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Impact of Mungbean Research and Extension in Bangladesh

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Abstract: An ex-post rate of return analysis was considered to estimate the internal rate of return (IRR) to BARI-released improved varieties of mungbean that have been replaced the local varieties. The growth rate of area, production and yield before the release of mungbean varieties were 18.99, 20.85 and 1.86%, respectively. After the release of improved varieties of mungbean, the area and production were increased dramatically but their growth rates were not satisfactory for various reasons, which should be studied. The internal rate of return to total investment in both mungbean research and extension was calculated at 34%. It was found that in 1997-98, about 19% more mungbean production was made available because of the farmers' adoption of the BARI-released mungbean varieties. The potential relative yield of BARI Mung-2 over the local varieties was found 43% higher. The cost of production of high yielding varieties of mungbean was 49% higher than the local varieties. Under various assumptions about the magnitude of the benefits and the research and extension expenditures, the IRR ranged between 18 and 50%. This indicates that the funding of mungbean research and extension is a good investment.

Key words: Impact, internal rate of return, adoption, yield advantage, ex-post analysis

INTRODUCTION

Pulse is an important food crop for Bangladeshi people. It is an important source of protein supply and it is called "Poorman's Meat". It is a common food item for Bangladeshi people in everyday meal. The farmers in the country are cultivating pulse from long past with a recent adoption of improved varieties. The Pulse Research Centre of BARI has developed 24 improved varieties of pulses along with other improved technologies (Razzaque and Satter, 2000). Pulse is grown mostly in the winter season. It is also grown in the kharif season. Therefore, pulses have the opportunities to cover more areas round the year. Four varieties of mungbean namely BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 were developed during 1987 to 1997 (Razzaque and Satter, 2000). These varieties are broadly cultivated in the farmers' fields since the release of the varieties. These varieties are produced and consumed within the country. However, for the research work of pulses and its extension, the contribution of BARC (Bangladesh Agricultural Research Council), DAE (Department of Agricultural Extension) and CDP (Crop Diversification Program) are greatly associated with BARI.

The present analysis thus took into the consideration the benefits from past pulse varietal development beginning 1987-88, the year when the first improved variety BARI Mung-2 was adopted and sown by the farmers. The present study can provide information for the policy makers, donors, researchers, extension people and the public on the contribution and the rate of return to past investments in mungbean research in Bangladesh. However, the study was conducted with the following objectives:

- To find the growth rate of area, production and yield of mungbean;
- To find the adoption of improved varieties of mungbean and yield advantages over local varieties and
- To estimate the rate of returns to mungbean research and extension.

MATERIALS AND METHODS

In the present study, data from different sources were used like published, unpublished, formal interview of the mungbean growers and informal scientists interview. Area, production and yield of mungbean varieties, harvest price and consumer price index (CPI) were collected from various issues of Statistical Yearbooks published by the Bangladesh Bureau of Statistics. The demand and supply elasticities were chosen after consultation of studies in this field. Since BARI is the principal institute for mungbean research, the research cost included mainly from BARI and the donor agency like CDP

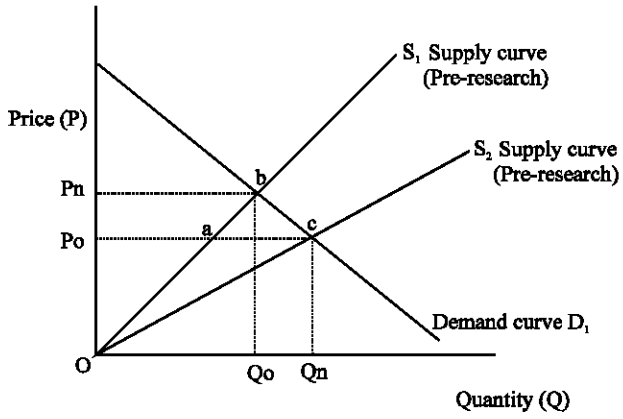

Fig. 1: Closed-economy economic surplus model

(Crop Diversification Program). The extension and promotion activities were done by DAE (Department of Agricultural Extension) and the related costs were collected from this organization. BARC (Bangladesh Agril. Res. Council) mainly provided the administrative costs. The on-farm yield data of different mungbean varieties were collected from the pulse program of BARI.

Analytical procedure: The Economic Surplus Model with Ex-Post analysis was considered for the present study to estimate the rate of returns of mungbean varieties that have been replacing the traditional varieties mungbean. The analysis was attempted with the closed-economy. The closed-economy commodity market is defined as a commodity that is totally produced and consumed domestically and is neither imported nor exported.

Economic surplus model: The concept of economic surplus has been used to measure economic welfare and the changes in economic welfare from policy and other interventions. (Alston *et al*., 1995; Currie *et al*., 1971). The economic surplus concept has been adapted to estimate the benefits from the adoption of improved varieties. The components of economic surplus are consumer surplus and producer surplus. Given the initial condition (i.e., pre-research supply curve S_1 and demand curve D_1), consumer surplus is depicted as Area PaPnb in Fig. 1. This is the surplus or benefit to consumers because of a functioning market. That is, consumers are paying a lower price for the commodity because of the quantity available through market activity. Consumer surplus is that area beneath the demand curve less the cost of consumption. The cost of consumption is the area below the price line P_n. Producer surplus is defined by Area P_nb0 in Fig. 1. Area P_nbO is the surplus left to the farmers after they have paid for the total costs of production. Area ObQ_n (Alston *et al*., 1995).

The adoption of an intervention by farmers such as an improved variety usually means one of two things: I. a farmer can supply more of the commodity using the same level of resources (i.e, same land area and other inputs), or ii. a farmer can supply the same level of commodity output but do it with less resources. In either case, this is depicted by a shift to the right of the supply curve as shown in Fig. 1 (the shift is from S_1 to S_2). This shift is the supply curve from the adoption of an intervention changes the initial equilibrium price and quantity of the commodity. This new price quantity equilibrium increases economic surplus. The change in economic surplus (economic benefits) is measured by comparing the difference in economic surplus between the pre-adoption period and the post-adoption period.

Given a shift in the supply curve S_1 to S_2, the change in consumer surplus is depicted in Fig. 1 as Area abc + Area P_nbaP_o. The shift in the supply curve (due to the adoption of an intervention) has decreased the price consumers now have to pay for the commodity. Because of the decrease in the price, the consumers as a group will now purchase more of the commodity. The decrease in the price of the commodity has made consumers better off. The change in consumer surplus (benefits) can be measured as a monetary value.

Given a shift in the supply curve S_1 to S_2, the change in producer surplus is depicted in Fig. 1 as Area Oac–Area P_nbaP_o. Area Oac in Fig. 1 represents the decrease in the cost of producing the same unit of the commodity that farmers now enjoy because they are using the intervention. This represents the benefits to the farmers from adopting the intervention and can be measured and quantified in monetary terms. The adoption of the intervention, however, has increased the quantity produced thereby decreasing the price of the commodity (P_n to P_o in Fig. 1) and is a loss to farmers' income. Farmers do make back some of this loss because now they sell more quantity (Q_n to Q_o in Fig. 1) of the commodity. But in the final analysis, the lower price means that farmers have lost an amount equal to that depicted by Area P_nbaP_o.. Farmers, as a group, gain from the adoption of an intervention if Area Oac is larger than Area P_nbaP_o. In some cases, Area P_nbaP_o. maybe larger. The size of the two areas depends on the elasticity (% change in quantity relative to a % change in price) of the supply and demand curves and the size of the supply curve shift. The total

social benefits to society from the adoption of an intervention is the summation of the change in consumer surplus plus the change in producer surplus (Area abc + Area Oac) minus the input cost change from adopting the new interventions. For some interventions, adopters may have to increase their input costs per hectare in order to obtain the advantage of the new variety (i.e. higher seed price, more fertilizer, or a change in farming systems methods) and these costs must be subtracted from the estimate of the total social benefits (Alston *et al.*, 1995). However, the mungbean market produces mungbean domestically and it is produced in a closed-economy market.

Akino and hayami method: empirical approach: The Akino and Hayami (1975) approximation formulas for calculating changes to producer and consumer economic surplus are described and will be used in this study. Although other methods are equally as good, the Akino and Hayami method is used in this study because it is a relatively straight forward method (Alston *et al.*, 1995).

The Akino and Hayami (1975) approximation formulas for calculating the change in economic surplus for a closed-economy analysis (Fig. 1) is as follows :

Area A (abc) $= 0.5\ PoQo\ ((k\ (1+\gamma))^2/\gamma + \eta))$ (1)

Area B (Oac) $= kPoQo$ (2)

Area C (PnbaPo) $= (PoQok(1+\gamma))/(\gamma+\eta))\ x\ (1-((0.5\ k(1+\gamma)\ \eta)/(\gamma+\eta))-0.5k\ (1+\gamma)$ (3)

Where,

Po = Commodity price (existing market price)

Qo = Quantity of the commodity (existing production)

Pn = Quantity price that would exist in absence of research

Qo = Quantity of the commodity produced that would exist in absence of research

k = Horizontal supply shifter

γ = Price elasticity of commodity supply

η = Absolute price elasticity of the demand for the commodity. For a closed-economy model, the estimated price elasticity of demand is used in the above formulas

The supply shifter k: The supply shifter k i.e., the overall yield advantage of improved varieties over the old varieties weighted by the area sown to the new varieties and is called the supply shifter. In the case of the Akino and Hayami (1975) approximation formulas, k is the horizontal shift from the equilibrium price Pn given S_1 to the equilibrium price Po given S_2 which corresponds to a distance equal to QnQo in Fig. 1 (Gardiner *et al.*, 1986; Nagy and Furtan, 1978). The supply shifter k is calculated as follows:

$$k_t = \sum_{i=1}^{n} [1 - \frac{Y_t}{Y_{it}}] \times A_{it} \quad (4)$$

Where :

Yit = Yield of the improved variety in year t

Yt = The yield of a base (or average yield of old varieties) that has been grown in the past and that would still be grown if no new varieties had been developed

Ait = The proportion of the total area sown to variety in year t

n = The number of improved varieties

Rate of return calculation: The internal rate of return (IRR) is calculated relating the total social benefit (TSB) minus an input cost change, if any, in each year to the research expenditure © in each year and is the discount rate that results in a zero net present value of the benefits. The IRR is calculated as:

$$O = \left[\sum_{i=1}^{n} (TSB_t - C_t)(1 + IRR)^{-t}\right] \quad (5)$$

The IRR can be defined as the rate of interest that makes the accumulated present value of the flow of costs equal to the discounted present value of the flow of returns, at a given point in time (Peterson, 1971). For example, an IRR of 25% means that on the average, each Taka invested in agricultural research and extension returns 25% annually from the date of the investment. Another interpretation is that if the yearly research and extension expenditures had been borrowed at an interest rate of 25%, the social benefits from research and extension would equal the cost of borrowing the funds.

Two types of data are mainly needed for the analysis: I. market related data andii. research related data. Market related data included quantity and price of mungbean and its supply and demand elasticities. Research related data included varietal adoption of mungbean, its yield advantage, input cost change and research and extension expenditures.

Market related data and information

Production and prices: Mungbean production (Qo) and mungbean harvest prices (Po) used in the analysis were converted to 1997-98 constant prices using the Bangladesh middle income group CPI Index.

Elasticities: Output supply elasticities and demand elasticities were estimated to be 0.70 and 0.20, respectively for the present analysis (Dey and Norton, 1993).

RESULTS AND DISCUSSION

Growth rate of area, production and yield of mungbean: Mungbean production has increased dramatically from 8 thousand tons in 1981-82 to 36 thousand tons during 1999-2000. The area has increased 15 thousand hectares in 1981-82 to 55 thousand hectares during 1999-2000.

Three periods were considered for the growth rate calculation of mungbean. First, from 1981/82 to 1986/87, i.e., before the release of the modern varieties of mungbean; Second, from 1987/88 to 1999/2000, i.e., from the beginning of the released varieties upto the study period considered and Third, from 1981/82 to 1999/2000 i.e., the whole study period.

During first six years from 1981-82 to 1986-87, the annual rate of change of area, production and yield of mungbean were 18.99, 20.85 and 1.86%, respectively (Table 1). After the release of the modern varieties of mungbean, i.e., after 1986-87, the average area and production of mungbean were increased but the rate of change of area, production and yield were decreased than the previous period. This indicates that more adoption of the modern varieties of mungbean are needed in the farmers' fields.

Table 1: Growth rates of area, production and yield of mungbean

Year	Area (ha)	Production (ton)	Yield (t ha^{-1})
1981-82	15300	8185	0.535
1982-83	14978	8400	0.561
1983-84	15298	8808	0.576
1984-85	15338	9052	0.590
1985-86	15134	8593	0.568
1986-87	57434	34563	0.602
1987-88	57934	33116	0.572
1988-89	58887	29408	0.499
1989-90	60126	31290	0.520
1990-91	57907	31550	0.545
1991-92	55621	32345	0.582
1992-93	53273	31140	0.585
1993-94	53775	30315	0.564
1994-95	54004	31745	0.588
1995-96	54885	32075	0.584
1996-97	55202	33785	0.612
1997-98	55004	34405	0.625
1998-99	55466	34405	0.620
1999-00	55061	36000	0.654
1981/82-1986/87:			
Mean	22247	12934	0.57
CV (%)	77	82	4
Growth Rate (%)	18.99	20.85	1.86
1987/88-1999/00:			
Mean	55934	32429	0.58
CV (%)	4	6	7
Growth Rate (%)	-0.61	1.03	1.64
1981/82-1999/00:			
Mean	45296	26273	0.58
CV (%)	41	42	6
Growth Rate (%)	7.78	8.45	0.67

Source: Yearbook of Agril. Statistics, BBS, Dhaka

Varietal adoption: The adoption level of BARI-released varieties of mungbean is shown in Table 2. BARI Mung-2 was the first popular variety released in 1987 followed by BARI Mung-3 in 1996, BARI Mung-4 in 1996 and BARI Mung-5 in 1997. BARI Mung-2 occupied 35% of the areas sown to pulse in 1998. Adoption of each of BARI Mung-3, BARI Mung-4 and BARI Mung-5 was 3% in the same time peroid.

Several varietal experimentswere undertaken since 1981 in various regions of the country but variety adoption rates were not recorded systematically except very few survey works were done scatteredly. So, the existing variety information as well as seed production information along with the considerable field experiences of the scientists were used to sketch out the percentage area sown by variety which is presented in Table 2.

Calculation of supply shifter k: The supply shifter k identifies the amount of production that can be attributed to varietal improvement research each year (i.e., the shift in the supply curve). The shifter accounted for the yield advantage of BARI Mung-2, BARI Mung-3, BARI Mung-4 and BARI Mung-5 over the local varieties. The shifter was calculated using the equation (4) and is presented in Table 3. For example, in 1997-98, 18.8% more mungbean production was made available because of farmers' adopting BARI-developed mungbean varieties.

Yield advantage: BARI-developed modern varieties of mungbean have replaced the local varieties starting in 1987. BARI Mung-2 was used as the reference variety for all the local varieties followed by BARI Mung-3, BARI Mung-4 and BARI Mung-5.

The potential yields of BARI Mung-2, BARI Mung-3, BARI Mung-4 and BARI Mung-5 were recorded as 1.07, 1.03, 1.05 and 1.00 t ha^{-1}, respectively and the local variety 0.61 t ha^{-1} (Anonymous, 1998). Thus the potential relative yield of BARI Mung-2 over BARI Mung-3 was found 4 percent, BARI Mung-2 over BARI Mung-4 was 2%, BARI Mung-2 over BARI Mung-5 was 7% and BARI Mung-2 over local variety was 43% (Table 3a).

Input cost change: There were likely higher costs per hectare to produce the BARI-developed varieties. These would include higher labour costs because of the increase in harvest and transport costs due to the production increase. Seed might be more expensive and farmers might

Table 2: Adoption of mungbean varieties

Variety and area	Year released	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Released Improved Varieties (RIVs):													
BARI Mung-2	1987	2%	3%	6%	10%	15%	15%	20%	25%	25%	30%	35%	35%
BARI Mung-3	1996										2%	2%	3%
BARI Mung-4	1996										2%	2%	3%
BARI Mung-5	1997											2%	3%
% Area sown to local varieties		98%	97%	94%	90%	85%	85%	80%	75%	75%	66%	59%	56%
% Area sown to HYV Mungbean		2%	3%	6%	10%	15%	15%	20%	25%	25%	34%	41%	44%
Mungbean hectares by category:													
Total hectares local varieties		56285	55623	55354	54113	49221	47278	42618	40331	40503	36224	32569	30802
Total hectares HYVs of Mungbean		1149	1720	3533	6013	8686	8343	10655	13444	13501	18661	22633	24202
Total Mungbean area (ha)		57434	57343	58887	60126	57907	55621	53273	53775	54004	54885	55202	55004

Table 3: Mungbean yield advantage and supply shifter k

Year	% Area BARI Mung-2 replacing Lvs	% Area BARI Mung-3 replacing LVs	% Area BARI Mung-4 replacing LVs	% Area BARI Mung-5 replacing LVs	% Area sown to LVs	Total mungbean area (ha)	Area BARI Mung-2 replacing LVs	Area BARI Mung-3 replacing LVs	Area BARI Mung-4 replacing LVs	Area BARI Mung-5 replacing LVs	Supply shifter k
1986-87	2%	0	0	0	98	57434	1149	0	0	0	0.009
1987-88	3%	0	0	0	97	57343	1720	0	0	0	0.013
1988-89	6%	0	0	0	94	58887	3533	0	0	0	0.026
1989-90	10%	0	0	0	90	60126	6013	0	0	0	0.043
1990-91	15%	0	0	0	85	57907	8686	0	0	0	0.065
1991-92	15%	0	0	0	85	55621	8343	0	0	0	0.065
1992-93	20%	0	0	0	80	53273	10655	0	0	0	0.086
1993-94	25%	0	0	0	75	53775	13444	0	0	0	0.108
1994-95	25%	0	0	0	75	54004	13501	0	0	0	0.108
1995-96	30%	2%	2%	0	66	54885	16466	1098	1098	0	0.146
1996-97	35%	2%	2%	2%	59	55202	19321	1104	1104	1104	0.176
1997-98	35%	3%	3%	3%	56	55004	19251	1650	1650	1650	0.188

Note: LVs = Local Varieties

Example(1986-87): k=(1-LV yield/BARI Mung-2 yield)X % Area BARI Mung-2 + (1-LV yield/BARI Mung-3 yield)X % Area BARI Mung-3 + (1-LV yield/BARI Mung-3 yield)X % Area BARI Mung-3 + (1-LV yield/BARI Mung-4 yield)X % Area BARI Mung-4 + (1-LV yield/BARI Mung-5 yield)X % Area BARI Mung-5= 0.009

Yield Advantage of BARI Mung-2 : 0.432 Yield Advantage of BARI Mung-3 : 0.410

Yield Advantage of BARI Mung-4 : 0.420 Yield Advantage of BARI Mung-5 : 0.393

Table 3a: On-farm mungbean yields by variety

Variety	Yield (t ha^{-1})
BARI Mung-2	1.073
BARI Mung-3	1.032
BARI Mung-4	1.050
BARI Mung-5	1.004
Local Variety	0.609

Source: Annual Report, 1997-98, LBMD Pilot Project, BARI

be using slightly more fertilizers per hectare. There were few studies on costs and returns of different pulses conducted by Agricultural Economics Division, BARI, Gazipur. It was found that the average cost of local mungbean pulse was Tk 3575 ha^{-1} whereas it was Tk 6645 ha^{-1} for modern pulse varieties (Hossain *et al.*, 1993; Islam and Karim, 2000). Therefore, the input cost change was found Tk 3070 ha^{-1}.

Research and extension expenditures: Table 4 presents yearly current research and extension expenditures. Total expenditures included BARI Pulse project expenditures, BARI-Main for salaries, CDP expenditure, BARC share of administrative costs and an estimate of DAE expenditures on mungbean. For the analysis, the current total expenditures were converted to 1997-98 constant prices using the middle income group CPI Index.

Harvest prices of mungbean and its quantity: Table 5 presents the harvest prices of mungbean and quantity in different years. For the analysis, pulse harvest prices were used and were converted to 1997-98 constant prices using the middle income group CPI Index.

Calculation of rate of returns: Equations (1) through (3) were used to estimate the total social benefits to mungbean pulse research and extension expenditures once the supply shifter k had been calculated. The equations were embedded into a computer spreadsheet for ease of computation. First, the yearly total social benefits were estimated using the small closed-economy model (Fig. 1). This was done by assigning the elasticity parameter (η). The analysis was undertaken for each year over the years 1986-87 to 1997-98. However, a research and development lag of 5 years was employed. Research expenditures started in 1981-82, extension expenditures started in 1987-88 and benefits started arriving in 1987-88.

Table 4: Research and extension expenditures for mungbean

Year	BARI pulse project expenditure (current Taka)	BARI main expenditure (current Taka) 2%	CDP expenditure (current Taka) 20%	BARC expenditure (current Taka)	Extension expenditures (DAE) for Mungbean (current Taka)	Total Mungbean expenditure (current Taka)	Total Mungbean expenditure deflated (1997/98=100)	CPI middle income group (1997/98=100)
1981-82		450000		709500		1159500	3524316	32.9
1982-83		510000		4427500		4937500	13677285	36.1
1983-84		522000		4090250		4612250	11676582	39.5
1984-85		261000		3170500		3431500	7816629	43.9
1985-86		840000		4783250		5623250	11666494	48.2
1986-87		825000		2696250	300153	2996403	5632337	53.2
1987-88		900000		2813500	349175	3162675	5334063	59.3
1988-89		915000	2040000	4097500	316484	6453984	10076687	64.0
1989-90		960000	3650000	3730250	411909	7792159	11128138	70.0
1990-91		1012500	2815000	5536250	424026	8775276	11513569	76.2
1991-92		1050000	4340200	6730500	455459	11526159	14391778	80.1
1992-93		1200000	6778600	3993250	553711	11325561	13948647	81.2
1993-94		1274895	5010600	1127500	1744279	7882379	9542832	82.6
1994-95		1357500	12240000	857000	2137516	15234516	17531088	86.9
1995-96		1419000	4400000	1306250	2321707	8027957	8870670	90.5
1996-97	6000000	1455000	4600000	3379250	2553196	16532446	17587708	94.0
1997-98	36000000	1577250	6100000	5908750	2693041	50701791	50701791	100.0

Note: HRC = Horticulture Research Centre; BARI= Bangladesh Agril. Res. Inst; BARC = Bangladesh Agril. Res. Council; DAE = Department of Agricultural Extension

Table 5: Mungbean harvest price and quantity

Year	Harvest price (Tk/ton) (current Taka)	Harvest price deflated (1997/98=100)	CPI middle income group (1997/98=100)	Mungbean production (ton)
1986-87	30734	57771	53.2	34563
1987-88	43596	73528	59.3	33116
1988-89	41077	64134	64.0	29408
1989-90	42229	60308	70.0	31290
1990-91	62889	82513	76.2	31550
1991-92	50857	63501	80.1	32345
1992-93	44427	54717	81.2	31140
1993-94	46222	55959	82.6	30315
1994-95	53108	61114	86.9	31745
1995-96	57074	63065	90.5	32075
1996-97	57074	60717	94.0	33785
1997-98	57074	57074	100.0	34405

Note: CPI = Consumer Price Index

Table 6: Rate of return to mungbean through Ex-post Analysis

Year	Supply elasticity	Demand elasticity	Supply shifter k	Mungbean price (Tk/ton) (Po)	Mungbean quantity (ton) (Qo)	Change in consumer surplus (CS)	Change in producer surplus (PS)	Input cost change	Change in total surplus (TS)	Research costs ©
1981-82	0.70	0.20								3524316
1982-83	0.70	0.20								13677285
1983-84	0.70	0.20								11676582
1984-85	0.70	0.20								7816629
1985-86	0.70	0.20								11666494
1986-87	0.70	0.20	0.009	57771	34563	32474132	-14965339	7635105	9873688	5632337
1987-88	0.70	0.20	0.013	73528	33116	59268897	-27022544	19084440	13161913	5334063
1988-89	0.70	0.20	0.026	64134	29408	91200227	-40226241	39132405	11841581	10076687
1989-90	0.70	0.20	0.043	60308	31290	150708689	63441403	599312255	27336031	11128138
1990-91	0.70	0.20	0.065	82513	31550	308321897	-121873544	76955745	109492608	11513569
1991-92	0.70	0.20	0.065	63501	32345	243258971	-96155457	92398725	54704790	14391778
1992-93	0.70	0.20	0.86	54717	31140	265970198	-98145403	106200390	61624405	13948647
1993-94	0.70	0.20	0.108	55959	30315	327150529	-111924473	125065545	90160511	9542832
1994-95	0.70	0.20	0.108	61114	31745	374142350	-128001276	136368690	109772383	17531088
1995-96	0.70	0.20	0.146	63065	32075	517024228	-151491061	160470105	205063062	8870670
1996-97	0.70	0.20	0.176	60717	33785	619646079	-157178684	190744725	271722669	17587708
1997-98	0.70	0.20	0.188	57074	34405	630039071	-149287249	230269185	250482637	50701791

Table 6: continued .....

Year	Net benefit (NB)	Net present value (NPV)	Internal rate of return (IRR)	Present value research cost (PVRC)	Change in in price absence of new varieties (Pn-Po)	Price in absence of new varieties (Pn)	Area ABC	Area AOC	Area BPPC
1981-82	-3524316	435877196	34%	84756979					
1982-83	-13677285								
1983-84	-11676582								
1984-85	-7816629								
1985-86	-11666494								
1986-87	4241352				0.00	0.01	239795	17268998	32234337
1987-88	7827849				0.00	0.02	657949	31588403	58610947
1988-89	1764894				0.01	0.03	2038536	48935450	89161691
1989-90	16207893				0.01	0.06	5665561	81601725	145043128
1990-91	97979039				0.02	0.08	17586023	168862331	290735874
1991-92	40313011				0.02	0.08	13874973	133228542	229383999
1992-93	47675758				0.02	0.11	20462553	147362242	245507645
1993-94	80617679				0.03	0.14	31832308	183393748	295318220
1994-95	92241295				0.03	0.14	36404693	209736380	337737657
1995-96	196192392				0.04	0.19	69539741	295993426	447484486
1996-97	254134961				0.05	0.23	101808532	360658862	517837547
1997-98	199780847				0.05	0.24	111489739	369262084	518549333

Table 7: Sensitivity analysis on the returns to mungbean research and extension

Parameters	Internal rate of return (IRR) (%)	Net present value (NPV)	Benefit cost ratio	Present value research cost (PVRC)
Base parameters	34	435877196	5.41	84756979
Supply shifter k decreased by 25%	18	133581460	2.33	84756979
Supply shifter k increased by 25%	44	758638206	8.72	84756979
Expenditure decreased by 25%	40	457066441	7.21	63567735
Expenditure decreased by 25% and supply shifter k increased by 25%	50	779827450	11.63	63567735
Supply elasticity increased by 50%	35	443570439	5.50	84756979
Supply elasticity decreased by 50%	35	441104564	5.47	84756979

The yearly total social benefits are presented in Table 6 along side total research and extension expenditures.

When calculating the rate of return, research was assumed to stop in 1997-98 but it was anticipated that benefits from BARI-developed varieties released between 1987-88 and 1997-98 will still occur until the year 2007-2008. The benefits for the year 1998-99 to 2002-2003 were set equal to the benefits that occurred in 1997-98. Thereafter, they were depreciated by 5% per year. A maintenance research plus extension expenditure of one-third of the 1997-98 research and extension expenditure figure was applied to each year from 1997-98 to 2007-2008. The computer spreadsheet function was used to calculate the IRR.

Using the base parameters, IRR was estimated to be 34% for the mungbean research and extension (Table 6). Thus, on average, each Taka invested, returns came 34% per year from the time it was invested until the year 2007-2008. The Benefit cost ratio was found 5.41 (Table 7).

Sensitivity analysis: A sensitivity analysis was undertaken in the study. When the yearly supply shifter k was decreased by 25%, there was a decrease in the rate of return to 18%, BCR 2.33 (Table 7). When the supply shifter k was increased by 25%, the IRR increased to 44% and BCR 8.72. When the expenditures were decreased by 25%, the IRR decreased to 40% and BCR 7.21.A simultaneous increase of 25% in the supply shifter and a 25% decrease in expenditures gave rise to a 50% IRR with 11.63% BCR. Again, with the 50% increase and 50% decrease in the supply elasticity, there were no any significant effect on the IRR and BCR.

The internal rate of return was found 34%. This IRR on investments in research and extension is a good rate of return. The analysis also includes the benefits over the local varieties. The benefit cost ratio was found 5.41 which indicated much higher benefits to the investment.

In the ex-post analysis, only the direct benefits from the increased yield was considered. Two other aspects have not been included which are: I. the benefits from maintenance research and ii. the increase in commodity quality through research.

There were research efforts both on the varietal development as well as non-varietal development from the Pulse Research Centre. There might be other expenditures like outreach and technical assistance from NGO's and other government agencies in addition to BARC expenditures and possibly additional expenditures that were incurred by international research centers and donor agencies in addition to those already accounted for.

Undertaking good quality impact assessment requires good data especially on adoption. Adoption information is important not only for rate of return studies but also for information feedback to researchers about how well a technology is being accepted, the determinants of adoption (who is adopting or not adopting and why) and the distribution of the adopted varieties. These are issues that need to be brought to the attention of researchers, extension personnel and policy makers.

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