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RESEARCH ARTICLE

Impact assessment of manually operated Ambika rice weeder on the economy of Chhattisgarh, India

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ABSTRACT

The impact assessment of an agricultural technology is a complex process of identifying the consequences of its commercialization, dissemination, multiplication and active adoption on a large scale by the end users. Many agricultural engineering technologies generate two kinds of benefits: reduction in cost of operation by virtue of decreasing time required for operation and saving in input and labour engagement, as well as increase in productivity due to the timeliness and uniform quality of farm operations. The present study attempted to estimate the impact of the adoption of Ambika rice (paddy) weeder for conducting weeding operations in line-sown rice on the economy of Chhattisgarh state in India. The economic surplus methods for assessing the impact of agricultural research was adopted for estimating the benefits attained by rice farmers, millers/processors, retailers and consumers. The study revealed that a net present worth of about ₹ 6450 crore (₹ 64500 million) was realized from the adoption of Ambika rice weeder for weeding in line-shown rice fields whereas, other associated stakeholders like millers/processors, rice retailers *etc.* earned a gross income of about ₹ 515 crore (5150 million) from the processing and value addition of surplus rice produced due to adoption of the technology. The aggregate economic impact was about ₹ 6965 crore (69650 million) as per 2011-12 prices for the period of 2012-13 to 2019-20 due to adoption of Ambika rice weeder by rice farmers in Chhattisgarh.

Keywords: Ambika rice (paddy) weeder, Economic surplus method, Impact assessment, manually operated weeder

INTRODUCTION

Impact assessment is defined as the process of identifying the future consequences of a current or proposed action or intervention. It is assessed in terms of reckonable outcomes such as income and employment generation, poverty reduction, conservation of natural resources, organizational and institutional change, *etc*. Currently, Indian agriculture is facing many challenges like never before. There has been a fall in public investment in agriculture, declining growth in partial and total factor productivity, increasing inter and intra-regional disparities, persistence of wide-spread poverty and decreased quantity and quality of natural resources like land, water and biomass (Singh and Agrawal 2018). Engineering interventions in the agriculture sector have been contributing in enhancement of input use efficiency, augmenting productivity of crops, reducing drudgery associated with various farm operations, ensuring environmental sustainability and also safeguarding nutritional requirements for the people. Agricultural mechanization is also crucial for increasing farm productivity and agrarian income for small and marginal farmers who constitutes about 86% of total cultivators in India. The farmers are also witnessing the shortage of agricultural labourers during peak periods, which can only be resolved by promotion of farm mechanization. As a result, they are adopting farm mechanization than ever before. The Indian government is also trying to transmit the benefits of mechanization to small and marginal farmers through diversified initiatives, such as Sub Mission on Agricultural Mechanization (SMAM), introduced in 2014-15 by the Government of India. During 2014-15 to 2020-21, a sum of about ₹ 45.57 billion was released under this scheme to the states and other implementing institutions. Distribution of various subsidized, improved agricultural equipment and machinery to individual farmers is also one of the objectives of this scheme. As a result, the nation witnessed phenomenal expansion of cropped area, cropping intensity and agricultural production along with an increase in farm power availability from 2.02

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kW/ha in 2016-17 to 2.49 kW/ha in 2018-19 (MoA&FW 2021). To corroborate this initiative, a number of promising and need based engineering technologies were developed by National Agricultural Research System in India, for which an impact assessment exercise needs to be conducted with socio-economic and environmental dimensions.

Rice is the main food grain crop cultivated in Indian state of Chhattisgarh, where it was cultivated in an area of 3.67 million hectares during 2019-20 with a production of 6.77 million tonnes. However, the yield of rice obtained in this state was only 1848 kg per hectare as compared to national average of 2722 kg per hectare (Agricultural Statistics at a Glance 2021). One of the major reasons for low yield could be the traditional cultivation practices in which sprouted rice seeds are broadcasted on puddled field. However, line-showing/ transplanting of rice are recommended for obtaining more yield which also requires efficient weed control practices. Pandey *et al*. (2018) reported that about 75% of rice area is under broadcasting, 15-17% is under transplanting and 8-10% area is covered by direct-drilling method of rice seeding in Chhattisgarh. For controlling weeds in directl-drilled and transplanted rice in marginal and small farms, the agricultural university of Chhattisgarh state namely Indira Gandhi Krishi Vishwa Vidyalaya (IGKVV), Raipur, developed a manually operated Ambika rice weeder which can be operated in line sown rice to cut and uproot the weeds between rows. This equipment became very popular among rice growers in Chhattisgarh because it not only reduced the cost of weeding operation as compared to hand weeding by 54.38% (Tayade 2016), but also contributed in yield increase by 14.35% as reported by Dange *et al.* (2017). They also observed that the average field capacity for Ambika rice weeder was about 0.016 hectare per hour and the working life of the equipment is about 1000 hours spread over a period of eight years. As the maximum crucial time available for each of two weeding operations is about two weeks, this equipment can cover about 1.79 hectare of land in *Kharif* (rainy) rice.

Considering these realized benefits from large scale adoption of Ambika rice weeder by farmers of Chhattisgarh over the last decade, its impact on farm sector as well as economy of the state was systematically assessed at various levels of the society.

MATERIALS AND METHODS

The manually operated Ambika rice weeder has a simple structure comprises of serrated strips, float, a frame and handle for operation. Strips are cut forcefully fit as a fiddle consistently along its length mounted on round cutting edge welded to outline (Tayade 2016). Ambika rice weeder is operated at a standing water of 5-6 cm between the rows of rice by pushing and pulling action of weeder (Netam and Mahilang 2018). Thus, it helps in killing of weeds as well as loosening the soil between rows, enhancing the microbiological activities, aeration and water intake capacity (Verma and Patel 2021). This made the equipment quite popular among the farmers and their demand for this equipment is met from various public and private suppliers. The yearly supply data were collected from records of such sources and various performance and operational parameters were recorded from published literatures and statistical compendiums. Area, production, and average yield of rice in Chhattisgarh during 2012-13 to 2019-20 was recorded from various issues of Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers' Welfare, Government of India. The supply of rice to all markets of Chhattisgarh *i.e.*, market arrival of rice and wholesale price offered during these years were recorded from online published data of Directorate of Marketing and Inspection, Ministry of Agriculture and Farmers' Welfare, Government of India. The wholesale and retail prices of processed fine rice were recorded from online published database of Department of Consumer Affairs, Ministry of Consumer Affairs, Food and Public Distribution, Government of India. The conversion factor of rice into fine rice and various by-products such as rice husk, broken rice, rice bran and other feeds for both parboiling and non-parboiling process of rice were adopted from a study on rice hulling and milling in 80 rice mills in Chhattisgarh, which reported that about 3967 tonnes of parboiled fine rice and 3100 tonnes of non-parboiled fine rice were produced from 6067 tonnes and 5900 tonnes of rice, respectively (Thakur *et al.* 2012). The ratio of value of raw material (rice) to various by-products was calculated and used for estimation of value of the all by-products over this period assigning respective weights for parboiling and non-parboiling methods of processing of rice. The findings from the study are summarized in **Table 1**.

Analytical framework

The data were analysed adopting Economic Surplus Model (Masters *et al.* 1996, Sant Kumar *et al*. 2011) for estimating social gain from research. This can be elaborated in **Figure 1**, depicting the shift of supply curve from S_1 to S_2 due to technological

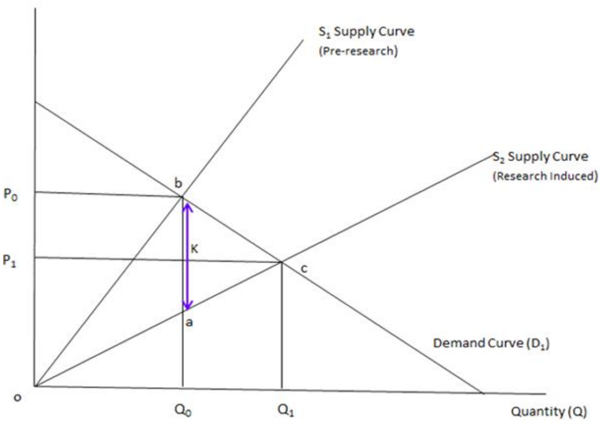

Figure 1. Technology induced vertical shift of supply curve

progress as an outcome of research while demand curve remains unchanged. As a result, the equilibrium point shifts from b to c, highlighting the change of volume of trade from earlier Q_0 quantity at P_0 price to higher quantity of Q_1 at a reduced price of P_1. The social gain from research, obtained by adding both the producers' surplus and consumers' surplus is measured by the area of triangle 'abc'. This is equal to $\frac{1}{2} \times K \times \Delta Q$ where, K is the research-induced vertical shift of supply curve (from b to a) and ΔQ is change in quantity produced. For estimating the K parameter, known as technology induced supply shift in relative terms in comparison with conventional technology (manual weeding by khurpi (hand operated small spade), reduction in cost due to growth in yield was estimated from proportionate increase in yield reported in literature. Further, the change in input cost per unit of output after the adoption of technology was estimated from the proportionate change in production cost due to the adoption of technology. Finally, a net proportionate change in the cost of production per unit of output was obtained by computing the difference between these two parameters. Further, the proportionate reduction in output price due to technology intervention (Z factor) was obtained by multiplying K factor with the ratio of price elasticity of supply (ε) to the sum of price elasticities of supply and demand (η). The change in consumers' surplus was measured as, $\Delta CS = P_0 \times Q_0 \times Z \times (1+0.5Z\eta)$ and annual change in producers' surplus was estimated as $\Delta PS = P_0 \times Q_0 \times (K-Z) \times (1+0.5Z\eta)$. Therefore, the total gain of the society from the research was expressed as, $\Delta CS + \Delta PS = P_0 \times Q_0 \times K \times (1+0.5Z\eta)$, where P_0 is Initial equilibrium price and Q_0 is the Initial equilibrium quantity before adoption of technology. For assigning the value of price elasticity of demand and supply into economic surplus model, appropriate values were taken from published literatures. The price elasticity of supply (ε) was recorded as 0.210 (Mohanakumar and Kumar 2018) whereas, the price elasticity of demand (η) was recorded as 0.247 (Kumar *et al*. 2011). The net present worth of the technology was estimated at a discount rate of 6% per annum (based on average real rate of interest during 2012-19) considering the cost of technology development in base year (2011-12) price. The total impact on economy due to adoption of technology (Ambika rice weeder) is sum total of net present worth of the technology at base year price plus the aggregate margin of millers from rice processing, retailers' surplus margin by selling fine rice and estimated benefit to consumers from an expected price fall due to technology induced growth in production.

The number of total units of Ambika rice weeder was obtained by gradually adding the number of units supplied each year, starting from 2012-13. The area and productivity of rice in the state of Chhattisgarh were recorded from various issues of Agricultural Statistics at a Glance, published by the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers' Welfare, Government of India. The area under line-sown rice in Chhattisgarh was calculated as one-fourth of total area under rice crop which constitutes the potential area for adoption of this technology. The area covered by Ambika rice weeder was obtained by multiplying its area covered annually by one unit (1.792 hectares per annum) with number of units in operation for each year. The adoption rate of Ambika rice weeder was calculated by dividing the area under the technology by the total potential rice area for its adoption. The values of various parameters for estimating technology-induced shift in supply curve to put into the economic surplus model were taken from various published literatures.

RESULTS AND DISCUSSION

During the period under study, the adoption rate of this equipment increased from 3.6% to 27.8% for

Table 1. Conversion of rice into various by-products with their value

Particular	Rice	Fine rice	Broken rice	Rice husk	Rice bran	Other feed
Quantity (tonnes)	11966.7	7066.7	1440.8	2719.9	401.0	338.3
Conversion Factor	1.0	0.59	0.12	0.23	0.03	0.03
Value (million ₹)	111.50	108.24	11.24	3.89	4.01	0.34
Conversion Factor	1.000	---	0.101	0.035	0.036	0.003

Table 2. Adoption of technology and primary benefit to farmers in different years

Year	Number of units in field	Area under rice ('000 ha)♦	Line sown rice area (ha)*	Area under technology (ha)	Adoption rate	Rice Yield (kg/ha)♦
2012-13	19040	3785	946250	34120	0.0361	1746
2013-14	39493	3802	950500	70771	0.0745	1767
2014-15	58097	3809	952250	104110	0.1093	1659
2015-16	73920	3816	954000	132465	0.1389	1516
2016-17	93501	3830	957500	167554	0.1750	2102
2017-18	109168	3761	940275	195629	0.2081	1311
2018-19	125392	3606	901500	224702	0.2493	1811
2019-20	141989	3666	916500	254444	0.2776	1847

*Constitutes 25% of total area under rice in Chhattisgarh state (Pandey *et al.* 2018).

mechanical weeding in rice cultivation (**Table 2**). The yield of rice was always recorded quite low in Chhattisgarh (less than 2 tonnes per hectare) during the period under observation.

The proportionate increase in yield over manually conducted hand weeding was taken as 14.35% (Dange *et al*. 2017) along with a 54.38% reduction in cost of production (Tayade 2016) for estimation. The proportionate reduction in cost solely due to yield increase was 0.6834 and the change in input cost per unit of enhanced output was estimated at 0.4755. The aggregate net change in cost of production per unit of output was 1.1589 under the given circumstances (**Table 3**). As the estimation procedure was an *ex-post* analysis after successful development and commercialization of the technology, the probability of success for the technology was taken as 1. Similarly, with the technology being in early phase of gradual adoption and a superior alternative technology not in sight for replacement, the technology obsolescence rate was ignored with complete preference for adoption as 1.

The incremental shift in supply curve due to adoption of Ambika rice weeder in relation to existing practices for weeding is elaborated in **Table 4**. With progress in adoption of the technology by the users, the supply curve shifted downward from 4.18 to 32.18% during the study period. Consequently, the supply price for rice was also reduced from 1.92 to 14.79% during the same period. The price as well as production of rice in Chhattisgarh before the adoption of the technology was recorded as ₹ 10290 per tonne and 6159000 tonnes, respectively, in 2011-12 which was also designated as the base year for the current inflation index.

The addition in producers' surplus, consumers' surplus and total surplus due to the adoption of technology was assessed with the help of K and Z parameters estimated earlier, price elasticities of supply and demand, as well as price and quantity produced at base period. The producers' share in total surplus was observed to be a little bit higher (54.05%) as compared to that for consumers' (45.95%) for the study period. The total surplus or net social gain, from the development and adoption of the technology was estimated as ₹ 9438.40 crores (₹ 94384 million) (**Table 5**). Considering the spending of about ₹ 0.03 crores (0.30 million) on research and development of the technology, the net present worth of the technology for a period of eight years after its successful commercialization was about ₹ 6450 crores (64500 million) due to adoption of the technology by the rice farmers by virtue of savings in cost of operation as well as returns from additional production.

Table 3. Parameters for estimation of technology induced supply shift for rice

Parameter	Value
Price elasticity of supply for rice (ε)	0.2100
Price elasticity of demand for rice (η)	0.2470
Proportionate increase in yield (ΔY)	0.1435
Proportionate change in cost of production (ΔC)	-0.5438
Cost reduction due to yield growth (ΔY/ε)	0.6834
Change in input cost per unit of output [ΔC/(1+ΔY)]	-0.4755
Aggregate change in net cost of production per unit of output	1.1589
Probability of success for technology	1.00
Preference for adoption due to obsolescence for technology	1.00

Table 4. Technology induced shift of supply curve and reduction in output price

Year	Technology induced proportionate shift of supply curve (κ)	Proportionate reduction in output price (z)	Price of rice before adoption (₹/tonne)*	Production of rice before adoption (tonnes)
2012-13	0.0418	0.0192	10290	6159000
2013-14	0.0863	0.0397		
2014-15	0.1267	0.0582		
2015-16	0.1608	0.0739		
2016-17	0.2028	0.0932		
2017-18	0.2411	0.1108		
2018-19	0.2889	0.1327		
2019-20	0.3218	0.1479		

*Source: Directorate of Marketing and Inspection, Govt. of India

Table 5. Producers' surplus, consumers' surplus and total surplus with net present worth

Year	Producers' surplus (₹ crores*)	Consumers' surplus (₹ crores)	Total surplus (₹ crores)	Technology development cost at 2011-12 prices (₹ crores)	Net present worth of technology (₹ crores)
2012-13	143.48	121.99	265.47		
2013-14	297.03	252.54	549.57		
2014-15	437.15	371.67	808.82		
2015-16	555.67	472.43	1028.10		
2016-17	702.69	597.43	1300.12	0.0292	6449.88
2017-18	837.26	711.84	1549.10		
2018-19	1005.73	855.07	1860.80		
2019-20	1122.27	954.15	2076.42		
Total	5101.28	4337.12	9438.40		

*One crore is equal to 10 million

The additional rice produced in different years due to adoption of Ambika rice weeder was assessed from the area covered by technology and the reported yield increase. The quantity and value of additional paddy and fine rice produced due to adoption of technology were estimated from conversion factors given in **table 1** and the average wholesale prices for the commodities at Chhattisgarh markets obtained from the online database of Department of Consumer Affairs, Government of India (**Table 6**). The values of rice and fine rice were estimated at their current price for respective years.

The values of all by-products estimated in proportional rates with value of rice, obtained from conversion factors given in **Table 1** due to non-availability of their price data, are exhibited in **Table 7**. Among by-products, broken rice was contributing maximum (₹ 41.48 crores) to the value, followed by rice bran (₹ 14.79 crores), rice husk (₹ 14.39 crores) and other feeds (₹ 1.23 crores) during the entire study period. Together, the fine rice and all by-products amassed gross revenue of ₹ 521.47 crores from raw rice worth of ₹ 410.82 crores.

During the study period, the rice millers earned a gross income of ₹ 110.65 crores from processing the surplus rice produced due to adoption of technology. The rice retailers earned a gross margin of ₹ 51.91 crores by selling the fine rice at retail prices (**Table 8**). The rice consumers got benefitted from expected proportionate reduction retail prices due to enhanced supply of rice at the market. The anticipated reduction in expenditure for consumers was estimated as ₹ 501.54 crores during the entire study period. Adjusting the paybacks realized by all beneficiaries with GDP deflator values for respective years, the aggregate benefits in real price achieved by all stakeholders was ₹ 515.35 crores at base year (2011-12) price levels. Therefore, adoption of *Ambika* rice weeder in Chhattisgarh contributed a

Table 6. Value added from main product after rice processing

Year	Additional rice produced (Q)	Additional rice produced (Q)	Rice wholesale price (₹/Q)	Rice wholesale price (₹/Q)	Rice retail price (₹/kg)	Value of rice (₹ Crores)	Value of rice (₹ Crores)
2012-13	85519	50502	1125	2010	22.33	9.62	10.15
2013-14	179531	106019	1241	2354	26.12	22.28	24.96
2014-15	247926	146408	1278	2513	27.93	31.68	36.79
2015-16	288164	170169	1236	2467	27.50	35.62	41.98
2016-17	505447	298482	1350	2451	27.32	68.24	73.16
2017-18	368035	217336	1392	2618	29.23	51.23	56.90
2018-19	584009	344875	1550	2688	30.05	90.52	92.70
2019-20	674393	398250	1507	2836	31.68	101.63	112.94

*One crore is equal to 10 million

Table 7. Value added from by-products after rice processing

Year	Broken rice		Rice husk		Rice bran		Other feed	
	Quantity (Q)	Value (₹ crores*)	Quantity (Q)	Value (₹ crores)	Quantity (Q)	Value (₹ crores)	Quantity (Q)	Value (₹ crores)
2012-13	10297	0.97	19438	0.34	2866	0.35	2418	0.03
2013-14	21616	2.25	40805	0.78	6016	0.80	5075	0.07
2014-15	29850	3.20	56351	1.11	8308	1.14	7009	0.10
2015-16	34695	3.60	65496	1.25	9656	1.28	8146	0.11
2016-17	60856	6.89	114883	2.39	16937	2.46	14289	0.20
2017-18	44312	5.17	83650	1.79	12333	1.84	10404	0.15
2018-19	70315	9.14	132739	3.17	19570	3.26	16510	0.27
2019-20	81197	10.26	153282	3.56	22599	3.66	19065	0.30
Total value		41.48	--	14.39	--	14.79	--	1.23

*One crore is equal to 10 million

Table 8. Benefits obtained by various stakeholders from processing and value addition of rice due to adoption of technology

Year	Millers' gross margin (₹ crores*)	Retailers' gross margin (₹ crores)	Rice supply (Ton)		Retail Price (₹ / kg)		Consumers benefit (₹ crores)	GDP Deflator (Base year: 2011-12)	Aggregate benefits of all stakeholders in real price (₹ crores)
			Without adoption	After adoption	Without adoption	After adoption			
2012-13	2.22	1.08	2170227	2175277	22.38	22.33	11.28	107.93	13.51
2013-14	6.58	2.74	3143869	3154470	26.21	26.12	27.69	114.61	32.29
2014-15	10.66	4.10	4006292	4020933	28.03	27.93	40.89	118.43	46.99
2015-16	12.60	4.82	3192447	3209464	27.65	27.50	46.80	121.13	53.02
2016-17	16.86	8.39	3908467	3938315	27.53	27.32	81.55	125.05	85.41
2017-18	14.62	6.63	2945955	2967688	29.45	29.23	63.53	130.02	65.21
2018-19	18.02	10.93	2829378	2863866	30.42	30.05	103.63	134.87	98.30
2019-20	29.09	13.22	3457949	3497774	32.04	31.68	126.17	139.68	120.62
Total	110.65	51.91					501.54		515.35

*One crore is equal to 10 million

total real income of ₹ 6965.23 crores from rice production systems as well as processing and value addition of surplus rice by all associated stakeholders.

Conclusions

The study emphatically established that the technology known as *Ambika* rice weeder offered two simultaneous benefits in a single operation. It had field cpapacity of 0.014 ha/h, weeding efficiency of 80.1% and cost of operation of 1574 ₹/ha. This technology not only reduced the cost of operation to a great extent but also improved the quality of operation, thereby enhancing productivited. As a result, the small-scale rice growers enjoy a higher return at a lower cost which enhances the profitability in rice cultivation. This low -cost and easy to operate technology was adopted on a very large scale and was contributed to the economy of the state despite witnessing a fluctuation in yield as well as price in a volatile market. One of the major hindrances to its faster adoption is that only 25% of the rice growing area in Chhattisgarh practiced line sowing / transplanting of seedlings, therefore, still vast scope of this technology can be adopted. The rice producers were the most benefitted segment of recipients, followed by the consumers and various intermediaries enjoying the advantages of the technology.

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