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The Impact of the HYV Technology on the Variability of Rice Production and Yield: Some Evidence from Bangladesh

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In recent years, the impact of the high-yielding varieties (HYVs) of cereals on the stability of cereals production has received increasing attention along with the growth potential of the technology. A number of studies, especially on Indian agriculture, have emphasized the destabilizing impact of the technology on foodgrains production. In contrast to such findings, the present analysis of rice production and yield in Bangladesh suggests a lower variability during the post-adoption period. Such conclusions are also supported by seasonal and regional data, although HYVs themselves are seen to be more variable than their local counterparts. An examination of the trends in variability during periods separated by the new technology provides an evidence of a reversal of trends. It is argued that, with the introduction of HYVs, complementary technological innovations and land/water resources development have taken place, which have enabled the farmers to reduce gross dependence on nature and played key roles in reductions in variability in rice production and yield in Bangladesh.

INTRODUCTION

In the dominant agricultural sector of many less developed countries, especially in South Asia, the production of foodgrains plays a crucial role. Foodgrain production in these countries is important not only because food is vital in a situation where the majority of the population live in absolute poverty, but also due to the increasing pressure of a rapid population growth on the existing food supplies. Major biological breakthroughs associated with the Green Revolution during the sixties in these countries opened up new possibilities in foodgrain production by shifting the means of expanding food production towards yield-increasing technology in a regime of limited land area. Although the growth potentials of the new high-yielding varieties (HYVs) of cereals (especially wheat and rice), along with complementary inputs, e.g., chemical fertilizers, pesticides, and mechanical irrigation, etc., have been widely recognized, their actual diffusion has not been as widespread as was initially expected in many of these countries. In Bangladesh, for instance, during 1989-90 only about 38 percent of the total rice area was cultivated

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under HYVs [Government of Bangladesh (1990)]. It has been pointed out that certain bio-physical limitations of the HYV technology, along with an inadequate and unfavourable institutional and organizational framework, have largely constrained their wider diffusion [Hossain (1980); IRRI (1978); Mellor (1978) and Rao (1975)].

Another aspect of the new technology which has received increasing attention in recent years is its impact on the stability of foodgrain production. Instability of foodgrain production leads not only to fluctuations in the incomes received by the producers and the nutritional levels of subsistence farmers, but also to fluctuations in the import requirements of foodgrains, thus creating a further uncertainty in the availability of scarce foreign exchange of the country concerned. A number of studies, especially on Indian agriculture, conclude that the introduction of the HYV technology has led to increased instability in foodgrain production [Barker *et al.* (1981); Hazell (1982); Hazell (1984); Hazell (1985); Jain *et al.* (1986); Joshi and Keneda (1982); Mehra (1981); Ray (1983) and Sen (1967)]. Recent studies on Bangladesh, on the other hand, suggest that the Green Revolution may have reduced the relative variability of foodgrain production [Alauddin and Tisdell (1988); (1988a)]. This paper seeks to investigate the underlying trends in the variability in rice production in Bangladesh and the impact of the new technology on such trends. Production of total foodgrain (e.g., rice and wheat) has not been considered in the analysis for two reasons. First, wheat in Bangladesh remained a minor crop until the seventies, when it received a tremendous boost in production.[1] Rice, on the other hand, is a traditional crop grown for centuries by almost all the farmers in the country. Second, wheat is grown only during the dry winter season and mostly in certain regions of the country.[2] In contrast, there are three major rice crops in a year – *aus* – *aman*, and *boro* – whose cultivation is spread over the entire country throughout the year.

MEASUREMENT OF INSTABILITY IN PRODUCTION AND YIELD

Although at the theoretical level it is suggested that the questions of stability – and adaptability should be properly distinguished [Evenson *et al.* (1979)], empirical analysis of the issue mainly proceeds in terms of measurement of variability in production and yield based on time series data. However, it is shown that when such measures are compared for different periods, the conclusions appear to be sensitive to changes in cut-off points and dropping of observations for 'unusual' years [e.g.,

[1]The average production of wheat in Bangladesh was only 68 thousand tons during the 1965-66 – 1969-70 period which increased to 1237 thousand tons during 1982-83 – 1984-85. [See BBS (1976); BBS (1986)].

[2]About 65 percent of total wheat production was accounted for by six regions out of twenty-three regions of the country during 1982-83 – 1984-85. See BBS (1986a).

Alauddin and Tisdell (1988)]. Changes in the assumption of arbitrary cut-off points and inconsistency in the deletion of observations may even lead to conflicting results. An alternative measure would have been to compute absolute and relative variability in terms of moving averages of relevant indices. This method does not measure instability around a fitted trend-line, and is independent of the choice of cut-off points. In the present paper, measures of variability have been computed, both at aggregate and disaggregate levels, during two specified periods. The periods have been distinguished in terms of the peak in the levels of production of rice and adoption of HYV technology. Furthermore, to facilitate comparisons, measures of variability in terms of moving averages of rice production and yield are computed and the underlying trends are examined.

SOME ASPECTS OF RICE PRODUCTION IN BANGLADESH AND THEIR IMPACT ON VARIABILITY

With a limited agricultural land base and a continuously deteriorating land-man ratio, efforts in the crop sector in Bangladesh, especially for cereals, have centred around the adoption of HYV technology along with modern inputs. During 1989-90, about 38 percent of the total rice area was planted to HYVs. However, there exist wide variations in the proportions of the HYV area cultivated under different varieties of rice. During the dry *(boro)* season, while nearly 80 percent of the area under rice was covered by HYVs, the same proportion during the wet *(aus* and *aman)* seasons was only 27 percent. One of the major factors that explains such wide dispersal in the seasonal variation in the HYV adoption rate is the availability of controlled and assured water for irrigation during the *boro* season, while cultivation of rice during the *aus* and *aman* seasons is mainly rain-fed. The area and production of the three varieties of rice are given in Table 1.

It can be seen that while total area under rice has marginally increased over the two periods, the increase in production has resulted mainly due to the substitution of area from local varieties to HYVs, especially during the *aus* and *aman* seasons. Over the two periods, total area under local varieties of *aus* and *aman* declined by about 4.4 million acres, while the area under HYVs increased by 3.8 million acres, implying a net decline of about 0.6 million acres. During the same period, the area under local variety of *boro* rice declined by about 0.7 million acres but the area under HYV increased by 2.4 million acres. Thus, the trend is towards an increase in rice area from the risky rain-fed seasons when floods and droughts are more frequent to the relatively safe winter season with irrigation. This trend itself is likely to have some impact on the variability in rice production in the country. As can be seen, the share of *boro* in total rice production has increased from 14 percent during 1967–1969 to nearly 25 percent during the 1982–1984 period. This points to the need of taking into considerations such varietal shifts in any analysis of variability of rice production in Bangladesh.

Table 1

Area and Production of Different Varieties of Rice in Bangladesh, 1967–1969 and 1982–1984

(Area in Million Acres
Production in Million Metric Tons)

Variety	Average of 1967-68 to 1969-70	Average of 1982-83 to 1984-85	Percentage Change
	A. Area		
Aus			
Local	8.09	6.42	–21.64
HYV	0.02	1.19	+5850.00
Aman			
Local	14.63	11.94	–18.39
HYV	0.01	2.65	+26400.00
Boro			
Local	1.55	0.85	–45.16
HYV	0.37	2.78	+651.35
Total	24.67	25.83	+4.70
	B. Production		
Aus			
Local	2.88	2.06	–28.47
HYV	0.03	0.92	+2966.67
Aman			
Local	6.87	5.63	–18.05
HYV	0.01	2.08	+20700.00
Boro			
Local	1.00	0.52	–48.00
HYV	0.54	3.02	+459.26
Total	11.33	14.23	+25.60

Sources: BBS (1976); (1986); (1986a).

ANALYSIS OF VARIABILITY IN RICE PRODUCTION AND YIELD

Intertemporal Comparison of Variability

As suggested earlier, the comparison of variability over two periods is sensitive to the choice of cut-off points. In order to reduce arbitrariness in such choices and make some meaningful comparisons, the peaks of rice production over the 1950–1984 period are observed and variability is compared over two successive peaks during two periods. The two periods – 1948-49 to 1960-61 and 1977-78 to 1984-85 – correspond to two phases of the introduction of the HYV technology. The first period corresponds to the pre-introduction period while the second to the post-introduction phase. Since average values during the two periods are different, only relative variability, measured in terms of coefficients of variation, is considered for both production and yield. The results for the aggregate analysis are presented in Table 2.

Table 2

Changes in Average Values and Coefficients of Variation of Rice Production and Yield in Bangladesh, 1948-49 to 1960-61 and 1977-78 to 1984-85

Crop	Average Value		Percent	Coefficients of Variation		Percent
	1948-1960	1977-1984	Change	1948-1960	1977–1984	Change
			A. Production			
Aus	1846.08	3073.00	66.46	19.01	6.61	–65.23
Aman	5476.85	7523.13	37.36	10.64	3.60	–66.17
Boro	345.31	2864.88	734.49	16.68	23.36	40.05
Total	7668.24	13461.01	75.54	10.61	5.51	–48.07
			B. Yield			
Aus	0.3240.399	23.15	11.65	4.46	–61.72	
Aman	0.392	0.515	31.38	8.94	4.38	–51.01
Boro	0.415	0.901	117.11	11.36	10.17	–10.48
Total	0.380	0.529	39.21	7.76	4.44	–42.78

Sources: BBS (1976); BBS (1986); BBS (1986a).

Note: Average values for production are in terms of thousand metric tons while those for yield are in metric tons per acre. Coefficients of variation are in percent.

For total production, while the average level has increased by nearly 76 percent, its variability has declined by 48 percent between the two periods. However, looking at the three varieties separately, one can see that, while for *boro* rice the production change has been quite substantial (735 percent), its variability has also increased by 40 percent. For the other two varieties *(aus* and *aman)*, the production increases are associated with declining variability in all cases, although for *boro* variety the decline is not as prominent as in the other two cases. Further, in contrast to the first period, the relative variability of *boro* variety for both production and yield is high compared to the other two varieties during the second period. In order to examine the issue further, Table 3 has been constructed. It gives the average value and coefficients of variation of the three varieties of rice in terms of local and HYV seeds separately as well as total local and total HYV, for the second period as a whole. The relative variability of HYVs in each case is higher than the corresponding local variety both for production and yield, with the exception of *boro* yield. Also, the yield variability of all HYVs together is less than the combined local one.

A comparison of the variability of local varieties during the second period, with their corresponding counterparts in the first period (when no HYVs were cultivated), as given in Table 2, suggests that there have been substantial reductions in variability during the second period in case of both production and yield (except for *boro* local yield). Whether such trends have resulted from the introduction of HYV technology, or due to other factors, needs to be considered. In order to throw some light on the issue, the changes in variability have been examined for three groups of regions, differentiated in terms of intensity of adoption of new technology during the 1982-83 – 1984-85 period. Percentage area under HYV is used as a proxy for adoption intensity. The first group of regions is designated as the High Adoption Group (H, containing the regions of Bogra, Chittagong, Chittagong Hill Tracts, Comilla, Dhaka, Mymensingh and Noakhali), where the adoption rate exceeds 30 percent of cultivated area under rice. The second is the Medium Adoption Group (M, with regions of Dinajpur, Jessore, Khulna, Kushtia, Pabna, Rajshahi, Rangpur and Sylhet), with 15 to 30 percent. And, finally, there is the Low Adoption Group (L, containing Barisal and Faridpur), with less than 15 percent adoption rate. The results of the changes in variability over the two periods for the three groups are presented in Table 4. Although no clear-cut trend seems evident, certain interesting results can be identified.

During the first period, while relative variability for aggregate production is declining with regions having higher adoption intensities, the trend is reversed in the second period. During the first period, for the three varieties separately, no trends can be observed except that production appears to be more variable in most cases in the group with the least adoption. For the second period, the results are somewhat mixed. For *aus* and *aman*, variability declines with increases in the adoption rate. This is also true of *boro* local. In case of yield variability, again the results are mixed, even though it has declined

Table 3

Average Values and Coefficients of Variation of Rice Production and Yield by Varieties in Bangladesh, 1977-78 to 1984-85

Crop	Average Values	Coefficient of Variation
	A. Production	
Aus		
Local	2137.13	6.75
HYV	935.88	8.51
Aman		
Local	3743.12	4.82
HYV	1780.00	19.51
Boro		
Local	584.13	14.07
HYV	2280.75	31.10
Total		
Local	8464.38	4.97
HYV	4966.63	20.28
	B. Yield	
Aus		
Local	0.324	3.99
HYV	0.845	7.98
Aman		
Local	0.464	4.24
HYV	0.813	9.07
Boro		
Local	0.585	10.29
HYV	1.055	5.65
Total		
Local	0.424	3.24
HYV	0.915	2.72

Note: Average values for production are in thousand metric tons and those for yield are expressed in metric tons per acre. Coefficients of variation are in percent.

Table 4

Average Quantities and Coefficients of Variation of Rice Production and Yield by Regional Groups in Bangladesh, 1948-49 to 1960-61 and 1977-78 to 1984-85

Crops	Average Values						Coefficient of Variation					
	1948–1960			1977–1984			1948–1960			1977–1984		
	H	M	L	H	M	L	H	M	L	H	M	L
A. Production												
Aus Local	811.2	829.9	205.0	777.0	1073.6	282.0	19.0	17.0	36.4	4.9	10.1	13.4
Aus HYV	–	–	–	602.4	256.1	77.5	–	–	–	7.8	11.4	21.8
Aus Total	811.2	829.9	205.0	1379.4	1329.7	359.5	19.0	17.0	36.4	5.3	8.7	14.4
Aman Local	225.2	2245.8	968.2	1961.5	2873.5	908.0	11.9	15.5	12.6	9.7	2.7	5.3
Aman HYV	–	–	–	1171.1	524.6	84.3	–	–	–	15.7	33.0	28.0
Aman Total	255.2	2245.8	968.2	3132.6	3398.1	992.3	11.9	15.5	12.6	4.4	4.6	4.7
Boro Local	159.8	165.1	20.5	236.4	295.4	21.6	19.7	18.1	23.6	13.7	17.0	22.9
Boro HYV	–	–	–	1592.6	537.8	181.1	–	–	–	26.4	40.6	24.7
Boro Total	159.8	165.1	20.5	1829.0	833.2	202.7	19.7	18.1	23.6	22.8	27.0	23.0
Total	3226.2	3240.8	1193.7	6341.0	5561.0	1554.5	12.1	12.3	13.4	6.3	5.7	4.7
B. Yield												
Aus Local	0.33	0.32	0.31	0.34	0.33	0.28	14.6	10.0	15.3	4.1	5.9	12.2
Aus HYV	–	–	–	0.85	0.85	0.83	–	–	–	7.8	9.9	8.9
Aus Total	0.33	0.32	0.31	0.46	0.37	0.32	14.6	10.0	15.3	3.1	5.9	12.3
Aman Local	0.40	0.39	0.38	0.46	0.48	0.42	9.7	9.5	12.5	5.0	4.2	6.1
Aman HYV	–	–	–	0.80	0.85	0.83	–	–	–	10.3	8.0	8.9
Aman Total	0.40	0.39	0.38	0.55	0.51	0.44	9.7	9.5	12.5	4.9	5.1	5.5
Boro Local	0.42	0.41	0.39	0.61	0.56	0.49	14.3	14.4	10.7	16.9	14.2	8.4
Boro HYV	–	–	–	1.06	1.02	1.08	–	–	–	6.5	8.4	7.6
Boro Total	0.42	0.41	0.39	0.96	0.78	0.95	14.3	14.4	10.7	10.0	13.8	8.6
Total	0.38	0.37	0.37	0.60	0.49	0.43	9.1	8.1	11.1	4.2	5.3	3.5

Note: Average quantities are in thousand metric tons, and the yield in metric tons per acre. H High Adoption M Medium Adoption L Low Adoption. For definitions see text.

during the second period for all varieties in all groups (except *boro* local in group H) as well as in the aggregate.

The preceding analysis, therefore, indicates that both production and yield variability has declined in the aggregate after adoption of the HYV technology. However, the production variability of local varieties, both seasonal and annual, is substantially lower than that for the corresponding HYVs. Similarly, varietal yield variability of HYVs is higher than that for the corresponding local varieties, although HYV yield variability is lower in the aggregate. The analysis in terms of groups with differential adoption rates of HYVs indicates that there does not seem to exist any discernible trend between the changes in variability and the differential adoption rates of HYVs in various groups of regions of the country.

Trends in Variability in Rice Production and Yield

In order to examine the trends in variability of rice production and yield, the following analysis has been undertaken. The indices of production and yield are computed for the 1947-48 to 1984-85 period, with average production and yield, and with the triennium ending 1977-78 as the base. Five-yearly moving averages of the relevant indices are then computed in order to get a series of values of average indices of production and yield along with their standard deviations and coefficients of variation. Similar analyses are also conducted for *boro* variety of rice and the *aus* and *aman* varieties together. Finally, to facilitate some quantitative comparisons of the relevant measures of variability, trend lines are fitted for the entire period as well as sub-periods, reflecting introduction of the HYV technology. The results are presented in Table 5.

For the entire period, negative trends seem to be present in absolute and relative variability, except in case of standard deviation for production, even though the results are not statistically significant in certain cases. However, one important result that emerges from the analysis of total rice is: while positive trends appear to be present in the absolute and relative measures of variability during the pre-introduction phase, the direction is reversed in both cases during the post-introduction phase. This is true for production and yield. Thus, there seems to be a decisive break in the direction of movement of the relevant measures of variability since the adoption of the new technology. For the separate analysis of *boro* rice, the trends are not satisfactory. The standard deviation for production has positive trend coefficients, as also for yields, except for the second period. Relative variability is seen to be declining during the second period for both production and yield. For *aus* and *aman* varieties, again the stabilizing impact is quite prominent during the second period for both production and yield. The above results seem to suggest that the post-introduction phase is characterized by a declining variability in production and yield for total rice as well as for separate varieties.

In this context, one may like to examine the relative contributions of the local and

Table 5

Trends in Production and Yield Variability of Rice in Bangladesh, 1949 – 1982

Period	Variable	Regression Constant	Coefficients Time	R^2	*t*-Value
		A. Total Rice			
		a. Standard Deviation			
1949–1982	Production	5.63770	0.02138	0.0144	0.68 d
1949–1965	Production	3.60831	0.24404	0.3734	2.99 a
1966–1982	Production	8.19221	–0.21926	0.5214	–4.04 a
1949–1982	Yield	5.30219	–0.03414	0.0549	–1.36 d
1949–1965	Yield	3.86743	0.14944	0.1813	1.82 b
1966–1982	Yield	4.77037	–0.06370	0.1572	–1.67 c
		b. Coefficient of Variation			
1949–1982	Production	9.22850	–0.09827	0.1385	–2.27 b
1949–1965	Production	6.70096	0.19336	0.1142	1.39 c
1966–1982	Production	9.46662	–0.32113	0.6464	–5.24 a
1949–1982	Yield	7.03262	–0.09361	0.2221	–3.02 a
1949–1965	Yield	5.55706	0.09824	0.0521	0.91 d
1966–1982	Yield	5.31625	–0.10762	0.2910	–2.48 b
		B. *Boro* Rice			
		a. Standard Deviation			
1949–1982	Production	–1.83187	0.70683	0.6331	7.43 a
1949–1966	Production	–1.21392	0.56620	0.3874	3.18 a
1967–1982	Production	15.48825	0.26101	0.0369	0.73 d
1949–1982	Yield	5.30529	0.08407	0.0523	1.33 c
1949–1966	Yield	3.76987	0.22727	0.1601	1.75 b
1967–1982	Yield	10.08900	–0.27753	0.1013	–1.26 d

Continued –

Table 5 - (*Continued*)

		b. Coefficient of Variation			
1949–1982	Production	15.23599	0.11374	0.0140	0.67 d
1949–1966	Production	7.36052	0.96918	0.2800	2.49 b
1967–1982	Production	25.44025	–0.87915	0.1894	–1.81 b
1949–1982	Yield	11.51775	–0.14414	0.1087	–1.98 b
1949–1966	Yield	9.56922	0.06780	0.0087	0.37 d
		C. *Aus* and *Aman* Rice			
		a. Standard Deviation			
1949–1982	Production	7.23412	–0.03760	0.0271	–0.94 d
1949–1967	Production	5.31544	0.15372	0.1515	1.74 b
1968–1982	Production	9.69343	–0.43343	0.6707	–5.15 a
1949–1982	Yield	6.16294	–0.04289	0.0593	–1.42 c
1949–1967	Yield	5.32228	0.04519	0.0153	0.52 d
1968–1982	Yield	6.36086	–0.17586	0.4323	–3.15 a
		b. Coefficient of Variation			
1949–1982	Production	9.92952	–0.12404	0.1660	–2.52 a
1949–1967	Production	8.23719	0.03839	0.0054	0.30 d
1968–1982	Production	10.93238	–0.53321	0.6905	–5.39 a
1949–1982	Yield	7.50845	–0.08675	0.1594	–2.46 a
1949–1967	Yield	5.88509	–0.02698	0.0039	–0.26 d
1968–1982	Yield	7.10295	–0.23804	0.5032	–3.63 a

Note: a significant at 1 percent level; b significant at 5 percent level; c significant at 10 percent; d not significant.

the HYVs of rice to the declining trends in variability. Table 6 gives the results of trend analysis for local and HYVs of rice separately during the 1969–1982 period. It suggests that, in general, both the absolute and the relative variability of production and yield for local varieties are smaller than the HYVs, as reflected in low constant terms. Further,

Table 6

Trends in Production and Yield Variability of Local and HYV Rice: 1969–1982

Dependent Variable	Variety	Regression Constant	Coefficients Time	R^2	t-Value
		A. Standard Deviation			
Production	Local	15.76011	–1.06640	0.7654	–6.26 a
Production	HYV	25.25659	–0.58345	0.1281	–1.33 d
Production	Total	7.98912	–0.26884	0.5158	–3.58 a
Yield	Local	8.84747	–0.48604	0.7150	–5.49 a
Yield	HYV	19.01736	–1.50393	0.7273	–5.66 a
Yield	Total	5.11198	–0.12055	0.3147	–3.35b
		B. Coefficient of Variation			
Production	Local	15.28253	–0.99367	0.7804	–6.53 a
Production	HYV	54.79187	–3.78673	0.7149	–5.49 a
Production	Total	9.14901	–0.39101	0.6444	–4.66 a
Yield	Local	9.14220	–0.50705	0.7503	–6.00 a
Yield	HYV	15.08260	–1.12892	0.7068	–5.38 a
Yield	Total	5.68132	–0.18103	0.4609	–3.20 a

Note: a significant at 1 percent level; b significant at 5 percent level; d not significant.

such measures of variability have significant negative time trends. On the other hand, while the HYVs start with higher variability, both the absolute and the relative variability decline rather sharply, especially for yield.[3] This suggests that the introduction of new technology, though it creates destabilizing effects in production and yield, leads to a decline in such variability once the initial disequilibrating forces are overcome.

[3]For the view that yields of HYVs are more variable than those of local varieties, see Mehra (1981).

SOME FACTORS BEHIND OBSERVED BEHAVIOUR OF VARIABILITY

The above analysis indicates that the new technology can be identified with a period of declining variability in rice production and yield. Moreover, the post-introduction phase is characterized by low variability relative to the pre-introduction phase in absolute terms. Such observed trends seem to be consistent with the idea of technical change: the prevalence of traditional technology forces agricultural production to depend entirely on nature. The new technology, in this context, reduces gross dependence on nature by attaining a control over resource use. In the case of rice in Bangladesh, it may be argued that low variability during the post-introduction phase is related to the greater inducement to have the farmers use higher levels of modern inputs associated with the HYV seed. Moreover, the response to modern inputs by the traditional varieties has also been found to be low.

The use of modern inputs in Bangladeshi rice production has expanded rapidly since the adoption of the new technology. The total use of chemical fertilizer was only 2 thousand tons of nutrients during 1952-53 and it increased to about 50 thousand tons in 1965-66.[4] Fertilizer consumption after the new technology period increased rapidly and reached 583 thousand tons of nutrients during 1984-85 [BBS (1986); BBS (1986a)]. However, in spite of such rapid growth, the present levels of application are very low [Hossain (1985)]. In respect of irrigation, it is estimated that only about 5 percent of the cultivated land (about 0.9 million acres) was irrigated during the early sixties by traditional methods. The introduction of modern irrigation since the sixties, although it partly replaced these traditional sources of irrigation, led to rapid increase in the irrigated area. During 1984-85, total irrigated area in the country was more than 5 million acres (about 16 percent of total cropped area), of which the share of modern methods exceeded 80 percent. About 76 percent of the irrigated area was devoted to rice during the year [BBS (1986); BBS (1986a)]. Similarly, about 3 thousand metric tons of pesticides were applied during 1984-85.

The new technology in rice production is, thus, seen to be associated with an increased use of modern inputs; and, presumably, this has enabled the farmers to exert more control over nature. What has been the impact of such development on variability in the rice sector? In order to derive certain implications, let us first consider the changes in rice production and yield. Table 7 provides the calculated annual growth rates in production, area, and yield of total rice and the separate varieties for the 1947–1984 period and the two sub-periods of the study.

One can see that, for the entire period, the growth rate of yield has been substantially higher than that of area, though for the *boro* variety the expansion of area

[4]However, the use of fertilizer during the period was mostly limited to tea gardens and government experimental farms.

Table 7

Annual Growth Rates in Production, Area, and Yield of Rice in Bangladesh, 1947-48 to 1984-85

Period	Variety	Growth Rate (in Percent)		
		Production	Area	Yield
1947–1984	Total	2.01	0.85	1.16
1947–1984	*Boro*	7.94	4.96	2.98
1947–1984	*Aus* and *Aman*	1.29	0.52	0.77
1947–1965	Total	2.22	0.79	1.43
1947–1965	*Boro*	3.66	1.97	1.69
1947–1965	*Aus* and *Aman*	2.15	0.74	1.41
1966–1984	Total	1.80	0.53	1.27
1966–1984	*Boro*	5.70	4.21	1.49
1966–1984	*Aus* and *Aman*	1.01	0.11	0.90

Note: The growth rates are calculated by fitting semi-logarithmic trend lines to the relevant variables over the period.

has been more important than yield. A comparison of the growth rates of the two sub-periods indicates that the growth in production has been higher during the first period both due to higher growth rates in area and yield. Only for the *boro* variety, the growth in production is higher during the second period (1966–1984) due to a higher growth in the area cultivated. One can also notice a substantial reduction in the growth rate of area for the *aus* and *aman* varieties during the second period. These varietal shifts in rice production have some important implications for variability in total rice production in the country.

Let us first examine the increasing trends invariability during the first period and the relative higher variability of *boro* variety during the second period. An examination of the sources of growth in these cases reveals the significance of increases in area. For example, during the 1950-51 to 1965-66 period, the net cropped area in the country increased from 20.09 to 21.13 million acres while the cropping intensity increased marginally from 1.28 to 1.37.[5] Similarly, for the *boro* variety, total area cultivated increased from 2.70 million acres during 1977-78 to 3.89 million acres in 1984-85. Thus, one may argue that the increasing trends in variability during the first period may in part

[5]Cropping intensity is defined here as gross cropped area divided by net cropped area.

be attributed to the cultivation of rice in new and marginal lands, where soil fertility and hence yield and production are likely to be unstable.

The same arguments may also be applied to *boro* rice during the second period. One further aspect of the relatively unstable character of *boro* production and yield during the second period stems from the fact that cultivation of *boro* rice has been extended beyond the irrigated area available during the season. As *boro* rice is cultivated during the dry winter season, its production and yield are dependent on controlled availability of water for irrigation. However, the available statistics suggest that about 80 percent of *boro* area is under irrigation and the trend has been towards cultivation of *boro* rice in non-irrigated areas.[6] Moreover, since 80 percent of *boro* area is under HYVs, its production and yield are crucially dependent on timely availability of complementary inputs. Any divergence – and this happens quite often – is likely to inject variability. The interaction of all these factors explains the relatively high variability of the *boro* crop.

The analysis in the above section also reveals reduced variability of local varieties upon introduction of the new technology. Further, local varieties are less variable separately in both production and yield as compared to the corresponding HYVs. While the development of appropriate cultural practice in the cultivation of these varieties over long periods is certainly a factor in the greater relative stability of these crops, the contributions of other development in the rice sector also need attention. Better cultural practices associated with the new technology and the use of chemical fertilizers in the production of local varieties are important factors in generating stability.[7] In this context, the role of water resources development projects undertaken by the government needs to be emphasized. By 1984-85, a total of 6.4 million acres of cultivated land was brought under flood control and drainage schemes. The gradual expansion of such area over the years has had a stabilizing impact on rice production, especially during *aus* and *aman* seasons.

At this stage, it may be worthwhile to examine the extent to which the spread of HYVs themselves has influenced variability. To see such impacts, regression equations are estimated between the measures of variability and the percentage of the HYV area in the respective total area during the 1967–1982 period. The results are given in Table 8. The estimated coefficients in each case have a negative sign, implying a reduced

[6]During the winter *(rabi)* season, only about 33 percent of the net cultivable area can be cropped [MPO (1985)]. The remaining area is left mostly fallow due to lack of irrigation water. Thus, the farmers are inclined to expand the cultivated area during the season as far as possible even without irrigation. This usually results in low and erratic yields. Even total crop failures are not uncommon.

[7]Although the application of fertilizer in the production of local varieties is much less intensive compared to the HYVs, the evidence suggests that fertilizer application in local varieties is also increasing. The rates of application of fertilizer on treated land (in terms of pounds of nutrients per acre) during 1969-70 and 1981-82 are given below: 1969-70 – local *aus* 59, HYV *boro* 244, 1981-82 – local *aus* 70, HYV broadcast *aus* 123, HYV transplanted *aus* local broadcast *aman* 80, local transplanted *aman* 99, HYV *aman* 190, local *boro* 163, HYV *boro* 289. See [Hossain (1985), p. 21].

Table 8

Effects of the Increase in HYV Area on Production and Yield Variability of Rice in Bangladesh, 1967-68 to 1982-83

Dependent Variable	Variety	Regression Constant	Coefficients PHYA	R^2	t-Value
		A. Standard Deviation			
Production	Total	7.90995	−0.13376	0.4181	−3.17 a
Production	*Boro*	18.09167	−0.0072	0.0006	−0.09 c
Production	*Aus-Aman*	9.04398	−0.31186	0.5466	−3.96 a
Yield	Total	4.62970	−0.03298	0.0906	−1.18 c
Yield	*Boro*	13.05863	−0.10684	0.2575	−2.20 b
Yield	*Aus-Aman*	6.00848	−0.11669	0.2997	−2.36 b
		B. Coefficient of Variation			
Production	Total	8.98273	−0.19253	0.5068	−3.79 a
Production	*Boro*	33.07263	−0.30287	0.3856	−2.96 a
Production	*Aus-Aman*	10.08307	−0.37809	0.5465	−3.96 a
Yield	Total	5.10324	−0.05899	0.1877	−1.80 b
Yield	*Boro*	14.41085	−0.13606	0.3459	−2.72 a
Yield	*Aus-Aman*	6.63069	−0.15848	0.3511	−2.65 a

Note: PHYA refers to percentage of HYV area in respective total area cultivated. a significant at 1 percent level; b significant at 5 percent level; c not significant.

impact of the HYV area on both the absolute and the relative variability in production and yield of rice. However, one interesting point to note is that the coefficients of *boro* variety are smaller in absolute value than their corresponding values for *aus* and *aman* rice in every case. Thus, even though *boro* HYV covers a high percentage of total *boro* area, the impact of such area on reduction of variability is much less compared to *aus* and *aman* HYV area. This suggests that other factors, as discussed above, exert much more influence on variability than the HYV area itself.

CONCLUDING REMARKS

Studies on the impact of the Green Revolution technology, especially on India, suggest that the technology has contributed to increased variability in foodgrain production. This has led to a rather strong conclusion that "production instability is an inevitable consequence of rapid agricultural growth and there is little that can be effectively done about it" [Hazell (1982), p. 10]. The analysis of the Bangladeshi rice data in this paper, however, suggests that the period associated with the new technology is characterized by lower variability as compared to the pre-introduction period. Furthermore, the examination of trends in variability during two periods separated by the new technology provides an evidence of the reversal of trends. While the pre-introduction period is characterized by rising trends in variability, the post-introduction phase shows declining trends.

Evidence in the paper, therefore, leads to the conclusion that the Green Revolution technology, considered as a package, has not been a source of increased variability of rice production and yield in Bangladesh. This conclusion is in sharp contrast to the conclusions reached by other authors, especially those who have written on India.

However, the analysis in the paper differs from other studies in that only rice has been considered instead of total foodgrains. Foodgrain production in India includes other cereals. While variability of other cereals may be higher than that of rice since these are seasonal crops, the analysis in terms of rice can be treated as comprehensive for Bangladesh due to its overwhelming importance. Another aspect which deserves careful attention in such inter-country comparison is the contribution of agro-climatic differences to variability, since regions of India are much more diverse than those in Bangladesh in terms of these characteristics. While the analysis and consideration of these issues require further research, especially in terms of disaggregated data, the findings in this study provide positive evidence on the stabilizing role of the new technology.

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