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An Ex-Post Impact Analysis on Saline Tolerant Rice Varietal Research in Bangladesh

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Abstract: In ex-post rate of return analysis was conducted to estimate the economic impacts of saline tolerant rice varieties developed and released by the Bangladesh Institute of Nuclear Agriculture (BINA). The main objectives were to estimate: a) the aggregate economic benefits associated with BINA-developed saline-tolerant rice varieties and b) the productivity and profitability of saline-tolerant rice varieties by location and variety. An economic surplus approach was used in the analysis. There were two distinct parts: one was to calculate the research costs and the other part was to calculate the total benefits. The costs were calculated yearly from the beginning of the project in2005until2014. The benefits were calculated from the first year of release in year 2010until2025. The average per hectare BCR, net return, and yield were calculated as 1.71, $429and 4.84 tons, respectively. The estimated cumulative net present value (NPV) of benefits of adoption of the saline tolerant rice variety (discounted at 5%) were calculated as $220 million and the internal rate of return (IRR) of saline tolerant rice research and extension was estimated as 170 percent.
Keywords: Salt tolerant, Rice, Impact, Ex-post analysis.

INTRODUCTION

Bangladesh is predominantly an agro-based developing country. Agriculture is the dominant sector in the Bangladesh economy, contributing 17 percent to the Gross Domestic Product (GDP), of which about 13.4percent is contributed by the crop sector and about 9.6 percent is contributed by the rice sector alone [1].

The growth rate of GDP in Bangladesh mainly depends on the performance of the rice sector, although its losses due to natural calamities like floods, cyclones, salinity and drought are regular phenomenon. Agriculture remains the driving economic force and a major source of income. Rice as the principal food crop provides 54 percent of the agricultural value added, and more than 90 percent of the population consumes rice as their main source of calories. In Bangladesh, people living in rural areas consume more rice than those living in urban areas. Cereals supply 78.3 percent of calories in the diet of the people of which 70 percent are supplied by rice. Moreover, 54 percent of the daily protein requirement is obtained from rice.

Salinity is a major problem in the coastal region of Bangladesh, which contains an area of 2.5 million of hectares or about to 20% of the total land area and 30% of the cultivatable land area in the country. Approximately one million of hectares, or about 53% of the coastal area, have already been affected by salinity. Salinity intrusion has adverse effects on water, soils, agriculture, fisheries, ecosystem, and livelihoods. Rice occupies about 76 percent of the total cropped area of the country of which modern boro rice varieties (including saline tolerant varieties) cover nearly 42 percent of the area. In 1996, the total cultivated area under rice was 10.2 million hectares. By 2000, the area increased to 10.8 million hectares, but by 2007, it had decreased to 10.6 million hectares, but then by 2011, it had increased again to11.7 million hectares (Table 1).In 1996, production of rice was 18.9 million tons and in 2003, 26.2 million tons, with an annual growth rate of 7.6 percent. From 2004 to 2011, production increased to 34.3 million tons, the rate of increase being 55.3 percent, with an annual growth rate 14.8 percent. In the same period the population growth rate was 1.4 percent [1]. Per hectare yield of boropaddy at farm level was28.0 percent higher than the yield obtained on the total rice acreage over the period 1996-2011. In Bangladesh, rice production has increased considerably over the last three decades with the level of boro rice production in 2011, 254% higher than that in 1996after adoption of modern varieties. The cost of rice production also increased because of the increased price of the major inputs during the same period.

Table-1: Area, production and yield rate of boro rice in Bangladesh (including saline tolerant varieties)

	Area		Production		Yield
Financial Year	Million hectare	% of total rice	Million metric ton	% of total rice	Metric ton/hectare
1996	2.78	27.34	7.46	39.51	2.68
1997	2.89	28.14	8.14	43.16	2.82
1998	3.53	34.88	10.55	52.99	2.99
1999	3.65	34.08	11.03	47.81	3.02
2000	3.76	34.81	11.92	47.51	3.17
2001	3.77	35.37	11.77	48.44	3.12
2002	3.85	35.42	12.22	48.51	3.17
2003	3.95	36.47	12.84	49.03	3.25
2004	4.07	39.25	13.84	55.01	3.40
2005	4.07	38.65	13.98	52.70	3.44
2006	4.25	40.21	14.97	54.80	3.52
2007	4.61	43.57	17.76	61.39	3.85
2008	4.72	41.84	17.81	56.86	3.77
2009	4.71	41.46	18.06	56.47	3.84
2010	4.77	41.37	18.62	55.52	3.90
2011	4.85	41.42	18.98	55.34	3.95
1996-2003					
Mean	3.52	33.31	10.74	47.12	3.03
C. V.	0.86	1.34	5.83	5.28	0.50
Growth rate	2.94	27.57	7.59	41.77	2.76
2004-2011					
Mean	4.51	40.97	16.76	56.04	3.71
C. V.	0.65	0.35	2.34	2.35	0.26
Growth rate	4.08	39.31	14.77	54.26	3.66

Source: Bangladesh Bureau of Statistics, 2011

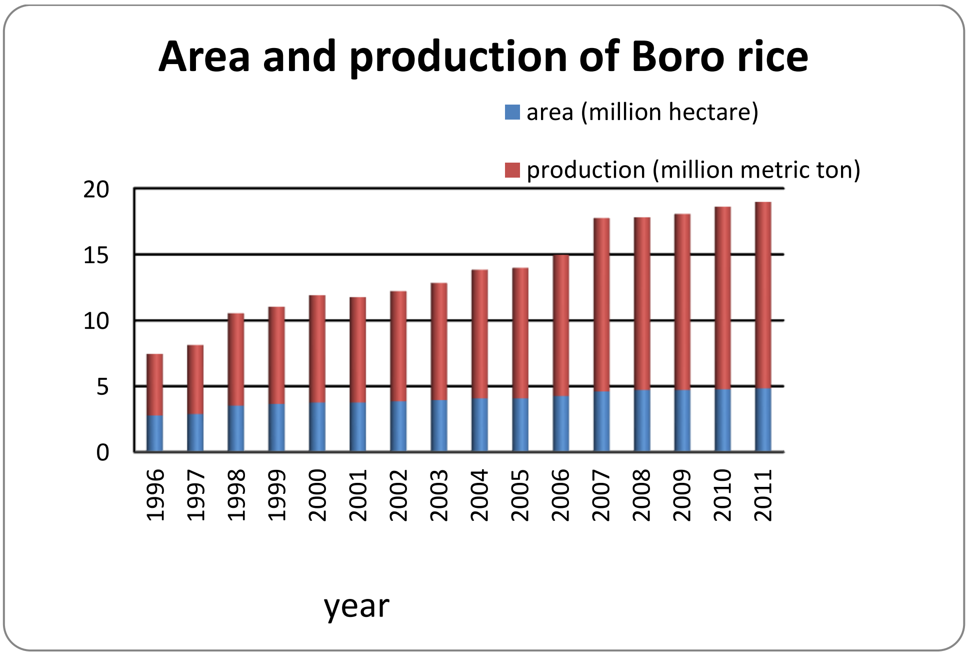

Fig-1: Bar diagram showing area and production of boro rice in Bangladesh

Rice production is the major crop in Bangladesh because its soil is very suitable for its cultivation. Area and production both are increasing day by day (Fig-1).More than 5000 rice genotypes are grown in Bangladesh, of which 77 are government recommended High Yielding Varieties (HYVs), 63were developed by Bangladesh Rice Research Institute (BRRI), and 14were developed by the Bangladesh Institute of Nuclear Agriculture (BINA). Most of the rice varieties are transplanted and are cultivated in three distinct local seasons: Boro (from mid-November to June), Aus (from mid-March to August), and Aman (from late June to January).Some saline-tolerant rice varieties (Binadhan-8, Binadhan-10, Brridhan 47 and Brridhan 55)are grown in the saline area of the country in the distinct boro season [2, 3].

BINA is a specialized agricultural research institute in Bangladesh with the mandate to use nuclear techniques in agricultural research to make breakthroughs in crop production to help attain self-sufficiency in food. Using a radiation/nuclear technique the institute has developed 74 improved mutant varieties of different crops (rice, jute, pulse and oil seed legumes, vegetables, etc.). Using the nuclear technique alone or in combination with modern biotechnology, agricultural researchers address key challenges of the 21st century such as of drought, salinity, high temperature, flooding and submergence problems. Out of the seventy-four high yielding mutant varieties (MVs) that have been developed by BINA, thirteen are of rice; three of jute; eight of chickpea; eight of mungbean; seven of lentil; each one of black gram and grasspea; ten of mustard; six of groundnut; three of sesame; four of soyabean; ten of tomato; and Biofertilizers for seven crops. However, there is no information on the economic performance, varietal acceptability by farmers, and constraints to the adoption of the BINA generated modern technologies or mutant varieties in Bangladesh. In view of the circumstances, the purpose of the present study is to assess the impacts of the BINA generated saline-tolerant rice variety Binadhan-8, one of the most important releases by BINA.

Objectives

The overall objective was to estimate the economic impacts of saline-tolerant rice varieties. The specific objectives were to:

- estimate the aggregate economic benefits associated with BINA-developed saline-tolerant rice varieties;
- estimate the productivity and profitability of saline-tolerant rice varieties by location and variety;
- Suggest policy guidelines/recommendations.

METHODOLOGY

This ex-post economic impact analysis utilized an economic surplus approach and benefit cost analysis to measure aggregate economic benefits and a related statistical analysis to measure the economic and resource use efficiency of saline tolerant rice varieties developed by BINA. Both tabular and statistical analyses were used to achieve the proposed objectives of economic impact assessment of saline tolerant rice varieties developed by BINA.

Analytical Model

Potential economic benefits of saline-tolerant rice varieties of BINA were estimated. We focused upon the saline-tolerant rice varieties for which production and prices are known and approach the benefit assessment by applying an economic surplus model, the most common method for analyzing the economic benefits of agricultural research in a partial equilibrium framework. Total economic benefits (change in total economic surplus or ΔTS) associated with a new saline-tolerant variety for a traded commodity is represented by the formula: $\Delta TS = P_w QK\,(1+0.5Ke)$, where P_w is the traded price; Q is the initial equilibrium quantity; e = supply elasticity, which reflects the responsiveness on the quantity supplied is to changes in price; and K = shift in the supply curve as a proportion of the initial price due to changes in yield and costs as adoption occurs. The latter is calculated as:

$$K = \left(\frac{E(Y)}{\varepsilon}\right) - \left(\frac{E(C)}{1+E(Y)}\right) p\ A\ (1\text{-}d),$$

where E(Y) is the expected proportionate yield increase per hectare after adoption of the new saline tolerant rice variety, E(C) is the expected proportionate change in variable input cost per hectare, p is the probability of success with the research, Ais the adoption rate for the technology, and dis the depreciation rate of the new technology [4].

Economic benefits were calculated as the change in total economic surplus for each year, and the costs were the expenditures on the research projects plus estimated costs after the projects related to developing and disseminating the new saline tolerant rice varieties. The costs and benefits were netted and totaled using the discount rate mentioned above to calculate a net present value (NPV) using the standard NPV formula:

$$NPV = \sum_{t=1}^{T} \frac{R_t - C_t}{(1+i)^t},$$

where: R_t = the benefits in year t; C_t = research, development, and dissemination costs in year t; and i = the discount rate. In other words, the NPV was calculated as the sum of future benefits, minus the costs associated with the project discounted over time. The spreadsheet begins with the first year of the target program or project, and continues for a total of twenty years.

Data and Key Assumptions

Several factors were considered in estimating the economic benefits of a saline-tolerant variety using the economic surplus model: (1) the change in cost per ton of production for those who adopt the new saline tolerant rice varieties; (2) the price of the commodity; (3) the proportion of farmers who adopt the variety over time; (3) the change in yield of the commodity with the new mutant variety; (4) the time it takes to develop the innovation, and the number of years for maximum adoption to be reached; (5) the nature of the market, as products that are traded may not experience price declines if production increases; (6) the benefits of research that is not yet completed depend on the probability that it will be successfully completed (or its inverse, the risk that it fails); (7) the discount rate for future benefits compared to current benefits; and (8) the number of years over which a new technology is used before it is replaced (although, with a 5% discount rate, the results are not very sensitive to this depreciation factor after about 20 years).

Several types of data were used to estimate the economic benefits of a mutant variety using the economic surplus model:

- **Prices**: Prices was converted to U.S. dollars per ton at $1=78 Taka. All commodity prices were obtained from different districts, weighted by production in the markets and averaged for 2010 & 2011.
- **Adoption rate**: A farmer survey was used to measure adoption. Based on that information, the intermediate adoption rates projected for the years between the first year of adoption and the year the maximum is reached are interpolated.
- **Production:** The total production of each saline tolerant rice variety was obtained for the years 2010 and 2011from the BINA reports for that rice.
- **Reductions in yield losses:** Changes in yields for saline-tolerant rice varieties were reported by agricultural economists of BINA and verified by examining survey-based estimates of yield losses.
- **Production costs:** To obtain the cost change per hectare, the percent change in production costs per hectare associated with adopting saline-tolerant rice varieties was taken into account.
- **Elasticity of supply and demand:** The elasticities of supply were assumed to be one for each crop, which is reasonable for annual saline-tolerant rice varieties that have several substitutes in production. Demand elasticities were used to measure the responsiveness of quantity demanded to a change in price. However, estimates of these elasticities were not available, and as an approximation, a demand elasticity of 0.5 (absolute value) was assumed for saline-tolerant rice varieties.

RESULTS AND DISCUSSION

In the study, the data and formulas were included in a spreadsheet. To the typical or most likely value of each key variable, we added a possible minimum and a possible maximum to create a triangular distribution, based on the assumptions or extrapolations from the preceding sub-section, in order to incorporate uncertainty in the economic analysis. We calculated the net present values of the annual economic benefits of the saline tolerant rice over 20 years at a discount rate of 5%. The total net present value (NPV) was calculated as the sum of the annual benefits. We also conducted an analysis to determine how sensitive the average NPV was to the key variables.

Farms were categorized into small (below 0.50 hectares), medium (0.50-2.50 hectares) and large (above 2.50 hectares) farms. For all farm groups, Satkhira area had the largest average farm size (0.58 hectares), followed by Khulna (0.39 hectares) and Bagherhat (0.38hectares). However, an analysis of variance showed that the difference in the average farm size in all farm groups across locations was non-significant. The average farm size of all farm groups in all areas were found to be 0.45 hectares.

The calculated yield advantage of farmers who planted modern saline tolerant rice varieties Binadhan-8 and Binadhan-10 is around 35percent higher than the traditional variety (Table-2).From table-3, the per-hectare mean and standard deviation of total cost were$629 and $214, respectively. The per-hectare mean and standard deviation of total revenue were $1058 and $360, respectively. Table 3 reveals that there are no significant cost and revenue differences among farm groups within an area, but between the areas there were significant cost and revenue differences. The estimated perhect are total cost for all farms in Khulna ($701) was significantly higher than that for Satkhira ($598) or Bagherhat ($587). But per hectare total revenue in all farms in Khulna ($1096) was significantly lower than that in Bagherhat ($1036) or Satkhira ($1022).

Table-2: Yield advantage saline tolerant rice varieties over traditional variety

Particulars	LVs/ traditional variety (n=60)	HYV (Binadhan-8)			HYV (Binadhan-10)			Yield advantage*	
		Farmers practice (n=60)	Demons-tration plots (n=40)	Average Yield (t/ha)	Farmers practice (n=60)	Demons-tration plots (n=40)	Average Yield (t/ha)	Bina-dhan-8 (%)	Bina-dhan-10(%)
Yield (t/ha)	3.14	4.84	5.88	5.36	4.89	5.93	5.41	1.70 (35.12)	1.75 (35.79)
*Yield advantage of farmers practiced HYV variety over traditional variety									

Source: Field survey, 2014.

Table-3: Per hectare mean and std. deviation of total cost & total revenue of Binadhan-8

Area	Farm category	Mean		Std. Deviation	
		Total Cost ($)	Total Revenue ($)	Total Cost ($)	Total Revenue ($)
Satkhira	Small	739.31	1292.58	68.94	148.48
	Medium	654.92	1131.88	95.01	194.51
	Large	219.00	295.40	29.12	49.50
	All	598.12	1022.43	209.23	405.43
Khulna	Small	807.08	1281.76	127.34	169.31
	Medium	816.72	1244.24	67.72	188.66
	Large	266.40	388.91	18.54	34.11
	All	700.68	1096.44	242.62	389.20
Bagherhat	Small	616.55	1243.79	108.39	94.90
	Medium	699.11	1090.35	100.09	225.05
	Large	313.99	497.69	21.83	33.74
	All	587.41	1036.26	170.36	318.24
All areas	Small	732.49	1274.18	135.01	146.56
	Medium	700.84	1136.32	108.22	208.80
	Large	266.46	424.13	45.53	62.23
	All	628.74	1058.22	214.30	360.49

Source: Field survey, 2014

The estimated cumulative net benefits of adoption of the saline-tolerant rice variety(discounted at 5%) over twenty years ranged from over $210 million to $543 million.(Table-4).The total net present value (NPV) for investments in the varietal research and extension of saline-tolerant rice was calculated as the sum of the annual benefits ($220 million). Sensitivity analysis indicated that the variable with the biggest impact on the NPV was the level of change in rice yield resulting from the adoption of Binadhan-8.However, the undiscounted research and development costs for Binadhan-8 varietal research at BINA was estimated to total $1.40 million to bring the saline-tolerant rice variety from laboratory to the end users. In order to assess the economic impacts of the varietal research and extension of saline-tolerant rice variety in BINA, the internal rate of return was calculated. Using the base parameters, the IRR of saline-tolerant rice research and extension was estimated at 170%, implying each dollar invested in research and extension returns 170 percent annually from the date of investment until 2025. Sensitivity analysis revealed that the IRR of the programme was estimated to range from 148 percent to 173 percent under various assumptions, which indicates that the investments from the Bangladesh Government and donor agencies for programme were justified. Increases in yield and adoption percentages increase benefits significantly as expected, while increases in supply elasticities lower them. If yield increases by 1.9 tons/ha rather than 1 ton for saline-tolerant rice in Bangladesh, benefits rise by81 percent. Similarly if yields only increase by 0.5 tons/ha, benefits are 50 percent lower. If the probability of research success was only 50 percent rather than 100 percent or adoption 50 percent lower, benefits would drop the same as they would if yield dropped by 50 percent. Once a variety is developed and released, adoption rates by farmers depend on institutional constraints associated with the seed system, extension services, and other factors. The timing and the rate of adoption assumed in the study depend on the current institutional structure and they may vary if institutional factors change. It is also unclear how much additional saline land might be brought into production. If an additional 5 percent of the salt affected area were brought into production, continuous improvement, and dissemination of a modern saline tolerant rice variety relative to the economic benefits of these varieties. It is a sound policy for the government of Bangladesh to invest in the dissemination of high yielding saline tolerant rice.

The Benefit Cost Ratio (BCR) was calculated at1.71, indicating that each dollar invested in research and extension of saline tolerant rice will generate on average, 1.71 dollars for the study period (Table-4). Across areas, the BCR for small farmers (1.79) was higher than for medium farmers (1.65) and large

benefits would increase by more than 5 percent as the surplus results would include those resulting from a zero production base on those areas. The analysis shows how small the investment cost is of maintaining, farmers (1.61). Among the areas, the average BCR was highest in Bagherhat (1.80) followed by Satkhira (1.73) and Khulna (1.58). The farmers in all areas achieved an average net return of $429 per hectare, with the return highest in Bagherhat ($449) followed by Satkhira ($439) and Khulna ($398). On average, the yield of Binadhan-8 was found to be 4.84 t/ha, and it was also observed that the per-hectare yield was highest in Bagherhat (4.96) followed by Khulna (4.89) and Satkhira (4.65), which means that Bagherhat is better in rice production.

Table-4: Per hectare yield, BCR and net return of saline tolerant rice Binadhan-8

Area	Farm category	Yield (ton)	BCR	Net return ($)
Satkhira	Small	5.77	1.75	553.27
	Medium	5.07	1.73	476.95
	Large	1.71	1.69	150.85
	All	4.65	1.73	439.21
Khulna	Small	5.70	1.61	474.68
	Medium	5.50	1.53	427.52
	Large	1.82	1.51	133.65
	All	4.89	1.58	397.99
Bagherhat	Small	5.93	2.08	627.23
	Medium	5.31	1.60	391.24
	Large	2.26	1.59	183.70
	All	4.96	1.80	448.85
All areas	Small	5.79	1.79	541.68
	Medium	5.24	1.65	435.48
	Large	1.95	1.61	157.67
	All	4.84	1.71	429.48

Source: Field survey, 2014

Other socio-economic impacts are possible with the adoption of improved saline-tolerant rice varieties. These include higher incomes, reduced poverty, and improved health and welfare. Also, since women are traditionally involved more than men in harvesting and processing of rice, they too will benefit from the adoption of improved saline-tolerant varieties. This analysis focused generally on Binadhan-8 as representative of an improved saline-tolerant variety. This analysis may be useful for Binadhan-10 and other improved saline tolerant rice varieties. These extensions are recommended for future studies.

Table-5: Economic returns to the varietal research and extension programme of salt tolerant rice varieties developed by BINA

Year	Supply Elasticity (E)	Demand Elasticity (N)	Yield Change	Gross Propor. Cost Change	I. Cost Change Per Ha.	I. Cost Change Per Ton	Net Change	Prob Of Success	Adopt Rate	K	Price	Quantity	Cts	Cost	Benefit	Npv* ($)	Irr
2005	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.00	0.00	192.00	19,000,000.00	0.00	100,000.00	-100,000.00	2,199,911,996.40	1.70
2006	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.00	0.00	192.00	19,000,000.00	0.00	130,000.00	-130,000.00		
2007	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.00	0.00	192.00	19,000,000.00	0.00	200,000.00	-200,000.00		
2008	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.00	0.00	192.00	19,000,000.00	0.00	220,000.00	-220,000.00		
2009	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.00	0.00	192.00	19,000,000.00	0.00	250,000.00	-250,000.00		
2010	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.00	0.00	192.00	19,000,000.00	0.00	100,000.00	-100,000.00		
2011	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.01	0.01	192.00	19,000,000.00	21,135,545.27	100,000.00	21,035,545.27		
2012	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.03	0.02	192.00	19,000,000.00	63,553,240.74	100,000.00	63,453,240.74		
2013	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.05	0.03	192.00	19,000,000.00	106,166,409.47	100,000.00	106,066,409.47		
2014	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.08	0.05	192.00	19,000,000.00	170,452,674.90	100,000.00	170,352,674.90		
2015	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.10	0.06	192.00	19,000,000.00	213,554,526.75	0.00	213,554,526.75		
2016	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.12	0.07	192.00	19,000,000.00	256,851,851.85	0.00	256,851,851.85		
2017	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.14	0.08	192.00	19,000,000.00	300,344,650.21	0.00	300,344,650.21		
2018	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.16	0.09	192.00	19,000,000.00	344,032,921.81	0.00	344,032,921.81		
2019	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.18	0.10	192.00	19,000,000.00	387,916,666.67	0.00	387,916,666.67		
2020	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.20	0.12	192.00	19,000,000.00	431,995,884.77	0.00	431,995,884.77		
2021	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.21	0.1	192.	19,000,00	454,108,79	0.00	454,108,79		

										2	00	0.00	6.30		6.30		
2022	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.22	0.13	192.00	19,000,000.00	476,270,576.13	0.00	476,270,576.13		
2023	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.23	0.13	192.00	19,000,000.00	498,481,224.28	0.00	498,481,224.28		
2024	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.24	0.14	192.00	19,000,000.00	520,740,740.74	0.00	520,740,740.74		
2025	0.40	0.50	0.35	0.88	0.40	0.30	0.58	1.00	0.25	0.14	192.00	19,000,000.00	543,049,125.51	0.00	543,049,125.51		

*NPV at 5 % discount rate.

CONCLUSIONS

Clearly, the introduction of the saline-tolerant rice variety Binadhan-8 in Bangladesh has the potential for substantial economic benefits. Estimated net economic benefits of Binadhan-8 range from $2.10 million to 5.43 million over 25 years. Results are not sensitive to changes in the demand elasticity, but are sensitive to changes in the supply elasticity and yield. It is evident from the study that adoption of Binadhan-8 in place of traditional varieties generates substantial economic benefits to the society.

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