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Research Note

GROWTH ANALYSIS ON CHANGING WHEAT PRODUCTION IN BANGLADESH

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ABSTRACT

To estimate the growth rates of wheat in Bangladesh in terms of area, production, and yield, and to determine the factors responsible for changing production and yield time series data were used for the period of 1975-76 to 1998-99. The growth rates were estimated by using exponential production function and the determinants of yield levels were examined using Cobb-Douglas production function. During the period 1976-85, the growth rates of area, production and yield were relatively higher. After 1985, the growth rates were poor and stagnant. Then again after 1995, an increasing growth rate trend was found both in greater Dinajpur and Rangpur districts and in Bangladesh. However, the average growth rates of area, production and yield were 5.82, 6.02 and 0.55 percent respectively in Bangladesh. During the whole study period, wheat production increased by 787% (1.69 MT), contributed by area (58%) and yield (36%). Wheat yields were affected by several natural, physical and economic factors. Irrigated area coverage, price of the previous year and area coverage by modern varieties had positive influence on yield increase in Dinajpur. But in Rangpur, only price of the previous year had positive and significant effect on yield. So for continuing the increasing growth rate policy should be taken to keep higher price of wheat, expansion of more area under new high yielding varieties and irrigation.

I. INTRODUCTION

The spread of wheat cultivation in Bangladesh is justifiably presented as a success story in South Asian agriculture. In fact, very few countries in the world have experienced such a phenomenal growth in expansion of a nontraditional crop, as did Bangladesh in cultivation of wheat (Fig.l). Whatever the production increases, the contribution of different sources like area, yield etc., behind this production increase, need to be identified. The contribution of yield to increase production can be considered to be the technological development and adoption of such technologies by the farmers. Yet there has not been any updated study evaluating the contributing factors behind wheat production. This type of information is essential for proper planning for any further development of this crop. The objectives of this study were to estimate the growth rates of wheat in terms of area, production, and yield and to determine the factors responsible for changing production and yield.

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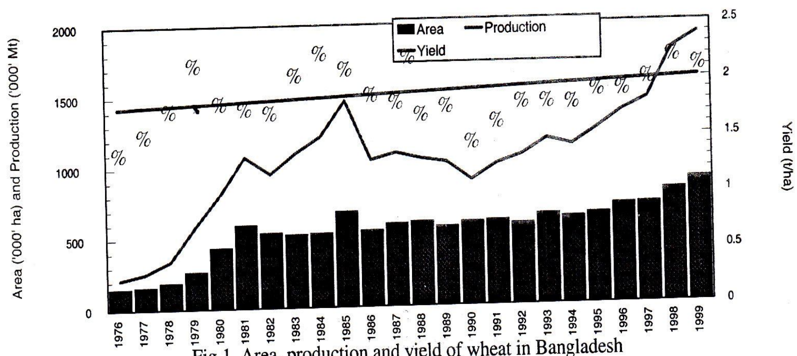

Fig.1. Area, production and yield of wheat in Bangladesh
Source: Statistical Year Book of Bangladesh. 1980. '85. '90. '95. '99.

The paper has been organized in four sections. Methodology and sources of data are discussed in section II. Production performances are presented in section III while conclusions are provided in the final section.

II. METHODOLOGY AND SOURCES OF DATA

Two districts namely greater Dinajpur and Rangpur, and whole Bangladesh were selected for this growth rate study. These two districts covered about 25% of total wheat area of Bangladesh. Time series data on production, area , yield, prices of wheat and rainfall, temperature in wheat growing season in the respective year etc. were collected from secondary sources like Bangladesh Bureau of Statistics (BBS), Department of Agricultural Marketing (DAM), Meteorological Stations, etc. Secondary data for the study covered the period from 1975-76 to 1998-99. The collected data were entered into computer and analyzed using *SPSS* and *Microsoft Excel* computer programmes.

Growth Rate Analysis: Although there are alternative methods by which the growth rates can be calculated for a specified data series, in this study the growth rates of area, production, and yield of wheat were estimated by fitting log linear functions as;

$$\ln Y = \ln a + bt$$

Where,

ln Y	= Natural log of production, acreage and yield of wheat
t	= Time (1975-76 to 1984-85, 1985-86 to 1994-95 and 1995-96 to 1998-99 referred as the first, second and third period)
a	= Intercept
b	= Growth rate for the period, to be estimated.

This equation is generally used on the consideration that the change in agricultural output in a given year would depend upon the output in the preceding year (Dandekar 1980, Minhas 1966). It has a limitation in that it assumes a uniform rate of growth over the entire period under consideration, which may not be true in reality. To study changes in the rate of growth, the time period is often divided into two or more sub-periods based on some external information or arbitrarily fixed criteria (Reddy et al. 1998). During the whole study period, wheat area and production had increased significantly from 1976 to 1985, and from 1986 to 1995 it remained unchanged. But from 1996, an increasing tendency of area and production was observed. So, for better understanding, the whole period was split into three sub-periods e.g., period I = 1975-76 to 1984-85, period II = 1985-86 to 1994-95, and period III = 1995-96 to 1998-99.

Factors Influencing Yield: There are basically two kinds of factors influencing crop yield. One is 'exogenous' that are beyond the control of the producer (e. g., temperature, rainfall) and another one is 'endogenous' factors that can be changed by the producer such as crop management practices. There is much evidence that shows wheat crop is very much sensitive to temperature. Higher temperature in grain filling stage reduced wheat yield. So, it was hypothesized that yield of wheat would depend on rainfall and temperature during growing periods, grain price of previous year, coverage of HYV and irrigated area and a trend variable capturing the effect of technological change (where a quantification of techniques and also variation i.e., line sowing, seed rate and seeding time, improve cultural practices and also variation of all the modern factor inputs are difficult to obtain). The above determinants of yield levels of wheat was examined by fitting Cobb-Douglas production functionof the following form using time series data for the period 1975-76 to 1998-99. Symbolically, the equation was;

$$\ln Y = a + b_1 \ln X_1 + b_2 \ln X_2 + b_2 \ln_3 X_3 + b_4 \ln X_4 + b_5 \ln X_5 + u$$

Where,

Y= Yield (t/ha)

X_1 = Rainfall (in mm) during the wheat growing period (December to March)

X_2 = Average temperature (in ^{0}c) of maximum and minimum during tillering and grain filling stage (February and March)

X_3 = Irrigated area coverage

X_4 = Harvest time price (Tk/ton) of the previous year

X_5 = Area covered by HYV wheat

$b_1, b_2, \dots \dots \dots b_5$ = Coefficients or elasticity of respective variables

a = Intercept, and

u = Disturbance or error term incorporating the effects of unknown and unexpected variables.

Sources of Production Changes: The data on yields and land use provide a basis for estimating the impact that changes in the factor mix have had in boosting wheat production since 1975-76. The general methodology and logic for explaining the sources of change in output are as follows. If crop production were calculated using the land area in production in 1998-99 and the yield for 1975-76, the result would be an estimate of the total production that would have existed in 1998-99 if the technology that generated the 1975-76 yields had remained unchanged. The difference between the actual 1998-99 production (which reflects 1998-99 yields and technology) and the surrogate production using 1975-76 yields would indicate the degree to which adoption of new technologies has influenced production. By an analogous process, the change in production due to change in land can be calculated. The algebric formulas bellow are an expression of this basic logic, with the addition of calculations for differences in production associated with changes in cropping patterns and the interaction of cropping pattern and yields. Though it is known that historical changes in the wheat area may have involve both changes in the area and also changes in land quality as wheat area shifted from more favorable land to more marginal land. However, shifting land quality factor was not considered in analysis due to unavailability of historical data on it.

Assuming the contributing factors which boost change in output are: change in area, yield, cropping pattern i.e., change in the proportion of the wheat in the total cropped area and the multiplicative effect of both cropping pattern and yield change. The components, which explain the changes in output between three periods for an individual crop, can be broken down algebraically as follows (Wannergren et al. 1984):

$$P_t - P_0 = Y_0 [A_t (1 + C_0 - C_t) - A_0] + [A_0 (1 + C_0 - C_t)(Y_t - Y_0)] + [A_t Y_0 (C_t - C_0)] + [A_t (Y_t - Y_0)(C_t - C_0)]$$

Where,

$P_t - P_0$	= Change in total output
$Y_0 [A_t (1 + C_0 - C_t) - A_0]$	= Change in areas
$[A_0 (1 + C_0 - C_t)(Y_t - Y_0)]$	= Change in yield
$[A_t Y_0 (C_t - C_0)]$	= Change in cropping pattern
$[A_t (Y_t - Y_0)(C_t - C_0)]$	= Change in interaction of cropping pattern and yield.

And

P_0 = Production of wheat in the base year 1975-76, 1985-86 and 1995-96

P_t = Production of wheat in the terminal year 1984-85, 1994-95 and 1998-99

A_0= Wheat crop area in the base year 1975-76, 1985-86 and 1995-96

A_t = Wheat crop area in the terminal year 1984-85, 1994-95 and 1998-99

C_0= Proportion of wheat area planted in 1975-76, 1985-86 and 1995-96

C_t = Proportion of wheat area planted in 1984-85, 1994-95 and 1998-99

Y_0 = Wheat yield in the base year 1975-76, 1985-86 and 1995-96

Y_t = Wheat yield in the terminal year 1984-85, 1994-95 and 1998-99

Given these equations, it is possible to calculate the relative importance of changes in (1) areas, (2) yield, (3) cropping pattern, and (4) interaction of cropping pattern and yield. Within this parameter, the analysis expresses the relative importance of each of the four factors in explaining the change in output for wheat but does not explain why the output was at a particular level.

III. PRODUCTION PERFORMANCE OF WHEAT

Growth Rate

The districts Dinajpur and Rangpur have been the forerunner in the adoption of wheat technology and have recorded spectacular growth in wheat production, productivity, and expansion of area. Growth rates experienced in wheat area, production and yield after 1975 and phenomenon of acceleration/deceleration or no change in growth rates over time in the northwestern districts and Bangladesh as a whole are presented in figures 2 to 4 and in table 1.

Area

The higher growth in area (above 26%) was found during period I (1975-76 to 1984-85) in both the districts compared to other periods. Poor growth rate in area was found in Rangpur (0.58%) as well as in Bangladesh (1.38%) during the period II (1985-86 to 1994-95). During this period Boro rice area increased rapidly due to open marketed irrigation machineries, which had a negative impact on wheat area. After 1995 i.e., in period III, the area growth has increased by 14% in both the districts. The average growth rate of area in Bangladesh was 5.82% (Table 1, Figure 2).

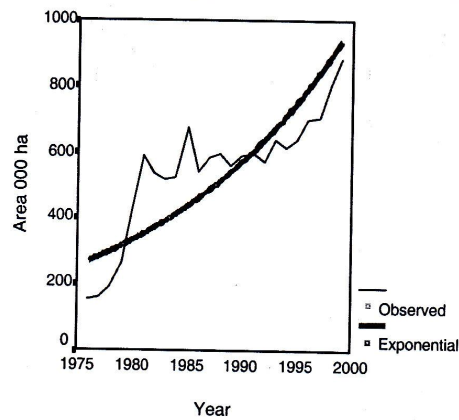

Fig. 2 Area growth rate (5.82%) in Bangladesh

Table 1. Growth rate (in %) of area, production and yield of wheat in Dinajpur, Rangpur, and Bangladesh during 1976-1999.

	Period	Rangpur	Dinajpur	Bangladesh
Area	I = (1976-85)	34.06 **(.73) 0.61899^{SE}	26.96 ** (.75) 0.45868	18.64 ** (.79) 0.28450
	II = (1986-95)	0.58 (-.09) 0.10615	7.15 ** (.86) 0.08695	1.38 (.57) 0.03467
	III = (1996-99)	14.67 * (.87) 0.07243	14.34* (.94) 0.04471	8.17 * (.88) 0.03804
	All = (1976-99)	7.24 **(.35) 0.66932	8.95 ** (.66) 0.46063	5.82 ** (.62) 0.32075
Production	I = (1976-85)	40.48 ** (.72) 0.73704	28.36 ** (.79) 0.44059	21.65 ** (.89) 0.22701
	II = (1986-95)	-0.90 (0.07) 0.13466	6.77 ** (.77) 0.11067	1.62 (.19) 0.08272
	III = (1996-99)	19.24* (.93) 0.06702	22.79 * (.91) 0.09346	12.11* (.90) 0.04947
	All = (1976-99)	8.42 ** (.33) 0.80181	9.43 ** (.66) 0.47583	6.02 ** (.58) 0.35499
Yield	I = (1976-85)	6.42 ** (.67) 0.13162	1.43 (.19) 0.07306	3.87 ** (.54) 0.10248
	II = (1986-95)	-1.46 (.06) 0.10597	-0.31(-0.09) 0.05935	0.28 (-0.11) 0.08109
	III = (1996-99)	4.22 (.63) 0.03851	8.38 (.72) 0.06285	3.95 (.56) 0.04003
	All = (1976-99)	1.19 * (.19) 0.15873	0.49 (.11) 0.08390	0.55 (.06) 0.11767

** and * indicates significance at 1% and 5% level, respectively.

Figures within the parentheses indicate the value of adjusted R^2, ^{SE} means Standard Error

Production

The higher growth rate of production was found in period I among the districts as well as in Bangladesh (21.65) followed by period III. Production growth rate was poor in Rangpur district (-0.9%) followed by Bangladesh (1.62%) during period II. This was actually the wheat area reduction effect during this period. Average growth rate of production in Bangladesh was above 6% during 1975-76 to 1998-99 but it was higher in Dinajpur (9.43%) followed by Rangpur (8.42%) (Table 1).

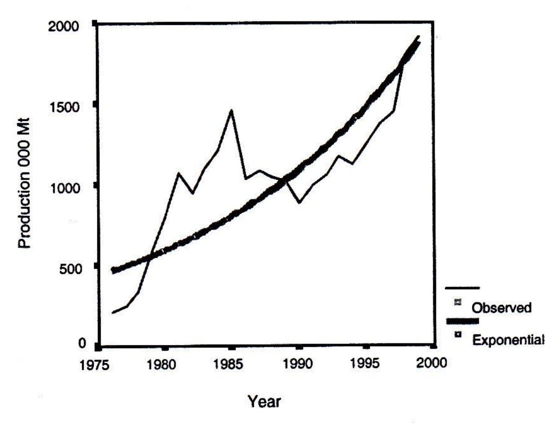

Fig. 3 Production growth rate (6.02%) in Bangladesh

Yield

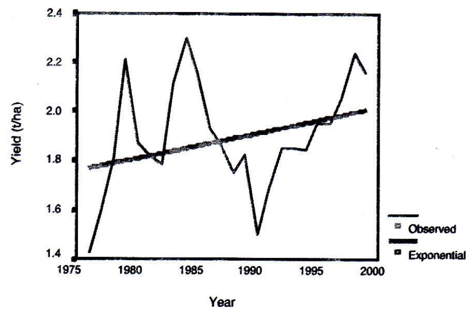

Fig. 4 Yield growth rate (0.55%) in Bangladesh

A similar trend, as in area and production growth, was found in yield growth over the periods I, II, and III. Higher growth rate of yield was found in Dinajpur (8.38%) during the period III followed by period I in Rangpur (6.47 %). But a negative growth rate was found in period II in Rangpur and Dinajpur (Table 1). During this period, expansion of Boro area pushed wheat to marginal land (less fertile land), which ultimately reduced wheat productivity. However, average yield growth rates over the period were higher in Rangpur (1.19%) followed by country as a whole (0.55%) (Fig. 4) and poor in Dinajpur. However, the growth rates of area, production and yield over the whole period were positive and in increasing trend was found.

Contribution of Different Sources of Output Growth

Assuming the contributing factors which boost change in output are: change in area, yield, cropping pattern i.e., change in the proportion of the wheat in the total cropped area and the multiplicative effect of both cropping pattern and yield change. The relative importance of changes in area, yield, cropping pattern and interactions between cropping pattern and changes in yield are shown in table 2. Among the two districts and Bangladesh, output change was higher in Rangpur (3457%) during the whole period (1975-76 to 1998-99), followed by Dinajpur (1941%). Output increase was higher during 1975-76 to 1984-85 period compared to other two sub-periods in both the districts and was poor during 1985-86 to 1994-95 (Table 2). Compared to the other sources, area contributed more to increase output followed by yield increase. During the whole study period, area contributed more in Dinajpur (62%) compared to Bangladesh as a whole (58%). But yield contributed more in Rangpur (44%) followed by Bangladesh as a whole (36%) during the entire period. Yield contribution for increase in production was negative in Rangpur and Dinajpur during 1985-86 to 1994-95 periods and increased production was mainly due to expansion of area followed by change in cropping pattern (Table 2). During this period, Boro rice area increased rapidly due to open marketed irrigation facilities, and Boro area pushed wheat to marginal land (less fertile land), which ultimately reduced wheat productivity. Yield contribution was highest in Rangpur (44%) over the whole period followed by Dinajpur (41%) in the 3rd period 1996 to 1999. This period actually represents the adoption of packages of wheat technology available to the farmers. During the 1st period, contribution of yield was due to the adoption of new wheat varieties. The contribution of cropping pattern and interaction between cropping pattern and yield was not remarkable to increase the wheat production. However, in Bangladesh, total wheat production increased about *1.69* million tonnes in whole study period *(1976* to *1999),* was mainly due to area expansion (58%) and yield increase *(36%)* (Table 2). This yield increase is the aggregated results of new technology development by the researcher and adoption by the farmers. So technology development and transfer programme of WRC (Wheat Research Centre) need to be continued and strengthened.

Table 2. **Sources of production growth of wheat in Dinajpur, Rangpur, and Bangladesh between 1975-76 and 1998-99.**

Period/ Location	Changes in output between the period (000 t)	Contribution of				
		Area (%)	Yield (%)	Cropping Pattern (%)	Interaction between yield and cropping pattern	Total
Dinajpur:						
1975-76 to 1984-85	103.52(669)a	80	12	8	1	100
1985-86 to 1994-95	70.43(80)	98	-11	13	*	100
1995-96 to 1998-99	147.00(87)	52	41	6	1	00
1975-76 to 1998-99	300.52(1941)	62	23	11	4	100
Rangpur: 1975-76 to 1984-85	188.97(2688)	54	39	4	3	100
1985-86 to 1994-95	28.43(26)	96	-5	9	*	100
1995-96 to 1998-99	95.00(61)	78	16	6	*	100
1975-76 to 1998-99	242.97(3457)	48	44	4	4	100
Bangladesh: 1975-76 to 1984-85	1249(581)	57	38	3	2	100
1985-86 to 1994-95	203(19)	90	6	4	*	100
1995-96 to 1998-99	539(39)	62	34	4	*	100
1975-76 to 1998-99	1693(787)	58	36	4	2	100

* Less than 1; a. Figures within the parenthesis indicate the % of increase.

Factors Influencing the Yield Growth of Wheat

Cobb-Douglas production function was used to estimate the degree of influence of factors (like rainfall, temperature, harvest time price of the previous year, area coverage by modern variety and irrigation) in changing yield growth of wheat. Due to unavailability of nationwide monthly temperature for long period, the factors influencing the wheat yield were only estimated for greater Dinajpur and Rangpur not for Bangladesh. Findings of the analysis are presented in table *3*, a short description of which is noted below:

The values of R^Z are *49* and 50 for Dinajpur and Rangpur, respectively which indicate that *49* and 50 percent of the variations in yield are explained by independent variables included in the equation. The F-values are *3.43* and *3.64* at Dinajpur and Rangpur, respectively and significant at 5% level of significance implying that all the specified independent variables are important for explaining the variation in the dependent variable.

Table 3. Estimated value of coefficient and related statistics of log-linear function model of wheat yield.

Explanatory variables	Coefficients	
	Dinajpur	Rangpur
Intercept	0.019	0.014
Rainfall (X_I)	-0.012 (0.009)	-0.002 (0.016)
Temperature (X2)	-0.922* (0.443)	-0.060 (0.912)
Irrigated area (X_3)	0.199** (0.072)	0.086 (0.095)
Harvest time price of wheat (X5)	0.392*** (0.132)	0.501** (0.209)
Area coverage by MV wheat (X_6)	0.005* (0.007)	0.013 (0.013)
R^Z (%)	49	50
N	24	24
F	3.427**	3.638**

Figures in the parentheses indicate standard error.
*** Significant at 1 per cent level. ** Significant at 5 per cent level.
* Significant at 10 per cent level

Rainfall (X_I)

For this analysis, total rainfall during the wheat growing period (December to March) in each year was considered in the whole study period (1976-1999). The yield coefficient of rainfall was negative in both the districts but not significant. Wheat is a sensitive crop to soil moisture. Heavy soil moisture in the seedling stage (within 25 days) partially, sometimes entirely, damages the wheat crop. Due to heavy rainfall, the seedling growth becomes stagnant and seedling colour will be red. To overcome this situation it takes more time and creates sterility problem. So, heavy shower in the initial stage as well as in grain filling/ripening stage, partially or fully damage the wheat crop that means negatively affect the wheat yield. For that reasons negative effect of rainfall was found in both the site. However, the coefficients were (-0.0116 and -0.0019) not significant (Table 3).

Temperature (X2)

Wheat is traditionally a cool (winter) season crop, but its area and production have been extended to other nontraditional areas from cool to high altitude tropics and later the subtropical where minimum temperature in the coolest month remains > 17.5 ° c (Fischer and Byerlee 1991). Terminal heat stress is also a common abiotic factor responsible for reducing wheat yield in about 40% of the temperate environment, which encompasses 36 million hectares in the world (Fischer and Byerlee 1991). Bangladesh furnishes a good example of this environment where wheat is grown in a short winter period. As mentioned earlier, about 80% of wheat in Bangladesh is grown after harvest of T. Aman rice, of which above 50% area is planted late due to delayed harvesting of rice and the crop frequently encounters high temperature stress during grain filling. There is a potential yield decline at the rate of 1.3% per day when sown beyond optimum time (Saunders 1990). The most striking effect of high temperature on wheat growth is the acceleration of plant maturity and the overall reduction of plant size (Shpilar and Blum 1991) and early leaf senescence (Reynolds et al. 1994). Late heat also causes abortion of the late forming florets and reduction of potential grain number. Reduced grain growth period results in low grain weight. High temperature in post anthesis period shortens the duration of grain filling such that each degree temperature increase during grain filling results in about 3 days decrease in the duration of grain filling regardless of cultivars (Bagga and Rawson 1977). Fischer and Maurer (1976) demonstrated a 4% reduction in grain yield for every unit increase in temperature between tillering and grain filling. For this study, average temperature of maximum and minimum of January and February was considered in each of the study year 1996-1999. The yield coefficient of temperature is negative in both the districts but significant at 10% level in Dinajpur only. It indicates that 1 percent increase in temperature, keeping other factors constant, would result in a decrease of yield by -0.922 percent in Dinajpur (Table 3).

Irrigated Area (X3)

Irrigation has significant effect on wheat yield. It is shown in different experiments that an yield increase of about 43% with one irrigation at crown root initiation (CRI), 48% with two irrigations at CRI and heading, and 54% with three irrigations at CRI, heading and grain filling stages (Ahmed and Meisner 1996). Rainfed wheat yield is significantly lower compared to irrigated wheat yield. So, naturally *average* wheat yield will be increased with the increases of irrigated area. The analysis showed the similar trend that coefficient of irrigated area coverage is positive for both the districts but significant at 5% level in Dinajpur. This positive coefficient indicate that 1 percent increase of irrigated area of wheat, keeping the other factors constant, would result in an increase of wheat yield by 0.199 percent in Dinajpur (Table 3). The coefficient for Rangpur although positive, but not significant.

Harvest Time Price (X4)

Higher product price of a respective crop always encourages farmers to produce that crop intensively. Higher product price influences farmers to invest more on fertilizers, irrigation, labour etc., to cultivate that crop, which ultimately boost up yield. So harvest time price of previous year was considered as one of the yield influencing factors of wheat. It was found that yield coefficient of harvest time price of wheat was positive and significant at 1% and 5% level and equals to 0.392 and 0.501 in Dinajpur and Rangpur, respectively. The result indicates that 1 percent increase of harvest time price, keeping other factors at their geometric mean level, would increase the yield by 0.392 and 0.501 percent at Dinajpur and Rangpur, respectively.

Area Covered by MV Wheat (X5)

Modern varieties (MV) are higher yielding than the previous indigenous ones. Up to date, Wheat Research Centre (WRC) has released 21 new high yielding varieties, starting from Sonalika in 1973 to Shatabdi in 2000. Area coverage by MV was zero in 1976 and it rose to 90% area in 1997. Area covered by MV showed positive effect on yield. The higher the area coverage by MV, the higher was the yield. The yield coefficient of area coverage by MV were positive in both the districts and were 0.005 and 0.013. However, the coefficient for Dinajpur only was significant, this indicates that 1 percent increase of area by MV, keeping other factors constant, would increase the yield by *0.005* in Dinajpur.

IV. CONCLUSIONS AND RECOMMENDATIONS

During the period *1976-85,* the growth rate of area, production and yield were relatively higher. After *1985,* the growth rates were poor and stagnant. Then again after *1995,* an increasing growth rate trend was found both in greater Dinajpur and Rangpur districts, and in Bangladesh. However, the average growth rates of area, production and yield were *5.47, 6.02* and *0.55* percent respectively in Bangladesh. About *1.6* million tons of wheat production increased in the whole study period of which *36%* contributed by yield. This yield contribution was mainly due to adoption of new high yielding varieties and improved technologies. So technology development and transfer programme of WRC need to be continued and strengthened further by upgrading it as an institute. Regression analysis of long term data particularly in Dinajpur showed that area coverage by modern varieties, and previous *year* harvest time price had positive influence on yield increase. So, by expansion of modern varieties, and with higher wheat grain price, wheat yield can be increased. Policy should be taken to keep higher and stable price of wheat and expansion of more area under new high yielding varieties. Government wheat grain procurement programme should also be strengthened.

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