Economic Affairs, Vol. 67, No. 03, pp. 371-377, June 2022
DOI: 10.46852/0424-2513.3.2022.30

Case Study

Economic Contribution of Innovations Developed in National Agricultural Research System (NARS): Case of GPU 28 Variety of Finger Millet

Suresh, K.

Department of Agricultural Economics, College of Agriculture, Raichur, Karnataka, India

Corresponding author: suresh.krishnanaik@gmail.com (**ORCID ID:** 0000-0002-7786-9287)

Received: 05-03-2022 **Revised:** 29-05-2022 **Accepted:** 11-06-2022

ABSTRACT

The economic impact of the most successful innovation in Ragi (finger millet) through GPU 28 variety in Karnataka was demonstrated using partial budgeting technique. The incremental benefit of GPU 28 variety of Ragi over Indaf 5 variety was estimated to be ₹ 3244 per acre. The economic impact of GPU 28 variety incorporating the probability of performance and the rate of adoption of technology including the depreciation of technology considering field conditions was ₹ 1168 per acre. The economic contribution of the variety for Karnataka state as a whole was ₹ 181.84 crores assuming 80 percent of the area under Ragi in Karnataka.

HIGHLIGHTS

- The new ragi variety GPU 28 benefitted the farmers through 49 percent more returns than the check variety.
- The improved variety of ragi crop has contributed ₹ 181.84 crores for the state of Karnataka.

Keywords: technology, partial budgeting, economic impact, finger millet, GPU 28

Measurement of technological contributions in rainfed crops is challenging as accounting for rainfall has no universally approved procedure. For instance, whether to consider the annual rainfall, number of rainy days, variation in rainfall, result in different results. In addition, considering the macro data on productivity of different crops due to input use, seldom considers the data on how irrigation water is provided for and measured. These complexities exacerbate the predicament of over estimation (Suresh, 2013).

In India the State Governments and the ICAR have been funding for agricultural research through the established network of research organizations in the country. This was made possible through committed and continued support to agricultural research, and the ability of research managers to visualize research challenges and evolve appropriate institutional responses to them (Pal *et al.* 2005). Agriculture is considered as state subject under Indian constitution. The green revolution during mid-60's and mid 70's enabled India to become self-sufficient in food production by 1982. Agricultural research in developing high yielding varieties and improved technologies was largely responsible.

How to cite this article: Suresh, K. (2022). Economic Contribution of Innovations Developed in National Agricultural Research System (NARS): Case of GPU 28 Variety of Finger Millet. *Econ. Aff.,* **67**(03): 371-377.

Source of Support: None; **Conflict of Interest:** None

Thus, the contributions of agricultural research helped to improve welfare gains and reduce poverty in rural and urban areas by lowering prices of food commodities due to increased production and productivity. Agricultural sector is the first to experience diminishing marginal returns compared to any other sector due to low capital per unit of land. The level of investment in public agricultural research extension and irrigation is of such an order that India is one of the largest publicly funded systems in the world (Evenson *et al.* 1999). Research has been the prime mover of agricultural growth in India. The National Agricultural Research System (NARS) of India is one of the largest in the world, investing about 0.3% of agricultural gross domestic product (GDP) (Pal *et al.* 2005).

The benefits from research may be from a new variety, or new method of cultivation, or processing, a new process, a new product, a new market, a new value chain, a new institution including new method/s of governance (e.g. e-governance). Some research may be basic in nature and may not have immediate application. The research benefits and costs are spread horizontally over areas, and vertically over years and hence time lags in quantification exist (Alston *et al.* 1995; Bantilan and Joshi, 1996). There may be externalities generated in the process. Some research may aim at capacity building, integrated farming systems, and social science research, and are not easily quantifiable. The time length of benefits from research are often indicated arbitrarily by scientists and there are no proven theories / concepts to estimate the same. This introduces bias in the estimation of rate of return to research investment. Further, the uncertainty and variations in the impact and adoption of research political, natural and economic environments (which influences commodity supplies), (iii) the market conditions (such as cob-webs), availability of quality infrastructure over time and space in adequate quantity, availability of extension to meet client needs, impact of technology at different locations, farm situations, adoption patterns, efficiency of extension system, receptivity of farmers, etc. do matter. Considering the costs of research and extension, as the researchers and extension specialists are simultaneously and over time involved in several studies / projects, the research and extension costs are available at aggregate levels and are not available crop wise, technology and innovation wise. In addition, there are synergies in research and extension system, responsible for adoption, which is also difficult to quantify. Intervening variables such as literacy, awareness, proactive role, education, capacity building, substantially contribute to adoption, are also difficult to quantify. For this study, the economic impact of research in the GPU 28 variety of Ragi (finger millet) developed by University of agricultural Sciences, Bangalore and released in 1997 after a research of 11 years by scientists was demonstrated with the objectives of estimating the changes in costs and returns due to adoption of new technology (GPU 28 variety) in Ragi and assess the ex-post economic contribution of research in ragi crop (GPU 28 variety).

MATERIALS AND METHODS

For this study, a random sample of 35 farmers cultivating GPU 28 variety of ragi as rainfed crop in eastern dry agro climatic zone of Karnataka (in Chintamani and Doddaballapura taluks), where Ragi is the major rainfed crop have been chosen. For comparison, 35 farmers cultivating the local check variety Indaf - 5 in Ragi have been chosen in the same agroclimatic zone. The field data on costs and returns from Ragi were collected from the sample farmers for 2013.

The returns to R &D investment at the level of scientist/s and organizational level are yet to be economically estimated, since the popular methods - TFP (Total Factor productivity) and ES (Economic surplus) are based on restrictive assumptions. The TFP is specific to crop/s which does not distinctly and adequately quantify research benefits of a specific innovation (such as use of rotary weeder, or vermin composting) in a farm, which are not crop specific. The ES approach is highly sensitive to the use of the price elasticity of demand and price elasticity of supply, which most often are not available for the region where the research is carried out, and often are borrowed for and from other regions, which defeats the very purpose of research. TFP (Evenson *et al.* 1999; Kumar *et al.* 2004, Chand *et al.* 2012) and ES (Alston *et al.* 1995; Birthal *et al.* 2012; Mrunthyunjaya *et al.* 2004: Joshi, 2003; Khatkar *et al.* 2004) thus assume the impact of all innovations in a crop over time and space but fail to quantify impact of R &D efforts of individual subjects / scientists, as the methods use secondary data collected for some other purpose, which are usually available at state or national level. However, in the NARS / AICRP/ SAU system, technological innovations are by scientists / technologists are crop and enterprise mechanization, post-harvest technologies, water saving technologies. It is proposed to use a simple tool of farm management so that any scientist can use the methodology to project his/her contributions realistically to highlight and upscale the individual research contributions. In addition the ES, TFP approaches are not transparent and unattractive to non-economists. TFP even ignores the contribution of the farmer, the man or woman behind the plough in the agricultural extension system and all the credit cannot just be credited to the developers of technology and the NARS. Therefore, it is crucial to develop and demonstrate methods which incorporate scientifically the role of technology, extension, management input in agriculture and crop enterprises due to climate change risks in rainfed farming.

Modified Partial budgeting – a simple pragmatic approach for quantifying R and D contributions in NARS

Partial budgeting technique is a simple, transparent method to quantify the economic contribution of technologies. This template is simple, transparent and easy to understand by non-economists so that academic transparency is appreciated. Here, the concerned scientist / innovator will get actively involved with the economist in computing the economic impact of innovation while filling the four components of partial budgeting. The economic costs involved in cultivation and in conducting research/extension, probability of field performance of innovation, depreciation of technology and rate of adoption are included. The eight steps in estimating the ex-post economic contribution of new technologies are as under.

Step 1 : The actual cost of cultivation of the GPU 28 (new variety) and that of the Indaf – 5 (the check variety) are obtained from farmers for the latest year. The field trials conducted can also be one of the sources of information for the scientist. The information obtained is analyzed in the partial budgeting format (Table 1). The format has four components namely (i) added costs due to new technology, (ii) reduced returns due to new technology (on the debit side), (iii)reduced costs due to new technology, and (iv)added returns due to new technology (on the credit side). Since the costs were obtained for Ragi GPU 28 (new technology) variety and Indaf 5 (the check variety), the added costs, reduced returns, reduced costs and added returns need to be obtained. The economic costs such as opportunity cost of capital, risk premium, and management costs were also considered.

Step 2: The research costs incurred in developing the GPU 28 variety of Ragi was obtained over time. The research costs include the salaries paid to the scientists and staff in this case since 1991 till 2000. The salaries paid each year along with operation costs incurred are compounded from the year of incurring expenditure till the present year (in this case for 2013). The expenditure on extension include expenses of demonstrations conducted and other costs involved in diffusion of innovations, including salaries paid to extension personnel and their staff. The expenditure is compounded at around 2 percent to reflect the real social discount rate as the R &D expenditure on research on millets / cereals is also a public expenditure.

Step 3: The total compounded value of research and extension costs was amortized in this over 10 years at 2 percent as it took ten years for the development of GPU 28 ragi.

Step 4: The total area of adoption of new technology was obtained from secondary sources / primary sources. It was found from discussions with officials of the Department of Agriculture, Government of Karnataka, that 80 percent of the area under Ragi is occupied by GPU 28 varietal innovation, which is useful for upscaling.

Step 5: The amortized cost of research and extension obtained in step 2 is divided by the total area of adoption (step 3), to obtain the estimate of current cost of research and extension per acre of new technology adoption.

Step 6: The probability of adoption of new technology is obtained by extension personnel. The probability of adoption can be considered as proportion of the new technology adopted by the farmers. Step 7: The probability of performance of new technology needs to be obtained by scientists/researchers/extension personnel involved. The probability of performance depends upon the field conditions, field diversity and field reality. If all is well, the probability of performance can be even 1 or 100%. If the climate was not favourable, the probability may drop to 0.6. The choice of probability rests with the scientist in consultation with the extension personnel.

Step 8: The depreciation of technology has to be provided by scientists/researchers. Technology also has its depreciation due to use of technology over time similar to wear and tear as well as obsolescence which is due to arrival of newer technologies, which makes the current technology obsolete. If there is no depreciation, then this value is 1.0, if the depreciation is 10%, then this figure is 0.9 and so on.

RESULTS AND DISCUSSION

Cost of Cultivation of GPU28 and Check Variety of Ragi (finger millet)

From Table 1, it can be seen that the cost of cultivation of GPU 28 ragi worked out to be ₹ 11,568 per acre, which was higher than the cost incurred for cultivation of the check variety (₹ 11,038 per acre) due to higher cost incurred towards human labour, machine labour, seeds, farm yard manure and chemical fertilizers. The human labour cost was high in GPU 28 farms since these farmers used more labour for harvesting and threshing of ragi. The expenditure incurred on farm yard manure was ₹ 961 for GPU 28 variety, while it was ₹ 637 for check variety. Thus, as higher quantities of farm yard manure are applied in GPU 28 farms, compared to check variety farms. The yield of both main product (12.45 quintals/acre) and by product (2.38 tons/acre) of ragi was higher for GPU 28 farmers than the check variety farmers. Though per acre total cost of cultivation was higher, the net return (₹ 6, 668) realized by GPU-28 farmers was higher than check variety farmers mainly in GPU28 farms. The net returns per acre for GPU 28 farmers were higher than the check variety farmers by 49 per cent, emphasizing the financial performance.

Economic impact of new ragi (finger millet) variety GPU 28

In the partial budgeting technique, the farmer intends to maximize profit from the new technology through the use of new Ragi variety GPU 28, by using the package of practices associated with the technology. This technique apparently reveals the economic contribution of cultivating Ragi variety GPU 28 over the check variety Indaf 5 (Table 2). The added costs are due to use of new seed variety and the associated use of FYM, fertilizers and the associated cost of labor required to apply the inputs. The opportunity cost of additional expenditure of ₹ 489.94 per acre due to GPU 28 Ragi variety over the check variety Indaf 5 works to ₹ 12.25. The risk premium is ₹ 50 at the rate of 10% of additional expenditure. The management cost was estimated to the tune of 10% of additional expenditure. The research cost is computed by compounding the expenditure on salaries of the research faculty and personnel from the year of commencement of research on GPU 28 variety of Ragi, and amortizing the cost over 10 years as that was the number of years for the innovation of GPU 28 Ragi variety. Similarly the expenditure on extension was also considered. The check variety Indaf 5 is at least 30 years old, and accordingly the R &D and extension costs are assumed as close to zero.

The proportion of area under the GPU 28 Ragi was ascertained from the scientists and the Department of Agriculture, Government of Karnataka including the Karnataka State Seeds Corporation and the National Seeds Project of the UAS Bangalore. Currently about 80 percent of area under Ragi is covered by GPU 28 variety in Karnataka. The amortized cost of research and extension was thus divided by the area under GPU 28 variety to obtain the cost of research and extension as Re 0.15 per acre. Thus, the partial budgeting considered in addition to economic costs of production, the cost of research and extension per acre.

As the farmers do not use plant protection chemicals on ragi, and as there were no reduced costs (or savings) of inputs due to the new variety GPU 28, the reduced costs were taken as zero. The yield of ragi of GPU 28 is higher by 2.26 quintals per acre over the check variety Indaf 5. In addition, the fodder yield of GPU 28 was higher by 0.68 tonne per acre. The value of the added output due to additional grain and fodder yield is ₹ 3846.58. Thus, the total credit side of GPU 28 over the check variety of Indaf 5 was ₹ 3846.58, while the total debit side was ₹ 602.34. The difference between credit and

Table 1: Economics of cultivation of (GPU 28) ragi and check variety in Eastren dry zone of Karnataka (₹/acre)

Sl. No.	Particulars	Unit	GPU 28 Variety		INDAF 5 Check Variety	
			Quantity	Value (₹)	Quantity	Value (₹)
(A)	**Variable costs**					
1	Human labour	Mandays	19.78	3553.69 (30.72)	17.63	3230.83 (29.27)
2	Bullock labour	Pairdays	1.24	620.00 (5.36)	1.55	773.97 (7.01)
3	Machine labour	Hours	2.22	664.71 (5.75)	2.13	637.71 (5.78)
4	Seed	Kgs.	4.80	101.59 (0.88)	4.46	92.65 (0.84)
5	FYM	Tons	2.16	961.48 (8.31)	1.92	759.81 (6.88)
6	Chemical Fertilisers	Kgs.	89.26	1133.09 (9.80)	83.86	1043.08 (9.45)
7	Miscellaneous	₹		432.43 (3.74)		439.59 (3.98)
	Sub total			7466.99 (64.55)		6977.63 (63.21)
8	Interest on working capital at 7%			261.34 (2.26)		244.22 (2.21)
	Total variable cost			7728.33 (66.81)		7221.85 (65.43)
(B)	**Fixed costs**					
9	Land Revenue and Taxes	₹		15.00 (0.13)		15.00 (0.14)
10	Depreciation	₹		78.70 (0.68)		69.66 (0.63)
11	Rental value	₹		3580.48 (30.95)		3567.33 (32.32)
12	Interest on fixed capital at 9%			165.34 (1.43)		164.34 (1.49)
	Total fixed cost			3839.51 (33.19)		3816.33 (34.57)
	Total cost of cultivation (A+B)			11567.85 (100.00)		11038.18 (100.00)
(C)	**Returns**					
	Main product	Qtls	12.45	14949.60	10.49	12284.97
	By-product	Tons	2.38	3286.19	1.70	2104.24
	Gross return	₹		18235.79		14389.21
(D)	**Net return**	₹		**6667.94**		**3351.03**

debit due to GPU 28 variety over Indaf 5 was ₹ 3244 per acre.

Incorporating the Law of Diminishing Marginal Returns

The difference between credit and debit side (Table 2) provides the estimate of economic valuation of benefit of research on per acre basis as ₹ 3244 per acre reflecting the potential benefit. A linear extrapolation of this additional benefit to the area under GPU 28 variety of Ragi in Karnataka is the usual method employed by scientists. However, such a linear extrapolation is fraught with conceptual flaw as it does not incorporate the Law of Diminishing marginal returns (LDMR), which operates early in agriculture. Agricultural R &D, is no exception to this phenomenon. The LDMR is incorporated by weighing the additional benefit from GPU 28 Ragi variety with the probability of performance of technology (=0.8) and rate of adoption of technology (=0.5) as opined by the scientists and extension personnel (Suresh, 2013). Accordingly the actual benefit worked out to Rs. 3244.24 × 0.8× 0.5 = ₹ 1298 per acre.

The benefit obtained per acre needs to be scaled up to cover the area occupied by GPU 28 variety of ragi (finger millet) in order to obtain an estimate of the welfare gain for the State due to the new variety GPU 28 of Ragi (Table 3). As mentioned earlier, he probability of performance of GPU 28 variety of ragi in the field is assumed to be 0.8 since the scientists indicated that the varietal performance in the field conditions is to the tune of 0.8 as opposed to 1.00 in the controlled conditions and the rate of adoption of the GPU 28 technology is taken as 0.5 as indicated by the extension personnel. For upscaling, the rate of depreciation of technology also needs to be incorporated since technology too depreciates in the product life cycle. In consultation with scientists, a depreciation of 10 percent is assumed. Thus, the total economic impact of GPU 28 Variety of ragi considering field conditions per acre = 3244.24 × 0.8 × 0.5 × 0.9 = ₹ 1168 per acre for upscaling. This benefit of ₹ 1168 per acre is then extrapolated to

Table 2: Estimation of Economic Impact of Research contribution in Ragi (Variety GPU 28) in Karnataka using partial budgeting technique (2013- 14) (₹/acre)

Debit Side (A + B)			Credit Side (C + D)		
(A) Added Costs Due to GPU 28 variety of Ragi over the Check variety Indaf 5			**(C) Reduced costs due to use of GPU 28 variety of Ragi over the check variety Indaf5**		
	Qty (kgs)	Cost (₹)		Qty	Cost (₹)
i. Seed use of check variety Indaf 5	4.46	92.65	Savings in fertilizers, FYM, labor due to GPU 28 Ragi	0	0
ii. Seed use of GPU 28 variety	4.8	101.59	Savings in PPC /agro chemicals	0	0
Added seed cost due to use of GPU 28 seed		8.94	Reduced costs due to GPU 28 Ragi variety	0	0
			(D) Added returns due to GPU 28 variety of Ragi over check variety Indaf 5	Qty	Return (₹)
Additional cost of FYM and chemical fertilizers		285	Added yield of GPU 28 Ragi in qtls /acre	2.26	2664.63
Additional cost of labour	1 man day	196	Added fodder yield due to GPU 28 Ragi (tonne / acre)	0.68	1181.95
Total additional cost due to seed, labour and capital (additional working capital)		489.94	Total added returns due to GPU 28 ragi		3846.58
Interest on additional working capital @ 5% per year for 6 months		12.25			
Management cost @ 10% of additional working capital		50			
Risk premium @ 10% of additional working capital		50			
Research cost per acre (from Table 2)		0.13			
Extension cost per acre (from Table 2)		0.02			
Total of research and extension costs per acre		0.15			
Total of added costs		602.34			
(B) Reduced Returns due to use of GPU 28 Ragi variety over the check variety Indaf 5:	0	0			
Total Debit side: (A+B)		602.34	Total credit side (C+D)		3846.58
Economic worthiness of GPU 28 Ragi variety over the check variety Indaf 5:Credit side minus Debit side =3846.58 – 602.34 = ₹ 3244.24 per acre.					

Table 3: Economic benefits from the cultivation of GPU 28 variety of Ragi over the check variety Indaf 5 in Karnataka for 2013-14

1	Probability of performance of this technology = 0.8	0.8
2	Rate of adoption of this technology = 0.5	0.5
3	Depreciation of technology (if 1, no depreciation)	0.9
4	Economic impact of GPU 28 Variety of ragi considering field conditions per hectare = 3244.24*0.8*0.5*0.9 = ₹ 1167.93 per acre	1168
5	Area under ragi in Karnataka (2013-14) in acres	19.46
6	Area under GPU 28 Ragi is 80% of 1946098 acres	15.57
7	Total economic impact on 1556878 acres = 1168*1556878	₹ 181, 85 lakhs
8	No. of years for developing GPU 28 variety of ragi	11
9	Cost of salaries of researchers plus staff for 11 years (₹)	19.24
10	Amortized research cost of project per year ₹	1.97
11	Cost of extension demonstrations and salaries (₹)	2.68
12	Amortized cost of demonstrations and salaries per year (₹)	0.27
13	Research cost per acre (₹)	0.13
14	Extension cost per acre (₹)	0.02
15	Total research and extension cost per acre (₹)	0.15

cover the area (of 15,56,878 acres) under the GPU 28 variety of ragi in Karnataka, to obtain the economic impact of GPU 28 Ragi variety as equal to ₹ 181.84 crores for 2013-14.

CONCLUSION

The potential benefit estimated using partial budgeting is weighed with the use of probability of performance, rate of adoption to accommodate the law of diminishing marginal returns and the rate of depreciation of technology for upscaling of new technology instead of linear extrapolation of benefits. The findings of the study show that improved technology in ragi crop has contributed ₹ 181.84 crores for 2013, a substantial benefit of the new technology. Hence the Department of Agriculture, can popularise and encourage the widespread adoption of these high yielding crop varieties for improving the nutritive capacity of farmers and consumers.

ACKNOWLEDGMENTS

The authors acknowledge to Dr. M.G Chandrakant, Former Director of ISEC, Bangalore for guidance in preparation of this research article. The author is also grateful to an anonymous referee/reviewer for his valuable comments that helped bringing this paper in its present form.

REFERENCES

Alston, J.G. Norton and Pardey, P. 1995. *Science under Scarcity: Principles and Practices for Agricultural Research and Priority Setting,* Cornell University Press, Ithaca, NY.

Bantilan, M.C.S. and Joshi, P.K. 1996. *Returns to research and diffusion investments on wilt resistance in pigeonpea.* International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Birthal, S.P. Nigam, N Syam, Narayana, A.V. and Kareem, K.A. 2012. Potential economic benefits from adoption of improved drought tolerant groundnut in India, *Agric. Econ. Res. Rev.*, **25**(1): 1-14.

Chand, R., Kumar, P. and Kumar, S. 2012. Total factor productivity and returns to public investment on agricultural research in India. *Agric. Econ. Res. Rev.*, **25**(2): 181-194.

Evenson, R.E. Carl, Pray, E and Mark, W Rosegrant. 1999. *Agricultural Research and Productivity Growth in India*. Research Report: 109, International Food Policy Research Institute, Washington, USA.

Joshi, P.K. 2003. Impact Assessment of Agricultural Research - Concepts and Measurement. National Centre for Agricultural Economics and Policy Research, Pusa, New Delhi, India.

Khatkar, K.R., Mittal, B.S. and Singh, K.V. 2004. Impact assessment of processing of pearl millet for value-addition and development of heath foods, *Agric. Econ. Res. Rev.*, **17** (Conference No.): 151-162.

Kumar, P., Kumar, A. and Mittal, S. 2004. Total factor productivity of crop sector in the Indo Gangetic Plain of India: Sustainability issues revisited, *Indian Econ. Rev.*, **39**(1): 169-201.

Mruthyunjaya, Pal, Suresh, Pandey, LM and Jha, A.K. 2004. Impacts of selected technologies refined under NATP, *Agric. Econ. Res. Rev.*, **17** (Conference No.): 1-16.

Pal, S. Kumar, A. and Singh, A. 2005. Agricultural research intensity in India, Impact of Agricultural Research: Post-Green Revolution Evidence from India, National Centre for Agricultural Economics and Policy Research New Delhi, and International Crops Research Institute for the Semi-Arid Tropics, Patancheru-502324, Andhra Pradesh, pp. 9-15.

Suresh, K. 2013. Economic Impact of Public Sector Agricultural Research in Ragi and Redgram in Karnataka. Ph. D. Thesis. University of Agricultural Sciences, Bangalore (INDIA).