilience to waterlogging, lesser susceptibility to diseases and pests, consistent yields, and minimal production costs (Rahman, 1989). This led to a period of higher area and production between 1987-88 and 1997-98. The second decade, starting from 1998-99 to 1999-2000, once again witnessed a decline. In the third decade, spanning up to 2004-05, the trend of decreased area and production persisted. This decline was attributed to cultivation of local cultivars with traditional farming methods towards low yields, shortage of essential inputs, and (Rahman and Baten, 2016). However, starting in 2005-06 of the third decade witnessed a

resurgence in black gram cultivation, and this upward trend continued into the fourth decade. While the yield remained relatively stable during the first and second decades, it showed an increasing trend during the third and fourth decades, albeit with some minor fluctuations.

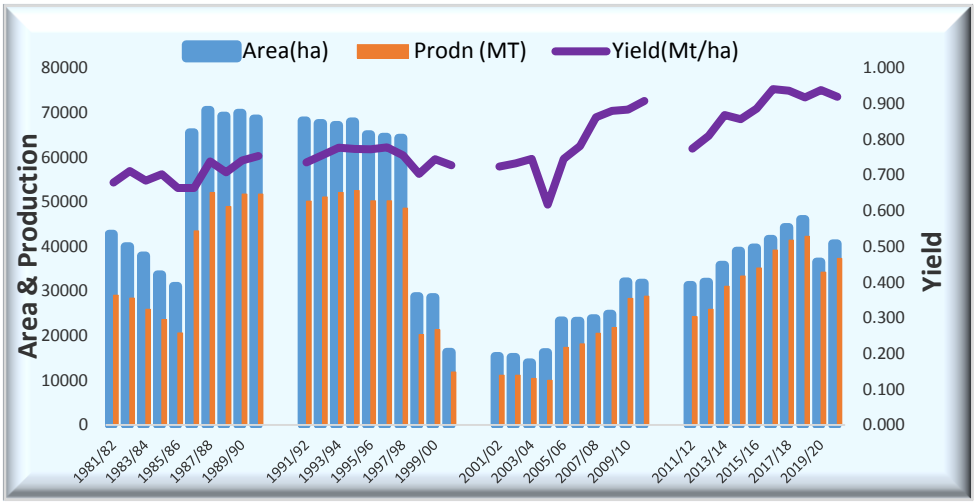

Fig. 1. Trends of area, production and yield of black gram during 1981-82 to 2019-20

Source: Using data from various issues of BBS in different years.

The overall indices showed that the area and production of black gram increased to some extent from its base period of 1981-1990 during 1991-2000. But the overall indices of area and production indicated a decreasing trend over the period from 2001-2010 to 2011-2020. On the other hand, the productivity indices revealed an increasing trend during the period from 1981-90 to 2011-20 (Table 1.). Despite the decrease in area, the yield of black gram has gone up in those periods which was mainly due to the cultivation of improved varieties (BARI Mash-1, -2, -3, -4 & -5) along with adoption of appropriate management technologies.

Table 1. Index of area, production and yield of black gram in Bangladesh

Period	Area (%)	Production (%)	Yield (%)
1981-1990	100 (52914)	100 (37565)	100 (0.704)
1991-2000	101.8	108.7	106.8
2001-2010	41.6	47.3	111.8
2011-2020	73.1	91.6	125.6

Note: Figures within parentheses indicate the 10-year average value in the base year of the indices.

Source: Various issues of BBS

Annual growth of black gram production

The overall annual growth rates scenario reveals that the area and production of black gram registered a negative growth rate during 40 years' period (1981-2020)

although the production growth rate was not significant at all (Table 2). On the other hand, black gram yield had a significant positive growth rate during the 40-year period. The growth rates of different periods show that some growth rates registered both in area and production were found positive and significant from 1981-1990, 2001-2010, and 2011-2020. Both area and production growth rates were found negative during 1991-2000 due to the limited adoption of HYV black gram technology (BARI released 3 black gram varieties during 1990-1996). However, the growth rates of yield were positive and highly significant for all periods except the period 1991-2000. The highly significant growth rates of productivity were mainly due to the adoption of improved black gram varieties and matching production technologies. This indicates that adoption of newly developed high yielding to be realized in farmers' fields.

Table 2. Annual growth rates of area, production and yield of black gram (1981-82 to 2019-20)

Period	Area (ha)	Production (mt)	Yield (t/ha)
1981-1990	8.57***	9.50***	0.93*
1991-2000	-14.13***	-14.60	-0.47
2001-2010	9.60***	12.77***	3.17***
2011-2020	3.01**	4.92***	1.92***
1981-2020	-1.43**	-0.68	0.76***

Note: '***' '**' & '*' represent 1%, 5% and 10% level of significant

Sources of growth of black gram production

Change in the mean area appeared to be the largest source of change in the mean production of black gram in all the periods. At the national level, changes in the mean yield were the main source of changes in black gram production in Bangladesh. The change in yield contributed 142.25% of the changes in the mean production of black gram at the national level. The overall scenario indicates that the positive change in production has been attributed to the positive change in the area (Table 3).

Table 3. Growth decomposition in the production of black gram (1981-82 to 2019-20)

Period	Effect (%)				
	Area (A)	Yield (Y)	Interaction	Residual	Total
	$\Delta A*Y$	$A*\Delta Y$	$\Delta A*\Delta Y$	$\Delta COV(A,Y)$	ΔQ
1981-1990	75.26	26.62	1.89	-3.77	100
1991-2000	93.71	1.14	-5.15	10.30	100
2001-2010	72.99	31.04	4.03	-8.06	100
2011-2020	89.73	11.20	0.93	-1.86	100
1981-2020	-3.29	142.25	38.97	-77.93	100

Source: Author's calculation using BBS data of different years

Instability of black gram cultivation

The estimates of instability in area, production, and yield of black gram are presented in Table 4. The instabilities of the black gram area (4.37%) and production (4.89%) at the national level were not so high, but the instability of production was little bit higher than the area instability. On the other side, the instability related to productivity was about -25.7% during 1981-82 to 2019-20 meaning that black gram productivity was almost stable and increasing over the stipulated period. The reason for the stability is due to release of three high yielding varieties (1990-1996)990-96 and their adoption at farm level between 2001-2020, resulted in increase in production.

Table 4. Instability indices for area, production and yield of black gram (1981-82 to 2019-20)

Period	Instability (%)		
	Area (ha)	Production (t)	Yield (t/ha)
1981-1990	2.03	2.20	-10.21
1991-2000	2.72	3.01	-10.52
2001-2010	1.03	1.45	-29.96
2011-2020	0.86	1.08	-26.21
1981-2020	4.37	4.89	-25.70

Source: Author's calculation using BBS data of different years

Conclusion

Over the study period from 1981-82 to 2019-20, an analysis of black gram cultivation revealed significant fluctuations in cultivation area, production levels, and yield. However, a closer examination of the last ten years presents a distinct perspective, showing a consistent upward trend in the cultivation area, production, and yield of black gram. This recent pattern indicates a positive shift in how black gram is cultivated and managed. The increase in yield can be attributed to the widespread adoption of improved varieties and advanced management technologies. These advancements have likely played a pivotal role in enhancing overall black gram productivity, contributing to the upward trajectory observed in both cultivated area and production. The success of sustainable agricultural practices relies on achieving a balance between high growth rates and low production instability, a critical consideration with significant implications for researchers and policymakers. In the context of this study, a comprehensive investigation into black gram production in Bangladesh has yielded insightful findings. The analysis of growth in black gram production underscores a positive and substantial increase in yield. However, it's important to note that this growth is modest, suggesting a need of genetic innovation and agronomic research in future. In contrast, a different trend emerges concerning black gram cultivation area and production, both showing negative growth rates. This decline raises concerns about the potential shrinking of cultivable land or declining interest among farmers in cultivating black gram. The vulnerability of agricultural production to natural disasters remains an enduring reality in Bangladesh,

introducing an element of instability. A national-level perspective reveals relatively lower degrees of instability when analyzing the extent of instability in black gram cultivation. This highlights the resilience of black gram cultivation in the face of climatic fluctuations, providing a sense of stability within the broader agricultural landscape.

Recommendations

Based on the conclusions drawn from this study, several recommendations can be put forth to foster sustainable growth in black gram production in Bangladesh. To begin with, agricultural researchers should release farmer-preferred black gram varieties that are both more climate-resilient and high-yielding, aligning with the domestic demand. Secondly, the improved black gram varieties and technologies already developed by BARI should be introduced to farmers through massive deployment initiatives. Thirdly, research and policy support are needed to increase the acreage and yield of black gram which will help increase the per capita availability of black gram, reduce import dependence, and to some extent stabilize prices. Ultimately, fostering collaboration between research institutions, quality seed production agencies, non-governmental organizations, agricultural marketing and private sector participants should be prioritized, as it holds the key to augmenting the growth and stability of black gram production in Bangladesh.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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