A study on economic impact assessment of tomato var. Kashi Aman using the economic surplus model

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Abstract

ICAR-Indian Institute of Vegetable Research, Varanasi, developed a 'Kashi Aman' tomato variety in 2013. Farmers in different parts of the country widely adopt and cultivate this variety. The present study helps in estimating the economic surplus generated as a consequence of research outputs for the development of tomato variety 'Kashi Aman'. The approximate spread of area under Kashi Aman variety was estimated at 247876.13 ha from 2014-15 to 2021-22, covering 146 districts in 25 states. The economic surplus model's estimated results showed a producer surplus of Rs. 19.18 crore, consumer surplus of Rs. 30.44 crores and total economic surplus of Rs. 49.62 crores generated from the variety. The Net Present Value (NPV) generated was Rs.48.83 crores and Net Present Benefit (NPB) was Rs.49.62 crores. The Internal Rate of Return (IRR) was 85% and Benefit Cost Ratio (BCR) 62.91 in the present technology. The total cost of cultivation of Kashi Aman variety of tomato was Rs. 194101 per hectare compared to Rs. 211303 per hectare of local variety. The net return in the Kashi Aman variety of tomatoes was Rs. 294149 per hectare while it was Rs. 218697 per hectare in local variety of tomatoes. The BC ratio was 2.52 and 2.04 for Kashi Aman variety and local variety of tomatoes grown by the farmers. The present study indicates that the investments made for the development of Kashi Aman variety of tomato was highly economical and provided evidence to the policymakers supporting the research investment.

Keywords: Economic impact assessment, tomato, Kashi Aman.

Introduction

The efficient resource allocation under scare resource use and the necessity to justify their use to society requires the assessment of the economic impacts of research. Economic analysis is helpful to know the social value of scientific knowledge and technologies and to make judgments about the trade-offs in the allocation of scarce resources in research (Alston *et al.* 1995). Economic impacts assessment of new technologies delivers helpful information to justify investment efforts in research and development to generate new technologies (Wander *et al.* 2004). Vegetables are most important constituents of Indian agriculture and nutritional security due to their high yield, short duration, economic viability, healthful richness and creating on-farm and off-farm employment. New vegetable varieties/hybrids and technological interventions have given tremendous boost to vegetable production. Vegetable production in India has touched a new height in recent years. Vegetables contributed an estimated area of 10.86 million hectares with a production of 200.45 million tonnes and productivity of 18.46 tonnes per hectare during the year 2020-21 (Anonymous 2022) is

the second biggest producer of vegetables in the world next to china. The ten major vegetables *i.e.* Potato (28.02%), onion (13.29%), tomato (10.57%), brinjal (6.42%), cabbage (4.77%), cauliflower (4.60%), tapioca (3.46%), okra (3.23%), pea (2.92%) and green chilies (2.18%) constituting around 80% of the total vegetable production in the country. Tomato (*Solanum lycopersicum* L.) is a major commercial vegetable and can increase the income of rural people with creating employment opportunities and improvement in living standard. In India, vegetable in general and tomato in particular is primarily grown by small and marginal farmers for whom it is an important source of income. Tomato is grown in open to greenhouse using hi-tech nursery and advanced cultivation practices for quality and high yield (Mahala *et al.* 2020, Verma *et al.* 2020, Kumar *et al.* 2021). Tomato is a popular, nutrition-rich vegetable that is an excellent source of vitamin C and also called poor's man orange. It is one of the most important vegetables having many end uses. Tomatoes are consumed as fresh vegetables because they contain essential nutrients and antioxidant-rich phytochemicals. Tomatoes contain minerals, vitamins, proteins, essential amino acids (leucine, threonine, valine, histidine, lysine, arginine), monounsaturated fatty acids, carotenoids and phytosterols (Ali *et al.* 2021). Tomato is produced in temperate, subtropical and tropical areas around the world (Blanca *et al.* 2012). The World production of tomato was 186.82 million tonnes from an area of 5.05 million hectares with a productivity of 36.98 tonnes/hectares during the year 2020. China is the leader in tomato production at global level with a 34.72% share (64.87 million tonnes) in total production. India ranks second in tomato production globally with an 11.01% share (20.57 million tonnes) in total production (FAO 2022). Tomato area, production and productivity in India during the year 2020-21 was about 845 thousand hectares, 21181 thousand tonnes and 25.07 tonnes/ha, respectively (Anonymous 2022).

An attempt was made in this paper to study the research investment for the development of Kashi Aman variety of tomatoes which generates economic returns to society. The present study was an ex-post assessment based on the economic surplus approach. The study helps in estimating the economic surplus generated as a consequence of research outputs. The information derived through the economic surplus approach is used to estimate benefit-cost ratio (BCR), internal rate of return (IRR) and net present value (NPV) of research outputs. Thus present study aims to contribute the discussion on benefits of Kashi Aman variety of tomato in terms of yield gain, reduction in cost and monetary benefits to producers, consumers and society. ICAR-Indian Institute of Vegetable Research, Varanasi developed a 'Kashi Aman' tomato variety in 2013 (H. C. Prasanna & Major Singh). This variety was recommended for release and cultivation in the states of Punjab, Uttar Pradesh,

Bihar, and Jharkhand and ideal for cultivation during Kharif and Rabi in recommended states. Salient features of this variety include resistant to tomato leaf curl virus disease (ToLCVD). Variety carries an allele of *Ty3* gene. It has shown high level of resistance in field tests and to infection by both monopartite and bipartite viruses in agro-inoculation experiments. Average yield of 50-60 tonnes/ha could be realized with the cultivation of this variety. The fruits of this variety are round and very firm with a pericarp thickness of 0.52 to 0.57cm. The average fruit weight of this variety ranges from 80 to 110 g with an average locule number of 3-4. The fruits are attractive, red in color with an average total soluble solid content of 4.6 °Brix at red ripe stage (Singh *et al.* 2016). With all these qualitative and yield advantages, the Institute released the variety, which was widely adopted and cultivated by many farmers all over the country. Hence, an attempt has been made to estimate the ex-post economic impact of the tomato variety Kashi Aman.

Material and Methods
The area coverage of the variety was estimated using the quantity of seed sale data from ICAR-IIVR seed sale center. The quantity of truthfully labelled seeds sold to farmers, and different Government and private agencies were collected from the ICAR-IIVR seed sale center. The approximate area under the variety was estimated considering the seed rate of 400 g/ha. The data on the quantity of breeder seeds sold to different Government and private agencies were collected and further, the conversion of breeder seeds to foundation seeds and then to certified seeds was estimated considering the average yield loss (due to biotic and abiotic factors) at 20% and seed multiplication ratio of 1:200. The Seed Multiplication Ratio gives the seed yield in kilogram obtained from 1 kg of seed sown. The economic surplus model given by Alston *et al.* (1995) generally assesses the returns on investments made on the research by analyzing the changes in consumer and producer surplus. The assumption made was a closed economy with a parallel supply shift (Figure 1).
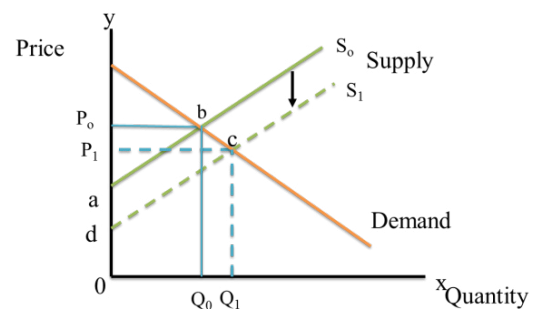
Annual gross benefit of research = abcd

Figure 1: Impact of research on varietal development

Total economic surplus was calculated using the following equations,

Change in producer surplus:

$$\Delta PS = Po * Qo * (K - Z) * (1 + 0.5Z\eta)$$

Change in consumer surplus:

$$\Delta CS = Po * Qo * Z * (1 + 0.5Z\eta)$$

Change in total economic surplus:

$$ES = \Delta TS = \Delta CS + \Delta PS = Po * Qo * K * (1 + 0.5Z\eta)$$

Where,
P_o = Base price of the commodity
Q_o = Base quantity
η = Absolute value of the price elasticity of demand
$Z = K \varepsilon / (\varepsilon+\eta)$ or the proportionate price reduction in the market, where ε is the elasticity of supply
Kt = Proportionate reduction in cost per ton of production in time t or research induced shift in supply which is given by,

$$K_t = \left(\frac{E(Y)}{\varepsilon}\right) - \left(\frac{E(C)}{1+E(Y)}\right)At(1 - d)^t$$

Where,
E(Y) = Proportionate yield increase per ha for technology adopters
E = Price elasticity of supply
E(C) = Proportionate variable input cost change per ha
A = Proportion of the area under the technology
d = Rate of depreciation of the technology

The Economic impact of the investments made on the research of varietal development was conducted ex-post i.e., after the variety was adopted and cultivated by the farmers. Various secondary and primary data sources are required for the Economic surplus model analysis, which has been discussed below. Change in yield and cost of cultivation: Primary data from 30 farmers across 3 different villages of Varanasi Districts, Uttar Pradesh were collected by personal interview through pre-tested questionnaires. The data on cost of cultivation, yield and returns from the farmers who adopted the technology *i.e.* growing Kashi Aman variety and the farmers who did not adopt the technology and was growing local variety of the crop or both, was collected for comparison. The cost of cultivation, gross return, net returns, cost of production and BC ratio was calculated for both Kashi Aman variety of tomato and the local variety grown in the area. The yield change compared to the local variety grown was estimated to be 8.14%. The input cost reduced in Kashi Aman variety of tomato compared to the local variety was estimated to be around 8%.

The elasticity of demand and supply
The demand elasticity of different agricultural commodities as estimated by Kumar *et al.* (2011) in which the demand elasticity for vegetables (-0.515) was obtained. The supply

elasticity for tomato was assumed to be 0.817 after review of literature of various studies (Anonymous 2018, Kumar and Mruthyunjaya 1995, Madhumurthy and Sundaramoorthy 2018). Rate of adoption of the technology: The adoption rate of the technology was assessed by discussion with the extension scientists and other stakeholders involved in the popularization of the variety. It was also projected for next 5 years to estimate the economic surplus over time. The research & development of the variety started in 2005 and the variety was released in 2013.

Production and wholesale price
The production estimates were calculated using the estimated area under the variety. The average wholesale prices of tomato was collected from 2014 to 2021 from Agmarknet.com and then converted to the real prices by deflating the figures using the wholesale price index for tomato for the same period collected from the Office of the Economic Adviser, Ministry of Commerce & Industry.

Probability of success
It ranged from 0 to 1. Probability of success of the technology was fixed after discussion with the breeder and scientists. Keeping in view the advantages of growing this variety by farmers, the probability of success was fixed at 0.8.
The technology's Depreciation factor is the rate at which the technology depreciates or becomes obsolete. In general any new variety of vegetable would last for around 10 years till an improved variety comes to the market and occupy the area. Accordingly, the technology's depreciation rate ranged from 1 to 0.6 over the period.

Cost Benefit Analysis
A profitability analysis was carried out to show the economic viability of the research using the Economic surplus model. The most commonly used parameters such as Net Present Value (NPV), Net Present Benefit (NPB), Net Present Cost (NPC), Internal Rate of Return (IRR) and Benefit Cost Ratio (BCR) were estimated. The Discount rate considered was 10% to calculate NPV.

Net Present Value (NPV):

$$\sum_{t=0}^{n}[(B_t - C_t)/(1 + r)^t]$$

Internal Rate of Return (IRR):

$$\sum_{t=0}^{n}[(B_t - C_t)/(1 + IRR)^t] = 0$$

Benefit Cost Ratio (BCR):

$$\sum_{t=0}^{n}[(B_t)/(1 + r)^t]/\sum_{t=0}^{n}[(C_t)/(1 + r)^t]$$

Where, B_t is benefit (changes in total surplus) in year t, C_t is cost in year t and r is the discount rate.

Results and Discussion

Total quantity of seed sale and the estimated area under Kashi Aman variety of tomato have been presented in Table 1. The approximate spread of area under Kashi Aman variety was estimated at 247876.13 ha from 2014-15 to 2021-22 covering 146 districts in 25 states (calculated from the sale of both TL and breeder seeds data). Area coverage under tomato and Kashi Aman variety has been presented in Table 2. The Average tomato area in the country was 8,15,000 ha during TE 2020-21. The annual average area under Kashi Aman variety of tomato in the country was 30,985 ha, around 3.80% of total tomato area in the country.

Results of the economic impact assessment of Kashi Aman using economic surplus model have been presented in Table 3. The cost of the technology of Kashi Aman variety of tomato was calculated by the salaries of the scientific, technical personnel and other manpower involved in the technology's research, development and extension according to their% time contribution. Besides laboratory and chemical cost, cost of field trails and multi-location trials, extension cost, cost of seed production and storage and Institutional charges at 10% was included. The total cost of the technology was Rs.1.83 crores. The estimated results of the economic surplus model (ESM) showed a producer surplus of Rs. 19.18 crores, consumer surplus of Rs. 30.44 crores and total economic surplus of Rs. 49.62 crores generated from the variety. The net present value (NPV) generated was Rs.48.83 crores, net present benefit (NPB) was Rs.49.62 crores and net present cost (NPC) was Rs. 79 Lakhs. The internal rate of return (IRR) was 85% and Benefit Cost Ratio (BCR) 62.91 in the present technology. The share of producer and consumer surplus in total surplus was 39:61. The Kashi Aman variety has earned Rs. 3.50 lakh from 2014-15 to 2021-22 under commercialization to 7 different private seed companies as registration fees paid to the Institute.

The total cost of cultivation and returns in tomato cultivation have been presented in Table 4 and 5. The total cost of cultivation of Kashi Aman variety of tomato was Rs. 194101 per hectare compared to Rs. 211303 per hectare of local variety. The total variable cost in Kashi Aman variety of

tomato was Rs. 159026 per hectare compared to Rs. 175928 per hectare of local variety. The share of fixed and variable cost in Kashi Aman variety of tomato was 18:82 in total cost of cultivation. The cost on seed, manures & fertilizers, plant protection chemicals, staking and fencing etc. mainly contributed to the reduction in cost of Kashi Aman variety of tomato production. The net return in Kashi Aman variety of tomato was Rs. 294149 per hectare while it was Rs. 218697 per hectare in local variety of tomato (Table 5). Cost of production for Kashi Aman variety of tomato was Rs. 4.17 per kg. It was Rs. 4.91 per kg in local variety of tomato. The BC ratio was 2.52 and 2.04 for Kashi Aman variety and local variety of tomato grown by the farmers.

Cost of cultivation according to various cost concepts has been presented in Table 6 which reveals that all the costs were higher in the cultivation of local variety of tomato over Kashi Aman variety of tomato. The cost A_1 was higher by around 13.60% in the cultivation of local variety of tomato over Kashi Aman variety of tomato. Similarly, the cost C_2 was higher by around 8.86% in the cultivation of local varieties of tomato over Kashi Aman variety of tomato. The costs reduction and additional returns incurred in the Kashi Aman variety of tomato production over local variety has been presented in Table 7. Table reveals that the increment in profit realization in Kashi Aman variety of tomato production was Rs. 75452/ha. The cost on seed, manures & fertilizers, plant protection chemicals, staking and fencing etc., mainly contributed to the reduction in cost of Kashi Aman variety of tomato production. The added return in Kashi Aman variety of tomato production was attributed mainly to the increased productivity and higher price realization over local variety. It can be concluded from the partial budgeting analysis that the adoption of Kashi Aman variety of tomato production technology would provide an additional profit to the farmers.

Kashi Aman variety of tomatoes has many advantages over the local varieties. The approximate spread of area under Kashi Aman variety was estimated at 247876.13 ha from 2014-15 to 2021-22, covering 146 districts in 25 states. The total cost of cultivation of Kashi Aman variety of tomato

Table 1: Total quantity of seed sale and the estimated area under Kashi Aman variety

S. No.	Particulars	Period (Years)	Total Seeds (kg)	Estimated area (ha)
1	Total TL seed sale from IIVR to farmers and different Government / private agencies	2014-15 to 2021-22	590.45	1476.13
2	Total breeder seed sale from IIVR, Varanasi to different Government /private agencies	2015-16 to 2019-20	3.85	-
3	Estimated quantity of foundation seeds produced from breeder seeds	2016-17 to 2020-21	616.00	-
4	Estimated quantity of certified seeds produced from foundation seeds	2017-18 to 2021-22	98560.00	246400.00
Total		2014-15 to 2021-22	99150.45	247876.13

During 2014-15 to 2021-22 (8 years) Spread of variety covering a total of 146 districts in 25 states

Table 2: Area coverage in the country

S. No.	Particulars	Details
1	Average tomato area in the Country (TE 2020-21)	8,15,000 ha
2	Average area under Kashi Aman variety of tomato in the Country	30,985 ha
3	Kashi Aman average area in relation to tomato area in the Country	3.80%

Table 3: Economic impact assessment of Kashi Aman using Economic surplus model

S. No.	Cost Benefit Analysis (Rs. crores)	
1	Net Present Value (NPV)	48.83
2	Net Present Benefit (NPB)	49.62
3	Net Present Cost (NPC)	0.79
4	Internal Rate of Return (IRR)	85 %
5	Benefit Cost Ratio (BCR)	62.91
Distribution of Economic Surplus (Rs. crores)		
6	Producer surplus	19.18
7	Consumer surplus	30.44
8	Total Economic surplus	49.62

Table 4: Total cost of cultivation in tomato (Rs./ha)

Particulars	Kashi Aman variety	Local variety
Variable costs		
Land preparation	7973	8133
Manure	8826	9067
Seeds	1000	10867
Fertilizers	17867	20467
Irrigation	7460	7360
Plant protection chemicals	26132	28730
Staking and fencing	18150	19998
Human labour (all operations)	44500	44250
Growth hormone & micronutrient	6920	7136
Marketing cost	17080	16470
Interest on working capital	3118	3450
Total variable cost	159026	175928
Fixed costs		
Rental value of land	34000	34000
Depreciation on implements	450	625
Interest on fixed capital	625	750
Total fixed cost	35075	35375
Total cost of cultivation	194101	211303

Table 5: Returns in tomato cultivation (Rs./ha)

Particulars	Kashi Aman variety	Local variety
Average yield (quintal/ha.)	465	430
Average price (Rs./Q)	10.50	10.00
Gross returns	488250	430000
Cost of cultivation	194101	211303
Net returns	294149	218697
BC Ratio	2.52	2.04
Cost of production (Rs./kg.)	4.17	4.91

Table 6: Costs in tomato production according to cost concept (Rs./ha)

S. No.	Items	Kashi Aman variety	Local variety
Cost concepts			
1	Cost A_1	125651	142741
2	Cost A_2	135851	152941
3	Cost B_1	126726	144116
4	Cost B_2	160726	178116
5	Cost C_1	160101	177303
6	Cost C_2	194101	211303

Table 7: Economic impact of Kashi Aman variety of tomato using partial budgeting (Rs. per ha)

Debit		Amount (Rs.)	Credit		Amount (Rs.)
A	Increase in cost		A	Decrease in cost	
i	Transportation	610	i	Seed	9867
ii	Others	350	ii	Manures & Fertilizers	2841
			iii	Plant protection chemicals	2598
			iv	Staking and fencing	1848
			v	Others	1008
	Total	960		Total	18162
B	Decrease in return	0	B	Increase in return	58250
	Total Debit	960		Total credit	76412
Profit			75452		

was Rs. 194101 per hectare compared to Rs. 211303 per hectare of local variety. The share of fixed and variable cost in Kashi Aman variety of tomato was 18:82 in total cost of cultivation. The net return in Kashi Aman variety of tomato was Rs. 294149 per hectare which is higher than the local

variety of tomato. The BC ratio was 2.52 and 2.04 for Kashi Aman variety and local variety of tomato grown by the farmers. Returns to the research investment made were Rs.48.83 crores. The total economic surplus generated due to Kashi Aman variety of tomato was 49.62 crores adopted and grown in different parts of the country. Adopting Kashi Aman variety of tomato production technology provides gains to producers and consumers. The present study indicates that the investments made for the development of Kashi Aman variety of tomato was highly economical.

References

Ali Md Y, Sina AAL, Khandker SS, Neesa L, Tanvir EM, Kabi, A, Khalil Md I, and Gan SH (2021) Nutritional composition and bioactive compounds in tomatoes and their impact on human health and disease: A review. Foods 10(1): 45.

Alston JM, Norton GW and Pardey PG (1995) Science under scarcity: principles and practice for agricultural research evaluation and priority setting. Cornell University Press, Ithaca, New York.

Anonymous (2018) Demand and supply projections towards 2033 crops, livestock, fisheries and agricultural inputs, Working group report. NITI Aayog, New Delhi.

Anonymous (2022) Final Estimates of 2020-21 and First Advance Estimates of 2021-22 of Area and Production of Horticultural Crops. Posted On 28 March, 2022 by PIB Delhi. https://pib.gov.in.

Blanca J, Cañizares J, Cordero L, Pascual L, Diez MJ and Nuez F (2012) Variation revealed by SNP genotyping and morphology provides insight into the origin of the tomato. PLoS One **7**(10): e48198.

FAO (2022) FAOSTAT Statistical Database 2020. Food and Agricultural Organization of the United Nations, Rome. http://www.fao.org/faostat/en/#data.

Kumar K, Sharma D, Singh J, Chandel N (2021) Heterosis for yield and yield attributing traits in tomato (*Solanum lycopersicum* L.). Veg Sci 48(1):41-48.

Kumar P and Mruthyunjaya (1995) Demand for fruits and vegetables in India. Agricultural Economics Research Review 8(2): 7-17.

Kumar P, Anjani Kumar, Shinoj P and Raju SS (2011) Estimation of demand elasticity for food commodities in India. Agricultural Economics Research Review 24(1): 1-14.

Madhumurthy N and Sundaramoorthy M (2018) A report on the study of tomato value chain and its financing. College of Agricultural Banking and Reserve Bank of India, Pune.

Mahala P and Sharma RK (2020) Evaluation of different growing media for tomato nursery. Veg Sci 47(1):146-149.

Singh PM, Singh N, Tiwari SK, Roy S, Rai AB, Singh S and Singh B (2016) IIVR Technologies for Commercialization, Technical Bulletin No. 69. IIVR, Varanasi.

Verma VK, Verma BC and Jha AK (2020) Effect of lime and organic manures on yield and quality of tomato and capsicum grown under protected condition in the mid-hills of Meghalaya. Veg Sci 47(1):62-68.

Wander AE, Magalhaes MC, Vedovoto GL and Martins EC (2004) Using the economic surplus method to assess economic impacts of new technologies: Case studies of Embrapa. Conference on International Agricultural Research for Development, October 5-7, 2004. Deutscher Tropentag, Berlin.

सारांश

भा.कृ.अनु.प.-भारतीय सब्जी अनुसंधान संस्थान, वाराणसी (उत्तर प्रदेश) द्वारा वर्ष 2013 में टमाटर की नई किस्म 'काशी अमन' का विकास किया गया। यह किस्म देश के विभिन्न हिस्सों में किसानों द्वारा व्यापक रूप से स्वीकार्य की गयी व इसकी खेती की जाती है। वर्तमान अध्ययन में टमाटर की 'काशी अमन' किस्म के विकास के परिणाम स्वरूप उत्पन्न आर्थिक अधिशेष का अनुमान लगाने में मदद करता है। वर्ष 2014-15 से 2021-22 के दौरान 'काशी अमन' किस्म के तहत कुल अनुमानित क्षेत्रफल 247876.13 हेक्टेयर था जो 25 राज्यों के 146 जिलों में फैला हुआ था। आर्थिक अधिशेष मॉडल के आधार पर उत्पादक अधिशेष रू. 19.18 करोड़ उपभोक्ता अधिशेष रू. 30.44 करोड़ एवं कुल आर्थिक अधिशेष रू. 49.62 करोड़ था। शुद्ध वर्तमान मूल्य रू. 48.43 करोड़ एवं शुद्ध वर्तमान लाभ रू. 49.62 करोड़ था। वर्तमान तकनीकी में रिटर्न की आन्तरिक दर 85 प्रतिशत एवं लाभ-लागत अनुपात 62.91 था। टमाटर की 'काशी अमन' किस्म में खेती की कुल लागत रू. 194101 प्रति हेक्टेयर जबकि स्थानीय किस्म में यह रू. 211303 प्रति हेक्टेयर थी। 'काशी अमन' किस्म में शुद्ध लाभ रू. 294149 प्रति हेक्टेयर जबकि स्थानीय किस्म में यह रू. 218697 प्रति हेक्टेयर था। 'काशी अमन' एवं स्थानीय किस्म में लाभ-लागत अनुपात 2.52 एवं 2.04 था। वर्तमान अध्ययन यह इंगित करता है कि टमाटर की 'काशी अमन' किस्म के विकास में किया गया निवेश किफायती था साथ ही यह नीति निर्माताओं को अनुसंधान निवेश के समर्थन का प्रमाण प्रदान करता है।