Bangladesh J. Agric. Econs. XX, 2 (1997): 1-19

THE GROWTH OF MV RICE PRODUCTION AND ADOPTION IN BANGLADESH

M. A. Jabber
R. Palmer-Jones

ABSTRACT

The study develops a model to estimate the growth of both production and adoption of modern rice varieties (MVs) in Bangladesh. Using secondary data on the level of adoption and production of MV rice and employing various statistical tools it was found that, out of three main rice crops (Aus. Aman and Boro). Boro has shown the fastest rate of growth in recent decades. The adoption of existing technologies has almost been exhausted. Furthermore, (a) MV adoption levels in the Aman season were below the centered moving average during the period 1972-94: (b) out of 21 greater districts of Bangladesh 17 had adoption levels below 50 percent in the 1990s and the figures ranged from 20 to 70 percent because the price of rice has gone up at a relatively low rate as compared to price of vegetables, spices and production inputs: (c) access to credit, availability of family labour. supplementary irrigation, soil type and rainfall are factors influencing MV T. Aman adoption levels across all the zones: and (d) cultivation of MV T. Aman is most profitable in the non-flood/nondrought zone as expected from known characteristics of MVs. Specific barriers to MV adoption in T. Aman season are tal varietal degradation due to seed contamination: (6) lack of location specific varieties: lcl lack of insect and disease-resistant varieties; and (d) lowprice of rice compared to other commodities (especially agricultural inputs) which make it difficult for tenant farmers to benefit from growing MV T. Aman rice. The research suggests that (i) location-specific and insect and disease-resistant varieties for T. Aman season need to be developed for the diverse agrqecological rice zones: (ii) the credit facilities be provided considering the amount of land devoted to MV rice than farm size: and (iii) rice farmers are to be motivated to grow BR-28, BR29 in Boro season, replacing the previous Boro varieties.

I. INTRODUCTION

Production of rice in Bangladesh has increased in the'two decades from independence in 1971 up to 199 L However, there has been a slight decline during the early part of the 1990x. because of continuous drought conditions in these years (BRRI, 1994). The introduction of modern technology and adoption of modern High-Yielding Varieties (HYVs) has increased yields and changed cropping patterns. It was even possible to accelerate yield growth during the 1980s, notwithstanding two *of* the worst floods in the country's history (Goletti. 1994).

The authors are respectively Principal Scientific Officer, Agricultural Economics Division, BRRI. Bangladesh and Staff Member, School of Development Studies, University of East Anglia, U.K. This article is based on the first author's Ph.D. thesis completed at School of Development Studies, University of East Anglia, U.K. The authors expiess their gratitude to the referees for their useful suggestions given on the manuscript of the paper.

Productivity growth, as measured by improvements in aggregate yields, was very high during 1985-90, even in comparison with the five main rice exporters, namely, Thailand, United States. Pakistan, Vietnam, and Myanmar (IRRI, 1992). The economy seems to be moving toward self-sufficiency in rice- a remarkable accomplishment for a country characterised by chronic food deficits. At the same time, the recent move in many developing countries towards a heavier reliance on the market and a progressive removal of regulatory measures that directly and indirectly control the operations of the food markets has also an influence on production levels in Bangladesh (Chowdhury, 1992; Goletti, 1994).

Goletti believes that self-sufficiency in food is achievable only through a growth in rice production, but does not analyse whether an increase in MV adoption has contributed to growth in production. This paper will analyse the rate of growth in rice production and levels of MV adoption for the years 1972-94. An attempt has also been made to bring out the relationship between production and MV adoption in different seasons. This has been done in order to assess the importance of each of the factors by season.

The paper has been organiged in four sections. Analytical framework is discussed in section II. Empirical results are presented in section III while conclusions are provided in the final section.

II. ANALYTICAL FRAMEWORK

Analytical Model of Growth of Rice Production

Analysis was carried out in order to examine the relationships between the growth rate of rice production yield, inputs and price, both within and between different seasons. In Bangladesh, prices fluctuate widely from year to year, particularly for rice; and rice production is responsive to changes in relative prices (Cummings, 1994; Rahman, 1986).

From data for the period 1972-94, growth rates of rice production are computed using the equation

$LnY_1 = \beta_1 + \beta_2 t$ (which is a modified version of the model given by Gujarati, 1995)

where Y_1 = rice production, β_1 = constant, β_2 = slope and t = time.

Adding the disturbance term to the above equation, the following can be obtained.

$$LnY_1 = \beta_1 + \beta_2 t + u_2$$

This is a log-linear model, in which the regressand in the logarithm of Y and the regressor in 'time', which will take values of 1,2,3 etc.

Such models are called semilog models because only one variable (in this case the regressand) appears in the logarithmic form. For descriptive purposes, a model in which the regressand is logarithmic will be called a log-linear model. Later, a model will be considered in which the regressand is linear but the regressor(s) are logarithmic. This will be called a linear-log model.

The continuous or linear-log model has been chosen to examine the actual and continuous growth of production over time-period. This model fits well for the study of growth in rice production, as this is a continuous activity throughout the year in different seasons.

Analytical Equation for MV Rice Adoption

In order to assess the progress of adoption of modern rice varieties since 1972 to 1994, the following equation has been used which is a modified version of the equation given by Gillspie (1990).

Actual = Trend + Cyclical + Seasonal + Residual

where,

Actual = Percentage MV rice adoption;

Trend = Central moving average (average of the three rice production seasons);

Cyclical effects = The effects of business cycles, i.e. cyclical functions

Seasonal effects = Obvious examples in Bangladesh are the seasonal variations in MV rice adoption

Residual = Actual – Trend (any other effect which is non-cyclical and non-seasons)

Rice being a food item whose price elasticity of demand or cyclical elasticity of demand are nearly or very close to zero, the cyclical effects can be safely ignored. If cyclical changes are ignored, the model becomes

Actual = Trend + Seasonal + Residual

It is necessary to remove seasonal variations from the data, so that the observed values give a better guide to long-trends. When seasonal variations are removed, the data are normally referred to as "seasonally adjusted". This method has been adopted as it shows the seasonally adjusted variation, which is quite important to the analysis of adoption of MV rice.

III. EMPIRICAL RESULTS

Growth of MV Rice Production in Different Seasons

What has been the impact of latest technological development on the growth of rice production? This section analyses the official time series data concerning area sown and rice production for different seasons form 1972-73 to 1994-95, to see whether production growth has accelerated since the introduction of modern varieties of rice.

Over the period 1972-73 to 1994-95, total output of rice from modern varieties grew at an exponential rate of 7.26 per cent, with a marked difference between seasons (Table 1). In the Aus (Summer) season, the growth rate was low at 2.14 per cent for the whole period, due to drought conditions and disease/pest attack. In the 1970s, the growth for the Aus season was very high (17.10%), due to the introduction of the BR1 variety. In the 1980s and 1990s the growth rate of MV rice in the Aus season is seen to decline, more rapidly in the 1990s, reflecting the ages of rice varieties and a shift in area to Boro rice. The rise in Aus production in the 1970s reflects a number of factors, including the spread of MVs (grown with irrigation) and declining jute a acreage. The more recent fall in Aus production reflects competition with increasing Boro rice areas (Palmer Jones 1992; A-130). As the BR1 old variety, it became less effective within a ten year period (Zaman, 1986).

Table 1. Growth Rates and Variability of MV Rice Production in Different Seasons, 1970s, 1980s and 1990s (%)

Growth/Variability	Aus	Aman	Boro	All
Growth Rate				
1970s, 1980s and 1990s	2.14	7.82	8.33	7.27
1970s	17.10	5.33	1.32	5.11
1980s	-2.63	11.30	9.76	8.58
1990s	-11.92	-3.99	-0.37	-2.80
Variability of Production				
1970s, 1980s and 1990s	4.32	2.70	2.08	1.36
1970s	5.98	3.65	2.70	1.77
1980s	2.52	1.97	1.01	0.92
1990s	2.29	2.47	1.54	1.54

Note. Variability of production is measured by the standard deviation of per centage differences between production figures and a quadratic trend.
The 1970s refers to the period 1972-73 to 1980-81
The 1980s refers to the period 1981-82 to 1990-91
The 1990s refers to the period 1991-92 to 1994-95 (the data are available for only four years)

Source. Analysis based on data from the Bangladesh Bureau of Statistics.

In the 1980s, the growth rate for the Aman season was very high at 11.30 per cent (Table 1), due to the introduction of the BR11 variety in the year 1980 (Jabber, 1996). The negative growth rate for the 1990s is mainly due to the ageing of this variety and its becoming less productive over time, coupled with recurring drought during the Aman season in each year from 1991 to 1994 (Jabber, 1996). The declining growth rate observed in the 1990s is not representative because data are only available for four years and these years were unusual in the sense that there was continuous drought.

In the Boro season, growth rate for the period 1972-73 to 1994-95 is very high at 8.33 per cent (Table 1), because of provision of irrigation. In the 1990s, negative growth rate is due to lack of new varieties of rice and ageing of the existing ones. However, it should be noted that this negative growth may not be representative, being based on data for four years only.

By taking the deviations of production figures from the trend, it is possible to analyse the variability of production (Table 1), which shows that production in the 1970s was more stable than in the 1980s and 1990s. The 1980s witnessed two of the worst floods in the country's history, while in the 1990s there has been drought during the production period in each of the four years for which data are available.

A negative correlation is observed between Boro and Aus season rice, production for MVs, indicating inter-seasonal compensation (Table 2). A bad crop is often followed by a good crop, making up for loss in production. This also partly explains why time series estimates of supply response based on a yearly production give very low elasticities, often not significantly different from zero (Mahmud et al., 1993). The failure to take this negative correlation into consideration has been responsible for an exaggerated assessment of food import requirements in the past (Hossain, 1990). Government could do better by waiting till the Boro crop before making an assessment of food import requirements, as this would give a more realistic picture of food grain availability.

Table 2. Correlation of MV Rice Production in Different Seasons

Crop	Aus	Aman	Boro	All MV
Aus	1.0			
Aman	0.038	1.0		
Boro	-0.412**	0.294	1.0	
All MV	0.089	0.841*	0.674*	1.0

Note. The correlations are based on residuals from quadratic trend regressions of crop production over time.
* significant at 1% level
** significant at 5% level

Source. Analysis based on data from the Bangladesh Bureau of Statistics.

The detailed season-wise production figures for rice (actual and predicted) are presented in Figure 1 (Aus, Aman and Boro). Predicted values were calculated based on the equation given by Gujarati (1995) :

$$LnY = a + b_t + u_t$$

where LnY = estimated log production, a = constant, b_t = slope and u_t = time error (Jabber, 1996) for calculations of combined production of MV rice, worked out as an example).

The production of MV rice in the Aus season shows relatively more variation on a year to year basis as compared to other seasons. The best growth was observed in the years 1972 to 1975, from 0.2 to 0.9 million tonnes clean rice per year. The new rice variety, BR1, mainly accounts for this increase.

Later production remained stagnant at around 0.6 million tonnes, which is attributable mainly to drought conditions. Contribution of this season to total MV rice production is about 10 per cent (Figure 1).

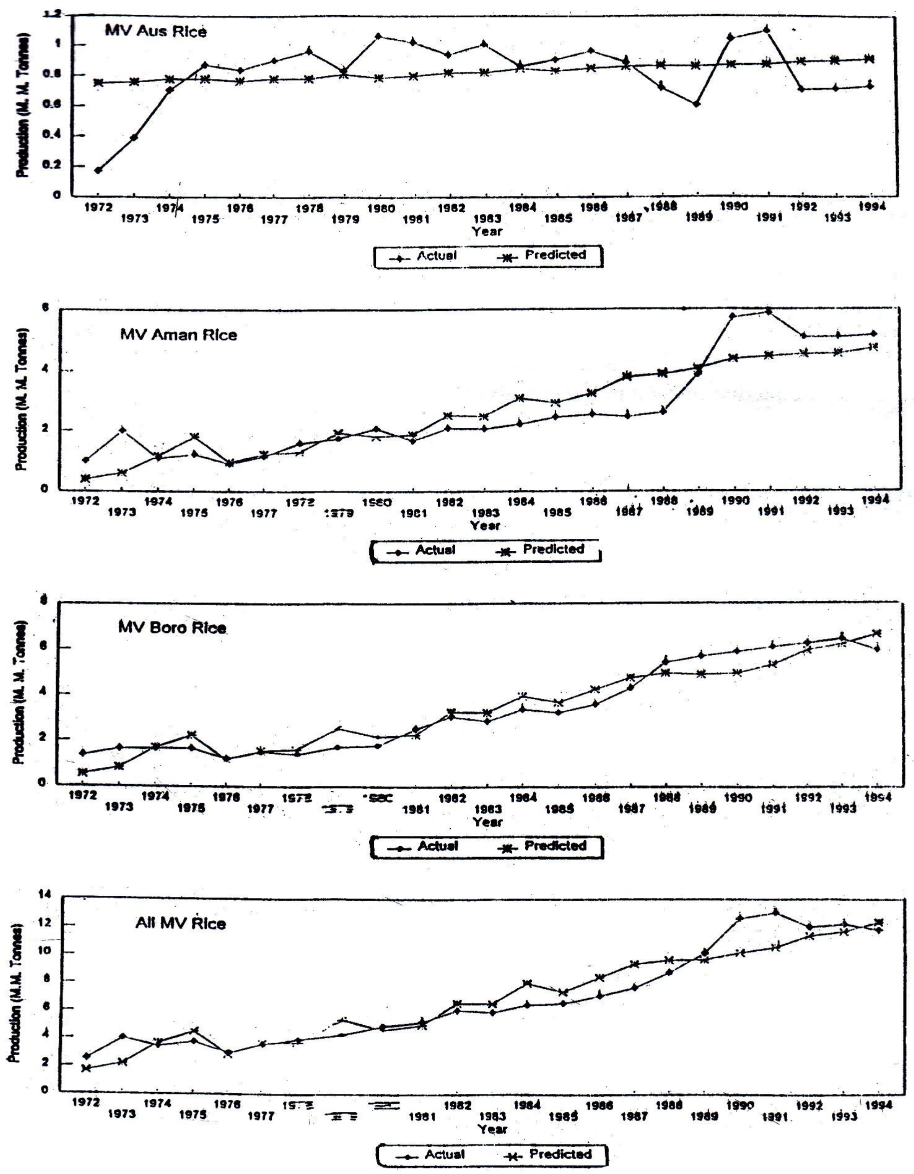

Fig. 1. MV Rice Production in Different Seasons, Bangladesh.

The production of Aman rice has been increasing consistently during the period 1974 to 1988, while 1989 and 1990 saw substantial increases. This is attributed mainly to two factors, the subsidised seedling multiplication and distribution scheme, which was in force from 1988 to 1991, and an increase in the acreage of MV rice by 19 per cent (BBS, 1994). The share of MV Aman rice is about 40 per cent of the MV rice total (Figure 1).

The production of MV Boro rice shows greater consistency compared to the two other seasons. The availability of irrigation facilities for Boro rice explains this resilience. MV Boro rice is totally supported by irrigation, 86 per cent by modern methods and 14 per cent by traditional methods (BBS, 1994). Only in 1994 did production decline marginally, and this is attributable mainly to the increase in price of fertilizers (Jabber, 1996). MV Boro rice constitutes nearly half of the total MV rice production (Figure 1).

Growth Rate of MV Rice Yields and Inputs

As discussed earlier in this paper, the growth rate of MV rice production during the 1990s (average of four years) is not comparable with the data for the 1970s and 1980s. Hence, this section limits the analysis to the periods 1970s and 1980s, so as to bring about comparable relationships between the two decades.

Average growth rate of rice yield has gone up from 2.13 per cent in the 1970s to 2.21 per cent in the 1980s. The main contribution to this increase is the growth rate for the Boro season (50%) from 1.01 per cent to 1.5 per cent, and partially that for the Aman season (10%) from 2.4 per cent to 2.62 per cent (Table 3). This increase in yield is on account of the adoption of modern inputs (irrigation, fertilizers and MV seeds) as a package, and also provision of transport infrastructure and electricity which facilitated the process of growth and development (Ahmed and Hossain, 1990).

Table 3. Growth Rate of Yield, Total Acreage, MV Acreage and Irrigated Acreage in Different Seasons, 1970s and 1980s (%)

Growth Factor/Period	Aus	Aman	Boro	Average
MV Rice Yield				
1970s-1980s	1.21	1.71	1.42	2.18
1970s	2.44	2.41	1.01	2.13
1980s	1.19	2.62	1.50	2.21
Total Rice Acreage				
1970s-1980s	0.80	1.03	4.61	1.39
1970s	1.28	1.01	1.46	1.05
1980s	-0.90	1.92	7.31	2.10
MV Rice Acreage				
1970s-1980s	6.95	7.98	8.81	7.35
1970s	15.25	2.45	3.78	4.91
1980s	-2.30	6.83	10.89	7.21
Irrigated Rice Acreage				
1970s-1980s	3.46	3.33	4.21	3.93
1970s	5.71	1.72	1.05	1.88
1980s	3.85	2.08	8.72	5.35

Note: The '1970s' refers to the period from 1972-73 to 1980-81
The '1980s' refers to the period from 1981-82 to 1990-91

Source : Analysis based on data from the Bangladesh Bureau of Statistics.

The average growth of total rice acreage during the entire period (1970s-1980s) is only 1.39 per cent. while the average rate for MV rice acreage is 5.35 per cent and for irrigated rice acreage 3.93 per cent. The substantial increase in MV rice acreage and irrigated rice acreage has contributed to the total increase in rice production during these two decades. The share of irrigated land devoted to foodgrain production is about 80 per cent. There has been a bias toward foodgrains as against other crops which declined from 13 per cent in 1972-73 to 8 per cent in 1987-88 (Mahmud, et al., 1993). Within the foodgrains sector, acreage under MV Boro and MV Aman rice has increased during the 1970s and 1980s, while there has been a decline for MV Aus during this period (Table 3).

Irrigation policy has been characterized by a reduction of subsidies and the removal of impediments to trade and distribution of irrigation equipment (Chowdhury and Shahabuddin, 1992). The liberalisation of import of irrigation equipment in 1988 has resulted in a wider spectrum of minor irrigation methods. Despite the removal of heavier subsidies on similar "approved" equipment, farmers have been able to expand irrigated areas at a faster rate because of the enhanced possibilities of choosing adequate equipment (Gisselquist, 1992).

The yield of MV rice (clean rice) increased from 1.29 tonnes/hectare in the 1970s to 1.65 tonnes/hectare in the 1980s, while the share of MV rice production has gone up from 29 per cent in the 1970s to 49 per cent in the 1980s. This is due to measures undertaken to increase in irrigation facilities which can be seen from the change in the share of irrigated rice production from 17.0 per cent in the 1970s to 24.58 per cent in the 1980s (Table 4).

Table 4. Yield and Share of MV and Irrigated Rice in Different Seasons, 1970s and 1980s

Yield/Share	Aus	Aman	Boro	Average
MV Rice Yield (Tonnes/hectare)[a]				
1970s-1980s	1.01	1.40	2.09	1.41
1970s	0.98	1.28	2.11	1.29
1980s	1.08	1.68	2.51	1.65
MV Rice Share (%)				
1970s-1980s	14	29	63	42
1970s	11	24	51	29
1980s	19	35	81	49
Irrigated Rice Share (%)[b]				
1970s-1980s	3.31	2.61	84.01	18.21
1970s	2.60	1.96	79.35	17.01
1980s	4.72	3.28	86.29	24.58

a = Clean Rice
b = Rice produced with irrigation facilities
Note: The "1970s" refers to the period from 1972-73 to 1980-81
The "1980s" refers to the period from 1981-82 to 1990-91
Source : Analysis based on data from the Bangladesh Bureau of Statistics

Fertilizer use has increased at an exponential growth rate of 10.8 per cent, from about 250,000 tonnes in 1972-73 to about 2 million tonnes in 1990-91. Since the early 1980s, Bangladesh has reduced fertilizer subsidies considerably and has promoted the development of private wholesale trade, which was previously controlled by the Bangladesh Agricultural Development Corporation (Chowdhury and Shahabuddin, 1992; Hossain and Dhaly, 1991). This process of liberalisation was accompanied by a slight decrease in the growth rate of fertilizer use in the 1980s, although it continues to be at a considerably high level of 9.3 per cent (Chowdhury and Shahabuddin, 1992).

Relative Price Trends of MV Rice and Agricultural Inputs

The relative price index for diesel (1972-73 = 100) rose sharply in real terms to 597 in 1995-96 (Table 5). Similarly, the price index of other agricultural inputs, labour (wages), fertilizer and insecticide, have also increased to 136, 116 and 111 respectively during 1994-95 (1972-73 = 100). The price index of rice during the corresponding period has gone up to only 104.

Table 5. Trends in the Prices of Agricultural Inputs and Harvest Prices of Major Crops in Bangladesh 1972-73 to 1995-96

Input/Output	Growth Rate* (% per annum)	Average (1972-73 base)	Price Index 1995-96	Relative Price Index (1972-73 = 100)
Diesel	25.56	100	2084	597
Agricultural Wages	12.59	100	474	136
Fertilizer	12.85	100	488	116
Insecticides	10.01	100	526	111
Cereals	9.39	100	337	69
Rice	9.43	100	349	104
Pulses	13.82	100	440	90
Mustard and Oil Seeds	8.22	100	316	65
Jute	12.65	100	595	122
Sugarcane	10.77	100	440	90
Tobacco	7.39	100	309	63
Potato	5.54	100	236	48
Spices	11.96	100	508	104
Vegetables	15.57	100	612	125
All Agricultural Prices	11.35	100	469	100

Note : *Estimated by semilog function fitted to least square trend line.

Source : Price Information Collected from Bangladesh Bureau of Statistics (Dhaka: various years).

The relatively low rise in price of rice in Bangladesh has followed the international trends of relatively lower price rises for primary commodities. Although Bangladesh is largely an agrarian economy, the country's ability to pay for imports of foodgrains grew in the 1980s. This is highlighted by the declining value of the food dependency ratio. Even though trade (external) in foodgrains was heavily controlled by the government during the 1970s and 1980s. this has not resulted in isolation of the domestic price from the international price. The trend of border prices of rice has been closely followed by domestic prices (Goletti, 1994).

The index of growth of rice production during the same period has gone up to 467 in spite f increases in the prices of inputs. The increase in irrigated area. shifting of rice area from local to modern varieties and an increase in MV rice area have contributed to the increase in production (Jabber. 1996).

The relative changes in prices of other commodities have had a minor effect on their share of area cultivated (Jabber, 1996). This did not have any negative effect on the rice area. mainly because the shares of these crops (spices, vegetables and potatoes) were small in relation to rice. Also, commodities such as vegetables and spices (basically the chilli crop) are more perishable, and Bangladesh does not have an extensive chain of cold storage or the swift marketing network which is needed for vegetable marketing.

The relative changes in prices of other commodities have not led to a change in cropping systems for the reasons indicated above. Furthermore, as the cultivation of modern varieties is more profitable than local varieties (Hossain et al., 1994), a shift from MVs to LVs is not envisaged.

Procurement Price of Rice

The way the government has implemented procurement activities in the past has been to buy a certain quantity at a pre-announced price, called the procurement price. Since procurement depends on the capacity and willingness of farmers and traders to sell. procurement is constrained by this supply decision unless some forced arrangement is put into effect (Gulati and Sharma, 1990; Palaska and Harris, 1991). This implies that procurement prices should be comparable with market prices. In fact, during the periods 1970s and 1980s, procurement prices were lower than market prices. Price elasticities of rice offtake for both modern and local varieties is negligible and the price elasticity for procurement of rice is quite high. i.e. for MV 0.49 and LV 0.56 (Table 6). Procurement is price sensitive and this price affects rice procurement for both the varieties.

Table 6. Price Elasticities of MV and LV Rice with Respect to Offtake and Procurement

Varieties of Rice	Offtake		Procurement	
	MV Rice	LV Rice	MV Rice	LV Rice
MV Rice	-0.07	0.02	0.49	0.03
LV Rice	-0.10	0.03	0.56	0.04

* = Offtake price is the price at which government sells to the public, through ration shops.

Note : Price elasticities are calculated based on the formula given by Henderson and Quandt, 1971.

Source : Computed by the researcher based on data from the Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh and Hamid, 1991.

Growth of MV Rice Adoption by Seasons

The time series data reviewed above show a large variation in adoption rates between the Boro season and the other two seasons (Figure 2). This may be because of the complementarity of the MV package - the need for irrigation, seeds and fertilizer to be used together - and the fact that it is only during the Boro season that irrigation is present.

In 1972, MV Boro adoption was 48 per cent (Figure 2), and at that time the irrigated area was only 18 per cent (BBS, 1990). In 1994, MV Boro adoption of 92 per cent was associated with an increase in the irrigated area to 34 per cent (BBS, 1994). Thus MV seeds and irrigation have played an increasingly important role in the adoption of MV Boro rice in Bangladesh. These findings agree with the hypothesis of Hossain (1986) and Boyce (1986). Through the Benchmark Survey, the present study found that a large variation in the diffusion of MV adoption is found among different AERZs in Bangladesh. By 1990-94, the proportion of land irrigated by modern methods had increased to over one-third in the districts of Bogra, Kushtia and Chitttagong, while it was still less than 15 per cent in the coastal districts of Patuakhali, Barisal, Khulna and Noakhali.

In 1972 the adoption rate of MV Aus rice was around 2 per cent (Figure 2) which increased to about 16 per cent in 1994. MVs of Aus cannot compete with MVs of Boro rice because of pest infestation, drought stress and lower yield (BRRI, 1988).

MV T. Aman rice cultivation is largely dependent on rainfall during the crop season. Infestation of weeds, insects and diseases are observed to be relatively low in the Aman season compared to the other two rice seasons, and evidence shows that the per hectare cost of MV T. Aman rice cultivation is lower than that of both MV Boro rice and MV Aus rice (BRRI, 1988). However, the analysis shows that adoption of MV T. Aman rice is below the central moving average for the whole period 1972-1994 (Figure 2).

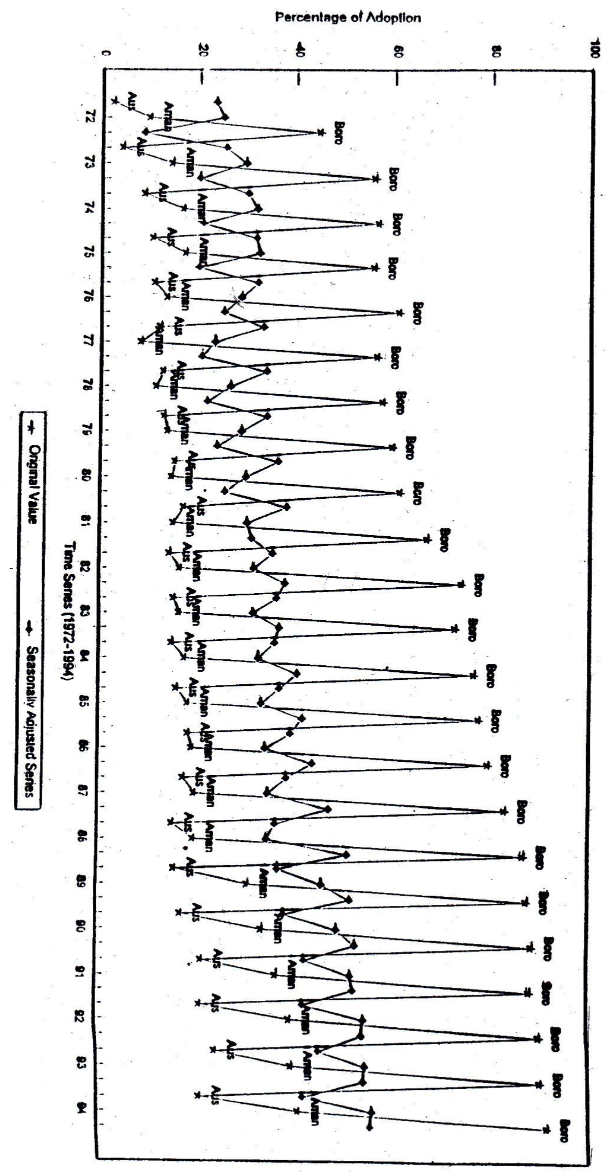

Fig. 2. Adoption of MV Rice in Different Seasons (Seasonally Adjusted Series).
Source : Bangladesh Bureau of Statistics.

In the 1970s. MV T. Aman rice adoption is low because diffusion of MVs was in its initial stages and extension activities were concentrated on traditional varieties (ITAP. 1982). In the 1980s. adoption of MV T. Aman rice rose to 38 per cent, which is due to large scale demonstration (extension) effects, release of new varieties of rice- such as BR I I(Jahber. 1996). the introduction of a new Training and Visit System and improved research linkages through the District Technical Committee and Regional Technical Committee (Brady. 1979).

In 1989 and 1990, adoption of MV T. Aman rice increased drastically. attributable partIN to the effects of the Agricultural Extension Department Seed Multiplication Project (spread over the period 1988 to 1991) in each Thana (Administrative Unit) during the Aman season. where seeds were supplied to farmers at subsidised prices. In addition. the government also subsidised insecticides and promoted their use (Dewan, 1991). Because of this initiative, the adoption ofMV T. Aman rice moved closer to the central moving average from 1989 to 199-1 Figure 2). Apart from these factors, the growth of irrigated area under MV T. Aman rice has increased at a faster rate, 2.08 per cent in 1980s as compared to 1.72 per cent in the 1970s (see Table 3)- which has further contributed to the increased adoption rate of 43 per cent in the 1990S.

Adoption of MV T. Aman Rice Varieties in Different Zones of Bangladesh, 1970s to 1990s.

Adoption of MV T. Aman rice is analysed zone-wise; Non-Flood/Non-Drought, Flood-Prone, Drought-Prone, Flood and Drought-Prone, Salinity and Tidal Submergence. Flash-Flood and Hilly Areas.

Among the seven zones, the adoption rate in the NFD Zone is highest throughout tile period (Table 7). this zone being more suitable because of absence of floods and droughts. A Training and Visit Extension System was also initiated in this zone (Awal. 1983). Seventy er cent of land in this zone is very much suited to MV T. Aman rice cultivation (BARC. 1991). Another important contributing factor is the establishment of irrigation projects such as Ganges Kobadek (GK). Chandpur Irrigation Project. DhanaQoda Irrigation Project and Cornofully Irrigation Project (National Minor Irrigation Development Project. 1994).

In the Flood-Prone Zone, the MV T. Aman rice adoption rate has 'one up from 18 per cent in the 1970s to 40 per cent in the 1990s (Table 7) an increase of 22 per cent. i.e. more than doubling during the period. This increase has been made possible on account of construction of the Jumuna Embankment (reduction of flooded area), the Gomoti Embankment and Flood Protection Project and absence of flood since 1988 (Orr and Quayum. 1988).

In the Drought-Prone Zone, the adoption rate was 15 per cent in the 1970s and 18 per cent in the 1980s. Low adoption rates reflect the depressed rainfall, droughts, and presence of Terrace Barind Tracts (unsuitable for MV rice cultivation) in this zone (Willie and Mustafizur, 1983). Also, the root system of MV T. Aman rice is less resistant to dry weather conditions as compared to local varieties (IRRI, 1992-93). In the 1990s, the adoption rate has increased to 32 per cent, mainly due to an increase in irrigation facilities (1000 deep tubewells) in the area (RLRRC, 1994).

Table 7. Growth Rate of MV T. Aman Rice Adoption in Different Zones in 1970s, 1980s and 1990s (%)

Zone	1970s	1980s	1990s
NFD	32	40	52
FP	18	26	40
DP	15	18	32
DFP	20	22	35
STS	13	16	20
FF	12	15	17
HA	28	30	42
Average	18	25	44

NFD = Non-Flood/Non-Drought, FP = Flood-Prone, DP = Drought-Prone,
DFP = Drought and Flood-Prone, STS = Salinity and Tidal Submergence,
FF = Flash-Flood, HA = Hilly Area

Source : Computed by the researcher based on data from the District Agricultural Extension Office.

In the Drought and Flood-Prone Zone, MV T. Aman rice adoption has increased from 20 per cent in the 1970s to 22 per cent in the 1980s and 35 per cent in the 1990s. This is due to the increase in irrigation facilities (low-lift pumps) in the zone, using water flowing in streams and collected in ponds (RLRRC, 1994).

The adoption rates of MV T. Aman rice in the Salinity and Tidal Submergence Zone and Flash-Flood Zone are low throughout the three decades, for the following reasons; (a) many areas are of high salinity with tidal submergence; (b) 0.6 million hectares of land is under poor water management in the polder areas, i.e. a water control structure is not operational; (c) tidal submergence reaches maximum levels in the middle of August, giving no scope for MV T. Aman rice cultivation; (d) high incidence of pest attack due to proximity to the Sunderban forest, which is a breeding area for pests; (e) a high proportion of absentee landlords, i.e. more than 50 per cent (Panaullah et al., 1993).

In the hilly areas, the adoption rate has increased substantially from 28 per cent in the 1970s to 42 per cent in the 1990s. This is mainly due to the facility of seepage water in the mountain tracts utilised for cultivation of rice. The growth of adoption is attributable to the increase in irrigation through deep and shallow tubewells (Islam et al., 1991).

Adoption of MV T. Aman Rice Varieties by Old Districts

Out of 21 greater districts of Bangladesh, 17 have MV adoption levels below 50 per cent (Figure 3) during 1990s and the rate of adoption range from 20 to 70 per cent. The factors responsible for this lower adoption are non availability of credit, family labour, supplemental irrigation etc. Unfavourable soil type and insufficient rainfall are the retarding factors to MV adoption in T. Aman season across the districts. Differences in land type has been considered as the most important factor responsible for the differentials in adoption level among the districts (Jabber, 1996). Further more specific barriers identifed for MV T. Aman adoption levels are (a) the old of existing varieties (at least 10 years old); (b) lack of location specific varieties; (c) lack of insect and disease resistant varieties; and (d) higher price of agricultural inputs which make it difficult for marginal and small farmers to benefit from growing MV T. Aman rice (Jabber, 1996).

IV. CONCLUSIONS

Growth in production of MV rice, the major staple food of the population, was sustained and increasingly stable during the 1970s and 1980s as a result of the diffusion of modern improved varieties and the spectacular growth in production of Boro rice, which is entirely irrigated. Overall rice production has been growing over the long time period. Boro rice production has been more sustained, although Aus rice production has been fluctuating. The process of growth has been associated with the adoption of modern inputs involving the combination of seed-irrigation and fertilizer techniques.

The country has maintained the food-population balance since independence. During the period 1972-73 to 1995-96, the price of rice has gone up at a relatively low rate as compared to prices of vegetables, spices and inputs (diesel, labour, fertilizers, insecticides). Rice, being the staple food, has a large demand for consumption. The demand for commodities like spices and vegetables is relatively low. This explains the non-shifting of rice areas to other crops.

About one-third of cultivated land has been brought under modern irrigation, mostly through public investment. Total Aman rice production has also increased, due to a changeover from local to modern varieties and adoption of the package of crop management techniques without further increase in cultivated area since the early 1970s.

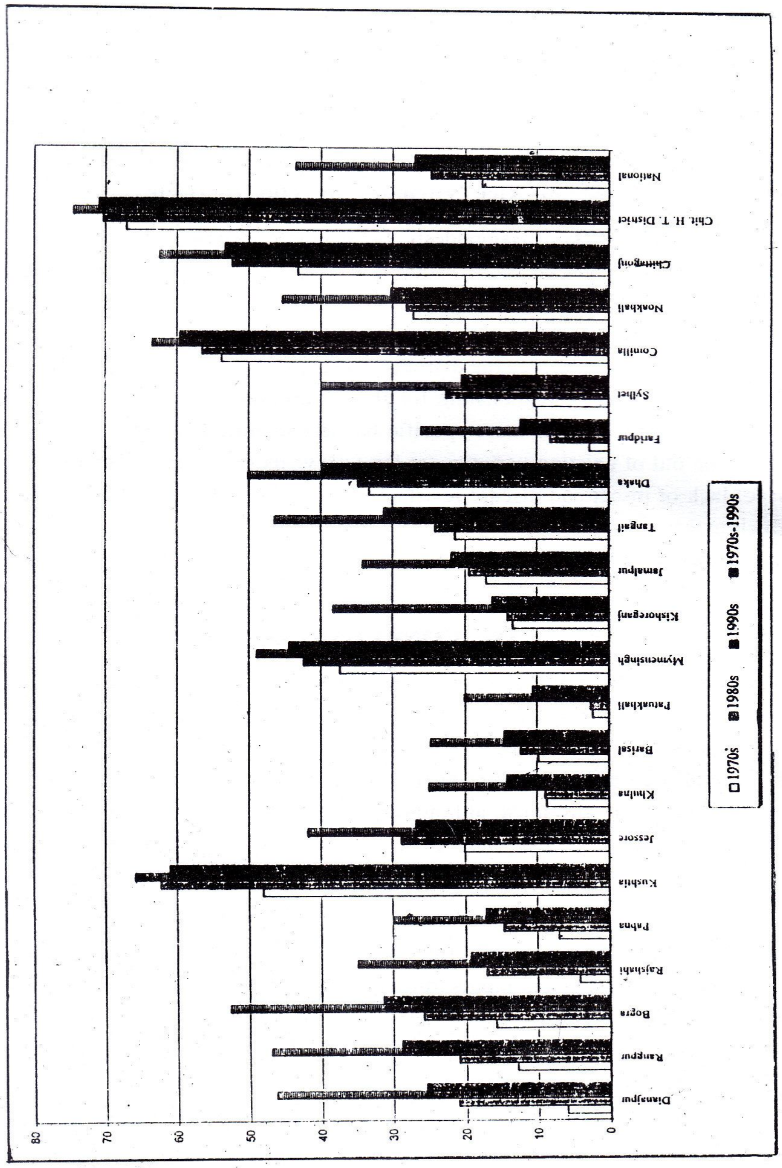

Fig. 3. Adoption of MV T. Aman Rice by Greater Districts in Bangladesh from 1970s–1990s.
Source : Bangladesh Bureau of Statistics

The government should play an important role as facilitator in the diffusion of MV seed through the Seed Multiplication Projects in each Thana by providing better quality MV T. Aman rice seeds. The government has invested directly in irrigation and drainage projects and increased the irrigated area.

Zone-wise adoption of MV T. Aman rice indicates an overall increase in all areas, although this increase has not been uniform across zones. From the analysis it can be seen that zone-specific factors explain differences in adoption levels for MV T. Aman rice. The Non-Flood/Non-Drought Zone has an adoption level above the average, Flood-Prone and Hilly Zones have closer-to-average adoption levels, while the other four zones have a much lower adoption level.

REFERENCES

Ahmed, R., and Hossain, M. (1990): Development Impact of Rural Infrastructure in Bangladesh. *Research Report 83*, Washington D.C.: International Food Policy Research Institute, 21-23.

Awal, M.A. (1983): Constraints to the Expansion of MV Rice Cultivation in Bangladesh, *Proceedings of the Workshop on Experiences with Modern Rice Cultivation in Bangladesh*, 5-32.

Bangladesh Agricultural Development Corporation, (BADC) (1982): Intensive Transplanted Aman Programme, Progress Report on Intensive Transplanted Aman Programme, Implementation Division, 11-38.

Bangladesh Agricultural Research Council (BARC) (1991): *Recommendations of the National Workshop on Risk Management in Bangladesh Agriculture*, BARC, Soils Publication No.36, 1-15.

Bangladesh Bureau of Statistics (BBS) (1990): *Statistical Pocket Book of Bangladesh*, Statistics Division, Ministry of Planning, Government of the Peoples Republic of Bangladesh. Dhaka, 137-141.

Bangladesh Bureau of Statistics (BBS) (1994): *Statistical Pocket Book of Bangladesh*, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, 73-78.

Bangladesh Rice Research Institute (BRRI) (1988). "Anual Internal Review", Paper Presented by Agricultural Economics Division, XXII, 35-47.

Bangladesh Rice Research Institute (BRRI) (1994): Anual Internal Review, Paper Presented by Agricultural Economics Division, XIV, 40-46.

Boyce, J.K. (1986). "Water Control and Agricultural Performance in Bangladesh", *The Bangladesh Development Studies*, **4** : 1-35.

Brady, N.C. (1979). "The Evaluation and Removal of Constraints of Crop Production", in 'Linking *Research to Crop Production*, (eds), (R.C. Staples and Kuhm, R.J.,) Plenum Press, New York.

Chowdhury, N.N. (1992): Rice Markets in Bangladesh: A Study in Structure, Conduct and Performance, Washington, D.C: International Food Policy Research Institute, Mimeo.

Chowdhury, W. H., and Shahabuddin, Q. (1992): A Study of Food Situation and Outlook in Asia. Country Report on Bangladesh, Washington D. C.,: International Food Policy Research Institute, Mimeo.

Cummings, John T. (1994): "The Supply Response of Bangladesh Rice and Cash Crop Cultivators", *The Bangladesh Development Studies*, 2: 235-251.

Dewan, F.K. (1991): On the Basis of Present Recommended Modern Varieties of Rice Cultivation and Prospect of Further Expansion, *Proceedings of the Workshop on Experiences With Modern Rice Cultivation in Bangladesh,* 15-18.

Gillespie, Ian, (1990): *An Introduction to Mathematics and Statistics,* Manuals and Report No.49, School of Development Studies, UEA, 139-143.

Goletti, Francesco, (1994): *The Changing Public Role in a Rice Economy Approaching Self-Sufficiency:* The Case of Bangladesh Research Report No.98. International Food Policy Research Institute, Washington, DC, 1-39.

Guesselquist, D. (1992). "Trade Reforms Open Door to New Technology", Paper Presented to the Annual Conference of the Association of Economic Development Studies on Bangladesh, November, 21-22, 1992, Washington D.C., World Bank.

Gujarati, D.N. (1995): *Basic Econometrics,* Third Edition, MC Grow-Hill, Inc., New York.

Gulati, A., and Sharma, P.K. (1990). "Prices Procurement and Production: An Analysis of Wheat and Rice", *Economic and Political Weekly,* March 31, **25 (13) :** A 36- A 47.

Hamid, M. A. (1991): *A Data Base on Agriculture and Foodgrains in Bangladesh* (1947–48 to 1989–90), Dhaka.

Henderson, J. M and Quandt, R. E. (1971): *Microeconomic Theory A Mathematical Approach (3rd Edition).* Mcgraw–Hill International Book Co., New York.

Hossain, M. (1986). "Irrigation and Agricultural Performance in Bangladesh:Some Further Results", *The Bangladesh Development Studies,* **4:** 39-56.

Hossain, M., Quasem, A., M., Jabber, M.A., and Akash, M.M. (1994): *Production Environments, Modern Variety of Adoption and Income Distribution in Bangladesh, Modern Rice Technology and Income Distribution in Asia, Boulder and London Lynne Rienner Publishers.*

Hossain, M. (1990). "Natural Calamities, Instability in Production and Food Policy in Bangladesh", *Bangladesh Development Studies,* **18(4):** 33-54.

Hossain, M., and Dhaly, M.R. (1991): Tracer Study on Recent Agricultural Policies in Bangladesh, Dhaka: Bangladesh Institute of Development Studies, Mimeo.

International Rice Research Institute (IRRI) (1992): Interanation Rice Research Newsletters, Vol. 17, Nos. 1,2,3,4,5 and 6 (Rice Literature Update).

International Rice Resarch Institute IRRI (1992-93): *Rice in Crucial Environments*, Manila, IRRI, 29-33.

Islam, J., Lukman, R.B., and Ghani, A. (1991): Supplemental Irrigation - A Safeguard Technique for Successful Cultivation of Modern Rice, (Transplanted Aman) in Bangladesh, *Irrigation and Drainage Systems,* Kluwer Academic Publishers Printed in the Netherlands, 155-170.

Jabber, M.A. (1996): Constraints to the Adoption of Modern Rice Varieties During the T. Aman Season in Bangladesh. Unpublished. Ph.D. Thesis, School of Development Studies, UEA, Norwich, UK.

Mahmud, W., Rahman, S.H., and Zohir, S. (1993): *Agricultural Growth Through Crop Diversification in Bangladesh.* IFPRI-BIDS Agricultural Diversification Study. Washington, D.C.: International Food Policy Research Institute.

NMIDP (1994): (National Minor Irrigation Development Project), Ministry of Agriculture, Bangladesh.

Orr. A.W., and Quayum, A. (1988): Agricultural Resource Use Under National Hazards: Deep Water Rice Bangladesh, *Research Report No.3,* Agricultural Economics Division, BRRI 3-20.

Palaskas, T.B., and Harriss, B. (1991): *Testing Market Integration :* New Approaches with Case Material for the West Bengal Food Economy. Institute of Economic Analysis, Oxford, U.K. Mimeo.

Palmer-Jones, R.W. (1992). "Sustaining Serendipity? Ground Water Irrigation, Growth of Agricultural Production, and Poverty in Bangladesh", *Economic and Political Weekly,* September 26, A-128 to A-140.

Panaullah, G.M., Farque, AKM and Roy, B.C. (1993): The Tidal Wetland of Bangladesh Problems and Research Issues, BRRI, Thursday Seminar, Joydebpur, Gazipur, 19 June, 1-15.

RLRRC (1994). (Rainfed Lowland Rice Research Consortium), "Achievements of the Rainfed Lowland Rice Research Consortium", Paper presented at the RLRRC Steering Committee Meeting held during Feb,28 - March 5, 1994 at Luknow, India, 1-36.

Willie, D., and Mustafizur, R. (1983): Physical Prospects of Soils on the Teesta River Floodplain and Barind Tract of Bangladesh, Strengthening of Soil Resources and Development Institute, FAO/UNDP Projects, BGD/81/623, SRDI.

World Bank (1992): *World Development Report,* Washington D.C. : World Bank.

Zaman, S.M.H. (1986): *Current Status and Prospects for Rainfed Foodgrain Production in Bangladesh,* BRRI, Gazispur publications No.75, BARC Printers 1-56.