Research Paper

An Evaluation of the Economic Impacts of Research on Hybrid Chilli Package by the Department of Agriculture

A.T. Sooriyaarachchi[1*], R.A.C.J. Perera[2], H.M.N.S. Herath[2]

[1] *Agriculture Economists, Socio Economics and Planning Center, Peradeniya, Sri Lanka*

[2] *Research Officer, Field Crop Research and Development Institute, Mahailuppallama*

**Corresponding author: arunasoori@yahoo.com*

Abstract

During the last few decades investments in the development of hybrid varieties and technological packages have been increased. However, few studies on the economic evaluation of these investments on innovations have been tested in Sri Lanka. This study estimated the net benefits and rate of returns to investment on research on hybrid chilli package developed by the Department of Agriculture in Sri Lanka. This innovation has a higher welfare gain to the society with producer and consumers point of view. The Economic Surplus Model analysis was used to determine the returns to investment and their distribution between producers and consumers. The yield of technical package was 300 percent higher than the average yields of existing varieties. The net present value of the investment was 12,290 million Sri Lankan Rupees. The internal rate of return and benefit cost ratios were estimated to be192 percent and 4.04, respectively. This indicates that investment in research on hybrid chilli package was economically viable. The present values of benefits to consumer, producer and economic surplus are 6,257, 10,497 and 16,752 Sri Lankan Rupees, respectively. The higher levels of adoption rate have led to increase the welfare gain to society. The enhancement of hybrid chilli seed production program and extension program helps to increase adoption. The strengthening of agriculture extension system is essential for the increase of the benefit of the innovations.

Keywords: Economic surplus model, Return to investment, Yield advantage

Introduction

With the increase in population and changes in food habits, the demand for chilli in Sri Lanka has increased significantly. The local green chilli demand was fulfilled by the domestic production and dry chilli demand is totally fulfilled by imports. Total value of dry chilli import has increased from 5,00 million Sri Lankan Rupees (LKR) in 2010 to14,850 million Sri Lankan Rupees (LKR) in 2019 (AgStat. 2019).

Realizing the escalating demand of food crops, the Department of Agriculture (DoA), has stepped forward the breeding program from Open Pollinated Varieties (OPV) to hybrid varietal development programs to improve land productivity.

Meanwhile, the private sector has been importing exotic food crop hybrids since late nineteen eighties. However, these exotic hybrids that were not adequately locally tested, sometimes, failed to perform consistently at farmer fields. They have realized less than 10% of adoption (Socio Economics and Planning Center. 2019).

In 2015, the national green chilli yield per hectare was very low (around 5 t ha^{-1}) and later it increased with the release of Hybrid Chilli Package (HCP). Hence, the DoA started research on hybrid variety development and improving agronomic packages (HCP) through the Field Crops Research and Development Institute (FCRDI) in 2010-2015 to increase chilli production. As a result, in 2015, two agronomic management packages were developed by the FCRDI, one based on the drip irrigation system and the other based on the sprinkler irrigation system for the MICH-Hy -1 hybrid chilli variety. This study focused on the agronomic management package developed based on the sprinkler irrigation system. Mulching with paddy straw, amendment of organic manure and application of DoA recommended inorganic fertilizer with Albert fertilizer mixture as a micro nutrient source were applied as a package under the sprinkler irrigation system. The extension staff of central and provisional government agriculture has contributed to disseminate the improved chilli variety and the package among farmers very successfully.

The experience and knowledge gained by researchers involved in research program has facilitated further HCP development. Therefore, this gain of knowledge is another benefit of future research program. The DoA has invested more in HCP. Some of the investments have been made for durable equipment of which services are taken for research. In addition to that, available infrastructure facilities, and human resources have been used for research program.

This study considered the benefits and cost from research of HCP and its farm level adoption in the country to produce dry chilli as well as green chilli. Overall objective of this study was evaluation of the economics of research on HCP. The specific objectives were:

1. To estimate yield advantage of HCP over conventional cultivation practices in chilli (CC),
2. To estimate the distribution of benefits from the technology development research and extension program that accrues to the producers and consumers of research on HCP,
3. To assess the efficiency of the research on HCP development program by estimating the rate of returns, net present value, and benefit cost ratio.

Materials and methods

Estimation of returns to investment

Following Alston *et al*. (1995) Economic Surplus Model (ESM) was adopted to estimate the rate of returns to investment in research on hybrid chilli package. The analysis was done under a closed-economy and a small open economic model for green and dry chilli markets in Sri Lanka, respectively.

Conceptual modal

The theoretical concept of ESM is illustrated in Figure 1. The economic surplus model has been widely used to measure economic welfare and the changesin economic welfare from policy and other interventions (Ayer and Schuh, 1972; Alston *et al*., 1995; Mahrouf and Rafeek, 2004; Hasan *et al*., 2009; Islam, 2009; Hasan and Banik, 2015). Usually, the ESM is used to estimate the benefits from the adoption of improved varieties and technologies. The components of economic surplus consist of consumer surplus and producer surplus. Given the initial condition in the Fig. 1 "OS_o"and "DD^1" represent initial supply function and Demand function, equilibrium price and quantities represent by "P_o "and "Q_o". After the introduction of HCP Supply curve shifts from "OS_o" to "OS_1". Demand function remain unchanged as "DD^1", new equilibrium price and quantities are represented by "P_1"and "Q_1". The supply by the conventional growers reduce to Q_o' and adopters of hybrid may gain area ABO with Q_1- Q_o' amount of supply.

For a closed economy model, the estimatedprice elasticity of demand (ηand supply (γ) is used in the below Akino and Hayami (1975) approximation formulas for calculating changes in producer, consumer and economic surplus (Fig. 1) as follows,

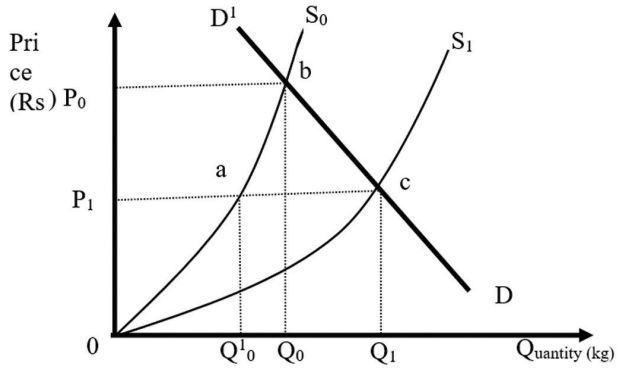

Figure 1. Economic surplus model (Adopted from Akino- Hayami 1975)

$$\text{Area A (abc)} = 0.5\, P_o\, Q_o \left(P_o\, Q_o k \right)$$

$$\text{Area B (Oac)} = kp_o q_o$$

$$\text{Area C } (P_1 baP_o) = \left(P_o\, Q_o k \left(\frac{(1+y)}{(y+n)} \right) \right) \times \left(1 - \left(\frac{0.5k(1+y)}{y+n} \right) - 0.5k(1+y) \right)$$

where:

P_o= Price of chilli (LKR/ton) (existingmarket price)

Q_o = Production of hybrid chilli (ton)(existing production)

k = Horizontal supply shifter

γ = Price elasticity of chilli supply

η = Absolute price elasticity of the demandfor the commodity.

Welfare gain for closed economy	*Closed economy model* Area from graph *green chilli*	Open economy model Area from graph dry chilli
Change in producer surplus	Area B (0ac)-Area C ($P_oba P_1$)	zero
Change in consumer surplus	Area A (abc) +Area C ($P_oba P_1$)	zero
Change in economic surplus	Area A (abc) + Area B (0ac)	Area B (0ac)

The supply shifter (*k*)

The supply shifter *k* is the overall yield advantage of HCP over the conventional local varieties weighed by the area cultivated to the HCP. When Akino and Hayami (1975) approximation formulas are considered, *k* is the horizontal shift in Fig. 1 (Hassan and Miah, 2003; Hasan *et al*., 2009; Hasan and Banik, 2015). The supply shifter k is calculated as follows:

$$kA = \sum_{i=1}^{n} \left[1 - \frac{y_t}{y_{it}} \right] \times A_{it}$$

Where:

y_{it}= Yield of the hybrid chilli package in year *t*

y_t= Yield of a conventional local/ existing variety chilli (Average yield)

A_{it} - Proportion of the total area cultivated to the HCP in year *t*

n = Number of improved chilli varieties (Assume as one)

Financial viability of investment on development of hybrid chilli package

Financial viability of investment on HCP was evaluated by using the net present value (NPV) (Hasan *et al*., 2009; Hasan and Banik, 2015) benefit cost ratio and internal return rates (Hasan *et al*., 2009; Hasan and Banik, 2015) for the period 2011 to 2025 period.

Source of data

Data were collected from both published and unpublished reports and informal interviews with scientists. The adoption rates were collected through informal interviews with scientists and extension workers. The supply elasticity was taken from previous studies (Mayadunne *et al*., 1999; Ratnasiri *et al*., 1999) and through consultation of experts of the field. The cost involved in research, extension, input costs, labor costs for HCP, were collected from the interviews with relevant officers of the DoA for 2011 to 2025 period. Data for convention cultivation of chilli was collected from cost of cultivation survey reports (DoA,2019). Sri Lankan rupee to USD conversion ratio was 180 (year 2015).

Assumptions

1. All factors other than price that influence supply of chilli remain unchanged.
2. Demand function of chilli remains unchanged during the period of analysis.
3. There is no significant government intervention adequately to influence chilli market prices during the period of analysis.
4. Quality of hybrids and OPV's chilli are homogeneous.
5. Sri Lanka is a net importing country for dry chilli
6. Introducing HCP is obsolete in 2025 and replaces another variety/ technology

Table 1. Types and sources of data

Data	Source
P_o = Market Price of chilli (LKR/ton) (respective year existing)	Department of Census and Statistics
Q_o = Production of hybrid chilli (ton) (respective year existing)	Department of Census and Statistics
γ = Price elasticity of chilli supply.	Mayadunne, *et al*. (1999), Ratnasiri, *et al*. (1999)
η = Price elasticity of chilli demand	
y_{it}= Yield of the improved varieties of chilli in year *t*	Field Crops Research and Development Institute
A_{it}- Proportion of the total area sown to the improved variety of chilli in year *t*	
y_t= Yield of average yield of existing chilli variety	Department of Census and Statistics
C_t = Cost of research and extension in year *t*	Department of Agriculture
CCPI	Department of Census and Statistics
Dry Chilli production (*t*)	Department of Census and Statistics
Import (CIF) price	Sri Lanka Custom

Results and Discussion

Adoption and yield advantages of hybrid chilli package

The development and diffusion of novel innovations is a very important factor by which the volume of change in economic surplus is determined. The chilli varietal adoption information along with the considerable field experience of the scientists and extension officers were used to sketch out the percentage area sown by variety grouping, which are presented in Table 2.

HCP was released in 2015/16. The HCP adoption increased from 2% in 2015/16 to 33% in 2024/25 (Table 2). This result of adoption of technology shows a gradual increase and then it is replaced by other technology. The HCP is replaced by the higher productive technology in 2025 (10-year period). The same result shows the adoption of Chilli (Hasan and Banik, 2015), Radish (Hossain *et al*., 2003), Onion (Hasan *et al*., 2009) and Rapeseed (Hassan and Miah, 2003) in Bangladesh.

shifter *k*

The higher the value of the supply shifter, the more is the shift inthe supply curve, resulting in higher benefit to the society. The supply shifter is the outcome of the simultaneous force of adoption percentage and HCP yield advantage. Table 3 shows that the rate of supply shifter gradually increased. The contribution of conventional chilli production (CC) increased from 74,835 tons in 2016 to 102,500 tons in 2025. The contribution of HCP increased from 6,000 tons in 2016 to 200,000 tons in 2025. The total green chilli production increases from 80,835 tons from 2016 to 302,500 tons in 2025.

Table 2. Conventional and hybrid chilli package usage in chilli cultivation

Year	Total cultivation area	Conventional cultivation area		HCP cultivation area	
	(ha)	(ha)	(%)	(ha)	(%)
2011	13,313	13,313	100%	0	0%
2012	14,728	14,728	100%	0	0%
2013	15,454	15,454	100%	0	0%
2014	13,978	13,978	100%	0	0%
2015	13,029	13,029	100%	0	0%
2016	15,267	14,967	98%	300	2%
2017	10,937	10,387	95%	550	5%
2018	13,553	12,453	92%	1,100	8%
2019	10,981	9,881	90%	1,100	10%
2020	13,700	11,700	85%	2,000	15%
2021	21,263	17,013	80%	4,250	20%
2022	26,700	19,950	75%	6,750	25%
2023	23,950	16,750	70%	7,200	30%
2024	26,199	17,699	68%	8,500	32%
2025	30,500	20,500	67%	10,000	33%

Table 3. Production from hybrid chilli package and supply shifter (*k*)

Year	Area of HCP replacing by CC (%)	Supply shifter (*k*)	Production from CC (mt)	Production from HCP (mt)	Total production (mt)
2011	0%	-	66,565	-	66,565
2012	0%	-	73,640	-	73,640
2013	0%	-	77,270	-	77,270
2014	0%	-	69,890	-	69,890
2015	0%	-	65,145	-	65,145
2016	2%	0.01	74,835	6,000	80,835
2017	5%	0.04	51,936	11,000	62,936
2018	8%	0.06	62,265	22,000	84,265
2019	10%	0.08	49,405	22,000	71,405
2020	15%	0.11	58,500	40,000	98,500
2021	20%	0.15	85,065	85,000	170,065
2022	25%	0.19	99,750	135,000	234,750
2023	30%	0.23	83,750	144,000	227,750
2024	32%	0.24	88,495	170,000	258,495
2025	33%	0.25	102,500	200,000	302,500

Yield advantage

Yield advantage of HCP is a very important factor to determine economic surplus. The yield performance of HCP at farmers' level ranged from 20 to 40 t ha^{-1}, which was closely related to the yields calculated by the FCRDI. However, in this study it is assumed 20 t ha^{-1} yield (minimum value of yield obtained by the farmer at research level observation). When compared to CC practices, the yield advantage of HCP was found to be 300 percent (Table 4). The same results were shown for radish (Hossain *et al*., 2003), onion (Hasan *et al*., 2009), chilli (Hasan and Banik, 2015) in Bangladesh.

Estimating the benefits from chilli research and extension

The FCRDI and extension system of the DoA at national and provincial level involve in the HCP development and dissemination to the farmers. The research cost accounts from 2011, when development of HCP started. The extension expenditures and input cost change with extension and inputs, which were born after the development of the HCP in 2015/16. Research cost is collected from FCRDI/DoA. Extension cost is collected from DoA. Input cost change is computed by consulting researchers and extension experts.

For this analysis, current total expenditures were converted to 2010 constant prices deflating by the CPI Index. The net present value was computed at 15% discount rate using deflated values. The present value expenditures of research, extension and input cost changes amounted to LKR 14 million, LKR 40 million and LKR 4,408 million (USD 0.07 million, USD 0.22 million and USD 24.49 million), respectively. Over the years, total cost was LKR 4,461 million (USD 24.79 million) (Table 5).

The net present value of consumer, producer surplus, total benefit and total net benefits ware computed for the period year 2011 to 2025. The net present value of total change in consumers' and producers' surplus due to chilli research and extension were estimated as LKR 6,257 million (USD 34 million) and LKR 10,497 million (USD 58 million). The estimated total surplus/ benefits ranged from LKR 16,752 million (USD 93 million). Furthermore, the total net benefits obtained from chilli research and extension was LKR 12,290 million (USD 68.27 million) (Table 6).

Table 4. Average green chilli yield, difference and advantage of hybrid chilli package

Average yield of CC (t ha^{-1})	Average yield of HCP (t ha^{-1})	Yield difference (t ha^{-1})	Yield advantage (t ha^{-1})
5	20	15	300%

Table 5. Expenditure (SLR) for change in hybrid chilli package (2010 Base year)

Year	Research expenditure (A)	Extension expenditure (B)	Input cost change (C)	Total expenditure (D= A+B+C)
2011	3,058,563	-	-	3,058,563
2012	2,844,040	-	-	2,844,040
2013	2,464,650	-	-	2,464,650
2014	4,549,929	-	-	4,549,929
2015	4,019,306	-	-	4,019,306
2016	3,866,246	7,714,918	233,409,227	244,990,391
2017	652,671	19,702,510	397,307,777	417,662,958
2018	639,028	23,084,874	778,004,857	801,728,759
2019	617,249	13,502,315	751,489,355	765,608,919
2020	593,508	14,689,332	1,313,792,579	1,329,075,419
2021	499,346	15,765,066	2,684,431,952	2,700,696,363
2022	480,140	18,108,151	4,099,528,433	4,118,116,724
2023	461,673	17,807,404	4,204,644,547	4,222,913,624
2024	443,917	17,122,503	4,772,900,460	4,790,466,880
2025	426,843	16,463,946	5,399,208,665	5,416,099,454

Source: - Based on data collected form researchers and extension workers in DOA

Table 6. Consumer surplus, produce surplus, total surplus change of adoption, total expenditure and net benefit of adoption (Mn. SLR) of chilli hybrid package (2010 Base year)

Year (A)	Change in consumer surplus (B)	Change in producer surplus (C)	Change in total surplus (D= B+C)	Total expenditure (E)	Net benefit (F=D-E)
2011	-	-	-	3.06	(3.06)
2012	-	-	-	2.84	(2.84)
2013	-	-	-	2.46	(2.46)
2014	-	-	-	4.55	(4.55)
2015	-	-	-	4.02	(4.02)
2016	246.37	426.09	672.46	244.99	427.47
2017	442.69	762.91	1,205.61	417.66	787.94
2018	726.07	1,246.70	1,972.76	801.73	1,171.04
2019	932.57	1,597.59	2,530.16	765.61	1,764.55
2020	1,150.20	1,959.19	3,109.39	1,329.08	1,780.32
2021	2,544.41	4,303.74	6,848.15	2,700.70	4,147.46
2022	4,542.62	7,628.35	12,170.98	4,118.12	8,052.86
2023	7,948.20	13,256.54	21,204.74	4,222.91	16,981.83
2024	8,930.64	14,842.92	23,773.55	4,790.47	18,983.09
2025	10,157.38	16,873.15	27,030.52	5,416.10	21,614.42

Rate of return of chilli research and extension

During the years 2011 to 2024 period, the Net Present Value (NPV), Internal Retrun Rate (IRR), and Benefit CostRatio (BCR) of HCP research and extension in a closed economy condition are shown in Table 7. All the estimates were calculated at constant (2010) prices with 15 percent discount rate. It was revealed that society benefited substantially from investment in research in HCP in Sri Lanka. The NPV was negative up to 2016 and after that it became positive. The NPV was found to be LKR 12,290 million (Table 5). IRR is 192% and it implies that the expenditure on research HCP could have been borrowed at 192 percent real rate of interest without incurring loss. The BCR was found to be 4.04 for research on HCP (Table 7). The NPV, IRR and BCR ratio in chilli study in Bangladesh shows 289 million Bangladeshi Taka, 55% and 5.48, respectively (Hasan and Banik, 2015). The values NPV, IRR and BCR of onion research in Bangladesh show 35.29 million Bangladeshi Taka, 25 and 3.09 (Islam, 2009). The IRR and BCR will be increased by increasing the adoption of the improved package of chilli. The value of the parameter indicated that the investment in research and extension of HCP in Sri Lanka is profitable and economically viable.

Table 7. NPV, IRR and BCR of adoption HCP

NPV (LKR)	IRR	BCR
12,290,246,481	192%	4.05

Foreign exchange savings from dry chilli

For a small open-economy market is one where the amount of exports or imports is small relative to total world trade in the commodity. Sri Lanka is net dry chilli importing country. Thus, there is little or no effect on the world price of the commodity (the small country assumption), where the elasticity of demand is perfectly elastic, a sufficiently large number of η (Nagy and Alam, 2000; Hassan and Miah, 2003; Hasan and Banik, 2015) are used. In this case, the price of the dry chillidoes not change with the shift in the dry chilli supply curve. There is no change in dry chilli consumer surplus; consumers are neither better off nor worse off. The change in economic surplus from the adoption of HCP is thus a change in producer surplus only and is identified by area "0ac"in Fig. 1. The amount of foreign exchange saved by the adoption of improved technological package is equal to $kP_0 Q_0$ (with assume excess chilli production used to as dry chilli).

The yearly increase in production of dry chilli is due to research saves the country's foreign exchange. First, the research-induced increase in dry chilli production for each year was calculated by multiplying the country's total dry chilli production by its respective supply function shifter *k*. Foreign exchange savings was calculated by multiplying the results by the world dry chilli price (CIF price of dry chilli is 282.50 LKR). The amount of producer surplus is equal to total economic benefit as well as it indicates of the foreign exchange savings. Thus, the increased production attributed to chilli improvement resulting from chilli research and extension (HCP) saves foreign exchange amounting to LKR 5,293 million (USD 29.40 million) (Table 8).

Table 8. Foreign exchange savings after the adoption of HCP (2010 Base year)

Year	Import (CIF) price (Rs.) (A)	Supply shifter (k) (B)	Dry Chilli production (t) (C)	Increased production from HCP (t) (D=B x C)	Foreign exchange savings (Rs. mn) (E=AX BXC)
2011	-	-	-	-	-
2012	-	-	-	-	-
2013	117.74	-	5,454	-	-
2014	128.95	-	3,978	-	-
2015	160.74	-	3,029	-	-
2016	193.43	0.01	6,167	91	17.58
2017	103.61	0.04	2,587	98	10.11
2018	140.81	0.06	6,853	417	58.74
2019	181.66	0.08	4,281	322	58.43
2020	139.10	0.11	9,700	1,062	147.73
2021	133.75	0.15	24,013	3,600	481.48
2022	128.61	0.19	36,950	7,006	901.03
2023	123.66	0.23	35,550	8,015	991.21
2024	118.91	0.24	41,699	10,147	1,206.50
2025	114.33	0.25	50,500	12,418	1,419.79

Conclusions

The results of the study indicated that the research and extension of HCP represents a lucrative both government and donors' investments in such a technology development research program. It is also needed to conduct a research on factor affecting dissemination of technologies and welfare distribution of investment in generation technological innovation in agriculture at producer, consumer, and general public.

It can be concluded from the aforementioned discussions that the modern technology development research and extension program of chilli in the country was found to be very efficient in terms of the higher NPV, IRR and benefit cost ratio.

References

Akino M, Hayami Y 1975. Efficiency and equity in public research: rice breeding in Japan's economic development. American Journal of Agricultural Economics 57: 1-10

Alston JM, Norton GW, Pardey PG 1995. Science Under Sarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Cornell University Press.

Ayer HW, Schuh GE 1972. Social rates of return and other aspects of agricultural research: The case of cotton research in Sao Paulo, Brazil. American Journal of Agricultural Economics 54: 557-569.

Socio Economics and Planning Center. 2019. Cost of cultivation of agricultural crops (Vol. 75). Socio Economics

and Planning Center, Department of Agriculture, Peradeniya

AgStat. 2019. Agricultural Statistics. Volume xvi. Socio Economics and Planning Center, Department of Agriculture, Peradeniya.

Hasan M, Banik BR 2015. Economic cost and returns from research and development: The case of chilli in Bangladesh. Asian Journal of Agriculture Development 12: 67-79.

Hasan MK., Islam MS, Mian MAM 2009. Returns to investment in summer onion research and extension in Bangladesh. Bangladesh Journal of Agricultural Economics 32:49-61.

Hassan MK, Miah MAM 2003. Impact of rapeseed and mustard research and extension in Bangladesh. Bangladesh Journal of Agricultural Research 28:15-31.

Hossain MI, Miah MM, Sattar M 2003. Returns to radish research and extension in Bangladesh. The Agriculturist 1:69-81.

Islam MS 2009. Returns to investment in summer onion research and extension in Bangladesh. The Bangladesh Journal of Agricultural Economics, 32:49-61.

Mahrouf A, Rafeek M 2004. Mechanization of paddy harvesting: the economic perspective. Annals of the Sri Lanka Department of Agriculture 5: 161-172

Mayadunne A, Bogahawatta C, Abeyratne F 1999. Area supply response to other field crops with uncertain prices and yields: the case of chilli. Tropical Agricultural Research 11: 239-254.

Nagy JG, Alam M 2000. Returns to wheat breeding research in Bangladesh. Bangladesh Journal of Agricultural Economics 23: 1-17.

Norton GW, Davis JS 1981. Evaluating returns to agricultural research: a review. American Journal of Agricultural Economics 63: 685-699.

Ratnasiri S, Marasinghe R, Weerahewa J 1999. Economic impact of trade liberalization for other field crops in Sri Lanka. Tropical Agricultural Research 11: 255-271.