IJAIR
International Journal of Agriculture Innovations and Research
Volume 3, Issue 1, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received : 19/05/2014 | Accepted on : 25/05/2014 | Published : 15/06/2014

Assessing the Economic Impact of Technology Adoption in Horticulture: Concepts and Case Study of 'Dogridge' Root Stock Adoption in Grape Cultivation in India

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***Abstract* – Assessment of economic impact of technology adoption is of significance for quantifying the benefits and return on investment in order to further facilitates prioritization of investment criteria. Though several partial measures are in use, they lack uniformity and acceptance by funding agencies from across countries. The present study provides the standard conceptual framework for economic impact assessment of technology adoption and further demonstrates the usefulness of a universally accepted 'economic surplus' method by quantifying the economic impact of wide spread adoption of root stock technology in the production of perennial horticultural crops like grape under three important growing regions from India. Besides providing a vivid gist of analysis, this paper also quantified the total economic surplus generated due to the adoption of a technology that is critical for grape production under semi-arid tropics. According to this study, the technology adoption contributed to about 15 to 20 % productivity enhancement and more than 40 percent increase in gross realization at individual farm level. The aggregate level economic impact measured using the Economic Surplus method, indicated an aggregate level total economic surplus due to technology adoption of Rs. 8844.35 crore between 1997 and 2007-08. The change in producer surplus worked out to Rs. 804.03 crore, resulting in an internal rate of return of 40% and a benefit to cost ratio of 186. The results thus quantify the aggregate benefits accrued due to technology adoption and also suggest a methodology that could help justify the enhanced investment into horticultural crop production systems.**

***Keywords* – Economic Impact, Technology Adoption, Returns to Investment, Economic Surplus Method, India.**

I. INTRODUCTION

Adoption of improved technology is a critical input for improved production efficiency and productivity in crops. However, despite their technical soundness, not all crop production technologies get adopted to the extent that the quantification of the aggregate benefits from their adoption justifies the investment into their research. Quantification of benefits from technology adoption both at individual farm level, and at an aggregate level is of relevance for estimating the return on investment into agricultural research and also for prioritizing research agenda. While adoption of improved varieties may have a direct relevance to crop productivity enhancement, contribution of other technological interventions such as improved package of practices towards enhanced productivity or overall profitability cannot be undermined. In some perennial fruits that are of temperate origin like the grape, innovative technical intervention like cultivation on 'root stock' instead of own root, is a huge leap forward for its successful adaptation to semi-arid tropics under saline and alkaline soil conditions.

Horticulture, comprising a variety of fruits, vegetables and plantation crops, medicinal & aromatic crops is a core sector having potential for triggering agricultural growth to over 4 percent and thus has been accorded priority status with enhanced budgetary allocation of over Rs. 41,000 crores in the XI Five Year Plan (2006-2012), a quantum jump considering the sector's outlay of Rs. 3.5 crores during the IV plan period (1978-82) (Anonymous, 2011). High profitability, enhanced productivity through effective adoption of improved technologies has been attributed as major contributing factors for this sector's growth. While the private sector's contribution towards R&D in vegetables and other annual crops is increasing, the same is not yet true in case of perennial horticultural crops like fruits. Though some efforts are being initiated very recently, public sector research and development efforts have dominated this sector for the last two decades. With the enhanced focus on horticulture, the need for quantification and assessing the economic impact of technology adoption for this set of crops has been on the rise either as a prelude or as a justification for priority setting.

Though efforts have been made to assess the economic impact of technology adoption using measures such as 'partial budgeting' and other simple methods of multiplying the per unit benefits across the area adopted, they often tend to be unrealistic, not uniform and lack a global acceptability. Keeping in view the growing significance for an objective assessment of economic impact of technology adoption, an attempt has been made in this paper to provide a conceptual perspective of economic impact assessment criteria, available methods and their usefulness taking a case study of 'impact of dogridge root stock technology adoption in grape.

The paper is divided into two sections, the first presenting the conceptual framework for economic impact assessment and methods available; section II presents a case study of economic impact assessment of dogridge root stock adoption in important grape growing regions in India using the Economic Surplus method of analysis.

II. DATA USED FOR THE CASE STUDY

Estimation of economic surpluses generated requires data on technological and economic parameters. These include yield and cost advantages, pattern and year wise extent of technology adoption, research and development expenditures and lags. These data were collected from primary as well as secondary sources, from three important grape producing regions of the country, Viz., Maharashtra, Karnataka, and Andhra Pradesh states. The total sample for this study comprised of 150; including all stakeholders involved in grape cultivation, i.e., grape growers, market functionaries and scientists, providing data for the well structured questionnaire specially designed for this study. Efforts were also made to collect data on research expenditures for 25 years, covering the period of technology initiation till 2005-06.

III. Results and Discussion

Section I

Why Impact?

Review of research suggests that improved technology, whenever adopted resulted in increased income and employment adding to the overall farm welfare. Continuous adoption of technology results in overall increase in crop productivity and increased production. However, technology adoption is not necessarily uniform across growing regions and appears to be influenced by a number of factors. Objective assessment of impact is a useful tool for identifying the constraining factors impeding technology adoption and hence growth. Technology development and disseminating agencies need to evaluate the process of technology adoption and its impact from time to time, to be able to refine their technologies for better impact. Documentation of accrual of benefits / profits due to technology adoption is essential for assessing investments and to develop research service road map for optimization of future research resource allocation. Above all, impact of technology adoption is of prime importance to investors, for assessing the returns to investment into research and for efficient allocation of scare resources and for investment prioritization.

When to assess?

Ideally, technology adoption and impact require twin assessments, 'before' and 'after' or 'with and without' the technology. Economists' frame work for impact assessment is categorized based on the time of evaluation as, *the ex ante*, *concurrent* and *ex post.*

Ex ante, assessment is an objective assessment for justifying the need for the specific research agenda. From a R&D point of view, such an assessment is essential for optimizing the allocation of limited research resources for generating outcomes that are absolutely useful. *Concurrent* evaluation is undertaken while the project is underway, primarily to identify research gaps and constraining factors that impede quick and uniform adoption of research outcomes. Such an evaluation provides scope for refinement and fine-tuning of technologies for specific clientele. An *ex post* evaluation process is the most ideal and essential when undertaken after a gap of time, post implementation to understand the effectiveness of research outcomes. It provides an acid test for the significance, relevance and usefulness of the technology. Outcome of each stage of assessment is valuable as they provide justification, scope for mid course correction as well as future direction for investment opportunities into R&D efforts.

How & what to assess?

Selection of impact assessment indicators is of utmost significance given the variation in technology and assessment points of view. Several partial measures of impact, such as 'change in costs and returns attributable to specific technology adoption', 'change in quantity and value of parameters' due to the intervention, while keeping all other related events constant, have been attempted in several impact assessment studies**.** A change in area, production and productivity itself is often used as proxy measure for contribution of research at regional or national levels. Enhancement of productivity, income and welfare, increased export, import substitution, increased health or soil and water conservation etc., 'with' and 'without' technology; 'before' and 'after' the use of specific technological intervention are among the most commonly used impact indicators. Impact assessment process also needs to include the perspective of assessment, varying from an individual, a group or at an aggregate level. The tools available for assessment and data needs for assessment vary depending on the type, scope and extant of impact anticipated to be assessed.

Impact indicators and tools for measurement

Impacts indicators can be classified primarily into two categories, viz., (i) tangible, those that can be measured through assignment of physical or monetary value and (ii) intangible, those that cannot be measured in monetary terms but have definite meaning for the overall welfare of the situation concerned.

Impact indicators also vary with the context and level of measurement as individual, group or aggregate level. Tangible measures of impact at *individual* farm or a group of farmers level include the change in yield, income, employment, and increase in efficiency of the farm, increased nutrition, reduction in the unit cost of production, change in cropping intensity etc., These measures can be arrived at by using economic evaluation techniques like the *partial budget, costs returns and profit analysis, benefit cost ratios, production function analysis* for estimating resource use efficiency.

The impact assessment tools for measuring the impact over a period of time for both individual and group of farmers also include equity, stability and sustainability parameters. Equity is measured by the 'Gini coefficient' of income distribution through Lorenz curve technique, while stability and sustainability are by estimating the *coefficient of variation(CV)* of different impact indicators across a sample data or over a period of time. The decision criteria being CV lower than 25 percent accepted as stable.

The economists and financial institutions however prefer the aggregate measures of impact that use the econometric approaches, Viz., *total factor productivity analysis* and *economic surplus models.*

Total Factor Productivity (TFP) analysis measures the shifts in production frontier or the increased output, which is not accounted for by increases in total inputs. TFP is an important measure to evaluate the performance of any production system and sustainability of the growth process. Growth in TFP is a necessary and sufficient condition for development in any production system (Kumar & Mittal, 2003).

Economic Surplus (ES) model provides a quantitative assessment of the net benefits accrued to the society on the whole taking into account the stream of costs attributable for the technology generation and the benefits from the technology discounted over the period of time. This technique also discerns the accrued benefit as that for producers and that for the consumers as well (Alston, et al, 1995; Srinivas, 2009).

In view of its global acceptance, a detailed account of estimation of ES has been provided herewith.

Estimation of Economic Surplus (ES) generated due to technology adoption

Adoption of an improved technology ideally is assumed to shift the supply curve of a given product to the right suggesting the possibility of higher production from the given set of inputs or lower use of inputs for a given level of output, thus resulting in 'producer's surplus'. Further, since the producer is able to supply a larger quantity of output at a given price, the consumer is able to get larger quantity for the same price or same quantity at lower price, thereby resulting in 'consumer a surplus satisfaction'. Economic Surplus model thus takes into account the elasticity of production and consumption there by accounting for both supply and demand side of the technology adoption, which is depicted in Fig 1 below, followed by a series of equations which provide a solution for the graphic representation of the estimation method.Given a negatively slopping demand curve, D, and a positively slopping supply curve S, the technological intervention is assumed to shift the supply curve to S'. As a result of this shift, the producer is able to produce Q' quantity with the same set of inputs as he used for the production of quantity Q output. As a result, the consumer also is benefited as he could get Q 'quantity at P' price. The area Oabc (Fig 1) is the total economic surplus, while the area PbaP' represents the consumer surplus

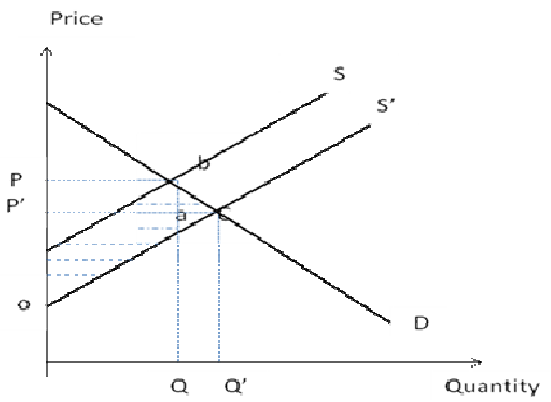

Fig.1. Economic Surplus model graphic representation

Change in Consumer Surplus

ΔCS = Area abc + Area PP'ab

Change in Producer Surplus

ΔPS = AreaOo'ac – Area PP'ab

Change in Total Surplus

ΔTS = Area abc + Area Oo'ac

It is estimated using the following set of equations

Total Surplus = K_t PQ $(1+0.5Z_t\eta)$ (1)

Where $Z_t = K_t\,(e/(e+\eta))$

Consumer Surplus

$\Delta CS = Z_t P\,Q\,[1+(0.5 \text{ X } K_t\,(e/(e+\eta))\,\eta$ (2)

Producer Surplus

$\Delta PS = (K_t\text{-}Z_t)\,P\,Q\,[1+(0.5 \text{ X} K_t\,(e/(e+\eta))\,\eta)]$ (3)

Where,

P = Price of Fresh grape (Rs/ton) (Current market price)

Q = Base Line Production of fresh grape (t)

K_t = Horizontal Supply shifter

γ = Price elasticity of Grape supply

η = Absolute price elasticity of demand for the commodity

Estimates of economic surpluses with and without research induced impact shows the 'consumer surplus' to be higher in most cases because of the increase in quantity and decrease in price. The producer surplus may be either higher (because of reduced costs of production or increased supply) or lower (because of lower price) depending on which effect dominates. The impact of research on producers depends on the elasticity of demand, the more elastic the demand; the higher is the producer surplus. For the entire economy, the total increase in economic surplus represents the social benefits from the adoption of the new technology. The magnitude of these benefits is determined by the shift in the supply curve to its right, which is estimated with the help of supply shift factor, 'K', which provides the vertical shift of the supply function and a measure of the magnitude of the net cost reduction per unit of output (Alston, et al, 1995).

A new technology adoption makes the supply curve to shift to the right. This shift reflects either a productivity improvement holding the input mix fixed at the without-research levels or cost savings from the with-research input mix or both. This cost reduction can be measured by the difference in cost of production with and without the new technology. Since this information is difficult to obtain in an ex-ante evaluation, Alston et al (1995) proposed an alternative method based on per unit of output industry-level gross cost reduction (vertical shift) by dividing the proportionate yield increase by the elasticity of supply[7]. However, for ex-post evaluations, the differences in with and without research costs, the calculation of the supply shift K is achieved using information about the unit cost reduction due to technology use, proportionate yield increase $\Delta Y/Y$, proportionate change in area under the new technology A_t, and the supply and absolute demand elasticity. The supply shift K is calculated as follows for each year t of the adoption process:

$K_t = \sum [1\text{-}(Y_t/Y_{it})] \text{ X } A_{it})]\,(e^*MC\ ^*n)$ (4)

Where, Yt and Yit represent the productivity changes; Ait, the proportional change in area under the technology in question for t year and MC represents the change in total cultivation cost due to new technology, 'e' and 'n' representing the supply and demand elasticity respectively.

Estimation of net Present Value and Internal Rate of Return

The evaluation of the net benefits is based on the measurement of two values, the net present value (NPV) and the internal rate of return (IRR) of the benefits of the development and the adoption of a new technology. These two measures are complementary.

The NPV determines the profitability of the new technology. This is shown by a positive value of the NPV over a period of time and for a given discount rate. The net present value of a project is the sum of the stream of future benefits B minus the costs C of the project discounted at a discount rate r during a period of time T:

$$NPV_t = \frac{\sum B_t - C_t}{(1+r)^t} \quad (5)$$

The IRR is the discount rate at which the present value of the benefits equals the present value of the costs or the discount rate at which the NPV equals zero. It provides a ranking of alternative situations through the measurement of the net present value per unit of research and adoption investments. The discount rate is the interest rate or the opportunity cost of the funds invested by the producers and government, in this case 10% has been used as the discounting/compounding factor for arriving at the discounted/present value of investments made. The internal return rate of a project is

$$R = [\sum (TSB_t - C_t)(1+IRR)^{-t}] \quad (6)$$

That rate of interest at which the discounted net present value is equal to zero is assumed to be the Internal Rate of Return. Though some exports do take place, the present case represents a closed economy model since the producers get paid in rupee terms; therefore the farm gate price only has been included for analysis purposes.

Research and extension expenditure

Estimation of economic surplus at the aggregate requires the estimation of net benefit accrued to the economy after accounting for the expenses incurred on R&D and extension and demonstration of the technology. This has been estimated year wise taking into account the proportion of scientific and technical man power involved and the proportion of establishment and other administrative overheads per year for each of the research institutions involved in the technology generation and dissemination.

Quantity and farm harvest prices

The actual quantity produced by the regions under consideration and the actual harvest prices received by grape growers in different time periods have been estimated based on information collected from the growers and taking into account the other sources as maintained by the grape growers association. The price elasticity of demand for grape in the target states were not available, the elasticity figures used for other horticulture crops from published sources were made use of for this analysis (Hussain*et al*, 2003; Kumar *et al*, 2003 and Surabhi, 2006).

Section II

Case study of estimation of Economic Surplus using Data on Grape Root stock technology adoption

Status of Grape cultivation in India

Grape in India is grown over an area of around 64,000 ha (2005-06) growing steadily since the early 90. India ranks 24th among the world grape growing countries, accounting for 0.86 percent of the World grape area and produces 1631,000 tones, (about 2.37 percent of the world grape production) and ranks 13th among the world grape producing countries. India holds the pride position of highest productivity at 25.5 t/ha as against the world average of 9.32t/ha.

The area under this crop in India has nearly doubled since early 90s, while production increased by 2.44 times and productivity by 23%. The compound growth rate of area for the period 91 to 2006 is 4.76 %, while that of production is 7.84%.

Four states, namely Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu account for over 94 % of the country's grape area and production (2005-06), which is a 6 percent higher share in area terms and 35 percent higher shares in production terms in comparison with the 1991 figures. Maharashtra (MS) has been the most important grape growing states, which has been registering continuously higher growth rate in area, production and productivity over the years. Between 1991 and 2006, MS registered 6.46 percent CGR in area and nearly 12 percent CGR for production growth. The 5 percent CGR in productivity appears to be the main contributor for this trend. Maharashtra accounted for 53 % of the area under grape in 1991-92, which has increased to 71 % by 2005-06. Karnataka which had 19 % of the area declined to 16%, while both AP and TN which had 5 % area also showed marginal decline in the grape area (NHB, 2008 ; Singh et al, 2004).

Impact of Root stock technology on Grape production

Though grape was primarily grown on own root, research into use of root stocks was initiated way back in the early 70s. Saline and alkaline soil conditions in Maharashtra region compelled the researchers from the Indian Institute of Horticulture Research (IIHR), Bangalore to evaluate series of root stocks that would benefit grape cultivation. The research results that standardized 'dogridge' as the most useful root stock in the early 90s were tested on the growers fields prior to release as a standard package of practice. The field level adoption which started during 96-97 started picking up by the millennium with adoption rates growing to > 60% in Maharashtra state alone. Other grape growing states, like Karnataka and Andhra Pradesh also started adopting grape cultivation on 'dogridge' root stock beginning 2001-02 onwards.

The area under root stock has been increasing every year and it is believed that grape cultivation in some of these areas might not have been possible but for the root stock technology.

Cultivating grape on root stock dogridge, has spread widely to include over 75-80% of the area under grape within a span of two decades. Maharashtra growers have also been able to take advantage of the technology for sale as diversified products such as fresh grapes for domestic and export market, raisins and wine. Other regions primarily specialize in fresh grape production for domestic market, occasionally able to export small quantities. Growers from Karnataka too produce for domestic as well as export purposes and convert to raisins in some specific pockets. The growers from AP specialize in domestic production alone, with marginal or occasional exports.

Table 1: Cumulative Grape Area under root Stock, productivity changes and Supply shifter Kt

Years	Area(ha)	Root stock (ha)	% adoption	yt/yit	Kt=(1-yt/yit)*ait	kt*costred*n
91-92	26100	0	0	0	0	0
1996-97	36800	33.75	0.091712	0.964706	3.24E-05	0.032369
1997-98	34800	54.34	0.156149	0.965909	5.32E-05	0.055362
1998-99	38600	124.2	0.321762	0.956522	0.00014	0.16228
1999-00	41700	247.34	0.593141	0.938776	0.000363	0.450303
2000-01	42000	576.74	1.37319	0.960784	0.000539	0.753908
2001-02	46400	2336.75	5.036099	0.944444	0.002798	3.637183
2002-03	47500	4415	9.294737	0.981818	0.00169	2.12934
2003-04	54800	7852	14.32847	0.982143	0.002559	2.96804
2004-05	58300	16324	28	0.99115	0.002478	2.230088
2005-06	60000	19200	32	0.991228	0.002807	2.357895
2006-07	60700	30258	49.84843	0.991304	0.004335	3.294331
207-08	62300	36500	58.58748	0.991379	0.005051	3.232413

Unitary elasticity of supply and 0.2 as own price elasticity of demand have been assumed.

Pattern of adoption of root stock technology

The adoption pattern for the root stock technology across growing regions showed spatial and temporal variations. However, the Growers Associations in each of the states were able to provide details on individual growers shifting towards root stock. Based on this data collected from the growers association, the overall adoption patterns for the technology has been arrived at, which is presented in Table 1**.** Maharashtra leads in the adoption of this technology, which was initially introduced during the early 90s, field tested during 1993-94 and subsequently started getting adopted since 1996-97. Though the technology has been developed and standardized from Bangalore, its adoption has not been as quick and wide spread as it is seen in Maharashtra. However, its adoption appears to have gained momentum since 2002 in Karnataka. Similar is the experience of growers in AP as well. The Tamil Nadu growers have just started adopting the technology only recently, hence, they have not been included for this study. Though efforts have also been made to standardize other root stocks, they are only in the initial stages of adoption. The cumulative annual variation in productivity due to technology adoption was obtained from the growers region wise for estimating the shift factor (Kt) is presented in Table 1.

Economic Gains from the technology adoption

Adoption of root stock technology has resulted in improved quality of grapes; reduced production costs through lowered expenses on pests and disease control and successfully lead to higher profits which are reflected not only in the production of fresh grapes for domestic markets, but also in the production of grapes for export, raisin and wine production. At individual farm level, there was at least 10-20 percent reduction in the total production expenses; 5-10 percent yield enhancement resulting in up to 20 percent increase in the overall net return. The technology also expanded the scope for the growers to use new varieties for wine grape production, since these could be grafted onto the well-established ‘dogridge root stock.

Yield and Returns

Productivity gain due to adoption of root stock was in the range of 10-20% across regions and uses. The highest annual productivity realized has been for domestic purposes under root stock grown grapes (Thompson variety) in Maraharashtra followed by Andhra Pradesh and Karnataka. The real impact was observed in the reduction in cultivation expenses and higher price for better quality of grapes for raisin and wine making purposes. The gross returns and net realization were higher at least by 15-20 % for the root stock grown grapes in comparison to the own root grown grapes. The per unit BCR for root stock grown farms were higher across the grape growing regions, suggesting the superiority of the root stock technology.

Estimated Benefit of technology adoption across regions

The use of technology resulted in reduction in cultivation expenses, enhanced yield and quality at individual farm level irrespective of the variety used or produced for different modes of sale. Based on a cross sectional data collected from sample growers across growing region, the economic benefit accrued per unit area has been estimated, as is presented in Table 2.

It could be seen from the table, that the adoption of dogridge root stock technology has resulted in enhanced yield, price or return. In Maharashtra, the yield advantage from Root stock use was 17 % for export oriented production, 20 % for raisin making and 10 % in wine production farms.

Table 2: Economic Benefits with and without the technology for unit area

	Domestic		**Export**		**Raisin**		**Wine**	
	Root Stock	**Own Root**	**Root Stock**	**Own Root**	**Root Stock**	**Own Root**	**Root Stock**	**Own Root**
Maharashtra								
Cost (Rs/ha)	123231	124589	190315	210000	134341	141250	126820	98526
	(23.45)	(22.45)	(32)	(28)	(27.89)	(21.34)	(24)	(32)
Yield (T/ha)	28.9	28	17.5	15	9.15	7.6	15.8	14
Price (Rs/t)	17.44	19.9	45	37	79.17	77	33.63	30.33
Gross Return	504016	557200	787500	555000	724405	585200	530513	424620
Net Return	380785	432611	597185	345000	590064	443950	403693	326094
BCR	4.09	4.47	4.14	2.64	5.39	4.14	4.18	5.13
Karnataka								
Cost (Rs/ha)	106589	112458	116589	102581				
	(32.3)	(32)	(27)	(25)				
Yield (T/ha)	24.5	22.5	12.54	11				
Price (Rs/t)	15.79	15	41	38				
Gross Return	386855	337500	514140	418000				
Net Return	280266	225042	397551	315419				
BCR	3.63	3	4.41	4.07				
Andhra Pradesh								
Cost (Rs/ha)	98562	102589	124589	114581				
	(32)	(35.4)	(29)	(24.5)				
Yield (T/ha)	15.68	14	12.58	10.5				
Price (Rs/t)	16.78	16.8	42	39				
Gross Return	263110	235200	528360	409500				
Net Return	164548	132611	403771	294919				
BCR	2.67	2.29	4.24	3.57				

Data compiled from sample survey and corroborated by discussion with MRDBS, Pune.

This appears to have resulted in nearly 20-40 percent increase in gross realization in different modes of sale, the highest realized being from exports followed by raisin making and wine making. Similar trends have been seen in other growing regions as well. This could be attributed to the fact that the quality based pricing is only seen for some products and the fresh sale in domestic market may not help producer realize such variations. Hence, the technology adoption impact could be visualized more prominently at the aggregate level where other modes of sale are prominent.

The technology impact is positive at individual grower level, and the technology adoption has also resulted in wider ramifications which include increased area, enhanced production as well as product diversification. While estimating the economic impact, researchers multiply these individual farm level benefits by the percent adoption of technology across growing regions and cumulate it over the number of years. However, the Economic Surplus method uses the average annual benefit using the improved technology and uses this value for arriving at the aggregate level impact taking into account the total production in each year. Since the set of equations are estimated year wise, the parameters of 'k', 'n' and 'e' take care of the responsiveness of the supply shift also as these supply and demand elasticity of the commodity in question are also used for the estimation matrix. Further, the economic surplus method also takes into account the research expenditure and the discounted value of the overall benefits aggregated over a specified period of time. Hence, it may be more realistic and useful a tool for estimating the economic impact of technology adoption for agricultural commodities.

Estimation of Economic Surpluses generated due to adoption of the technology.

Thus using the benefits per unit area in Table 2, a matrix of data for the total of 25 years has been developed for estimating the aggregate level surplus generated due to technology adoption and is also discounted over the total period. Thereby, the aggregate level economic surplus generated due to the adoption of root stock technology has been estimated and is presented in Table 3. The aggregate total change in consumer surplus due to the adoption of root stock technology in grape is Rs. 8040.32 crores, while the change in producer surplus was Rs.804.03 crores. Total economic surplus generated from the technology worked out to Rs. 8844. 34 crores. The total research costs for the technology generation and dissemination at current prices stood at Rs. 4.40 crore, there by generating a net total surplus of Rs. 8839.94 crore. Since the Maharashtra region accounted for the highest level of adoption of the technology in comparison to the other regions, it could be inferred that more than 95% of the estimated economic surplus could be attributed to have generated from this region alone.

International Journal of Agriculture Innovations and Research
Volume 3, Issue 1, ISSN (Online) 2319-1473

Net present Value and Internal Rate of Return

Since the matrix of data generated uses the discounted net cash flows, the net present value of the economic surplus generated due to adoption of grape root stock technology after meeting for the research costs is around Rs 8839.94 crore, fetching an internal rate of return of 40 % and a BCR of 182 (Table4).

Table 3: Estimation of Total Economic Surplus due to technology adoption

S.No.	year	Change in Consumer Surplus	Change in Producer Surplus	Change in Total Surplus	Research Costs	Compounded Research Costs	Net benefit
a	b	c	d	e	f	g	h
1	1975-76	0	0	0	148350	2847429.9	-2847429.9
2	1976-77	0	0	0	88960	1552263.04	-1552263.04
3	1978-79	0	0	0	100000	1586300	-1586300
4	1979-80	0	0	0	145000	2090900	-2090900
5	1980-81	0	0	0	155000	2031895	-2031895
6	1981-82	0	0	0	165000	1966470	-1966470
7	1982-83	0	0	0	175000	1895950	-1895950
8	1983-84	0	0	0	200000	1969800	-1969800
9	1984-85	0	0	0	245000	2193730	-2193730
10	1985-86	0	0	0	297800	2424092	-2424092
11	1986-87	0	0	0	297800	2203720	-2203720
12	1987-88	0	0	0	297800	2003300.6	-2003300.6
13	1988-89	0	0	0	297800	1821047	-1821047
14	1989-90	0	0	0	297800	1505081.2	-1505081.2
15	1990-91	0	0	0	321000	1622334	-1622334
16	1991-92	0	0	0	346150	1590213.1	-1590213.1
17	1992-93	0	0	0	394500	1647826.5	-1647826.5
18	1993-94	0	0	0	394500	1497916.5	-1497916.5
19	1994-95	0	0	0	394500	1361814	-1361814
20	1995-96	0	0	0	424500	1332081	-1332081
21	1996-97	9712906.256	971290.6256	10684196.88	444500	1268158.5	9416038.382
22	1997-98	33459060.57	3345906.057	36804966.62	394450	1022808.85	35782157.77
23	1998-99	127251407.6	12725140.76	139976548.4	334450	788298.65	139188249.7
24	1999-00	494672608	49467260.8	544139868.8	344450	738156.35	543401712.4
25	2000-01	1110988150	111098815	1222086965	244450	476188.6	1221610776
26	2001-02	7164060458	716406045.8	7880466504	294450	521470.95	7879945033
27	2002-03	5232026824	523202682.4	5755229507	182075	293140.75	5754936366
28	2003-04	8891944126	889194412.6	9781138539	282075	412957.8	9780725581
29	2004-05	8603079821	860307982.1	9463387803	237125	315613.375	9463072190
30	2005-06	11379778956	1137977896	12517756852	275000	332750	12517424102
31	2006-07	17593953829	1759395383	19353349212	375000	416250	19352932962
32	2007-08	19762233809	1976223381	21738457190	375000	375000	21738082190
	Total(Rs)	80403161955	8040316196	88443478151	8969485	44104957.67	88399373193
	Total Million Rs	80403.16196	8040.316196	88443.47815	8.969485	44.10495767	**88399.37319**

Compounded to 2007-08 prices

Table 4: Estimated rate of return on investment into Root stock research (Crore Rs)

S.No.	Economic gains	Value (Rs. Crore)
1	Total Economic Gain	8844.35
2	Present value of cumulative research costs	4.41
3	Net present value of Economic gains	8839.9
4	Benefit to Cost ratio (taking Producer surplus to investment)	182
5	Internal Rate of Return (%)	40

IV. Conclusion and Suggestions

Estimation of returns to investment into research is of significance given the shift in research and development priority away from cereals and pulses towards horticultural crops. The quantification of aggregate accrual of benefits could help researchers and policy markers judge the criticality of the technology in question. Though several partial measures of impact are available, it is important to use a method that has universal acceptability.

Hence this study demonstrates the use of Economic Surplus method for estimating the aggregate level benefits from the adoption of dogridge root stock technology in grape cultivation based on sample data from three important grape growing regions.

The results and discussion brought forth a total economic surplus of Rs. 8844.35 crore, nearly 90 percent of which appears to have been passed on as change in consumer surplus with Rs. 804.03 crore reaching the producers. The return on investment worked out highly feasible with an IRR of 40% and generating a Benefit Cost Ratio of 186 on the producers' surplus alone. Results thus suggest that return over investment into critical technologies in horticultural crop production are highly economical and add great social economic return, there by justifying the policy decision of enhanced budgetary support for these set of crops.

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