Impact of research investment on technology development and total factor productivity in major field crops of peninsular India

G.S. Ananth

Professor of Agricultural Economics, University of Agricultural Sciences, GKVK, Bangalore 560065, India

P. G. Chengappa*

Director of Instruction (Agril), University of Agricultural Sciences, GKVK, Bangalore 560065, India, Email: p.g.chengappa@cgiar.org and pgchengappa@yahoo.com **(Corresponding author)**

Aldas Janaiah

Scientist-Sr. Scale (Agricultural Economics) National Centre for Agricultural Economics and Policy Research (NCAP), Library Avenue, Pusa New Delhi-110 012, India
Email: ajanaiah@ncap.res.in

*Contact information:pgchengappa@yahoo.com, Tel: +91-80-23538665, Fax, +91-08-23624977, Department of Agricultural Marketing and Cooperation, University of Agricultural Sciences,GKVK, Bangalore 560065, India

Contributed poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

JEL Code # O3

Key words: research investment; TFP; technology development; India; field crops

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1. Introduction

Productivity growth is of paramount importance for agricultural growth. Increase in agriculture productivity can be induced by public investments in research, extension, human capital and infrastructure (Rosegrant and Evenson, 1994). Public investments in infrastructure, research and extension along with crop production strategies have helped to expand crop production and grain stocks in India. Of late, the investment in agriculture, particularly on agricultural research and development are on the decline so that future growth in production can only be input-based in many regions of the country (Kumar and Rosegrant, 1994). Public agricultural research systems in both developed and developing countries are increasingly facing resource crunch and are lately seeking priority-setting procedures to mediate the often-conflicting demands (Norton *et al*., 1992).

The pay-offs to agricultural research investment at aggregate (all India) level have been estimated by Evenson and Jha, 1973; Evenson and McKinsey, 1991; Rosegrant and Evenson, 1994; Kumar and Rosegrant, 1994 and more recently, Coelli and Rao, 2005. In India, agricultural is a state subject with the central (federal) Government playing the supportive role. Agriculture sector has been the focal subject of state Governments since more than two third of the population is directly engaged in this sector. All the states have invested considerable amount of resources to promote agricultural research, extension and education. But, the attempt to quantify returns to research investment in agriculture at the state or regional level are few. Accordingly, an in-depth analysis of returns to research investment at state or regional level assumes a

greater significance and is the focus of this paper. The specific objectives of the study are to measure (a) the impact of research investment on development of technologies and (b) the rate of return to agricultural research investment.

2. Data sources and Methods of Analysis

2.1 Data source

In the present study we have attempted to quantify the returns to research investment on major field crops viz., rice, sorghum, ragi, red gram, groundnut, sunflower, cotton and sugarcane grown in Karnataka, predominantly an agriculture state in peninsular India. These crops together occupy, 65 per cent of the gross cropped area and account for 43 per cent of the research investment in the state. The secondary data on expenditure incurred on research at the two State Agricultural Universities (SAUs) in Karnataka were collected for a period of twenty-five years from 1970-71 to 1994-95. The data on technologies and crop varieties released have been compiled from the annual reports and research documents of both the SAUs for the period 1970-71 to 1994-95. The district-wise area, production and productivity of major field crops were collected for the period 1970-71 to 1994-95 from the reports published by the Directorate of Economics and Statistics, Government of Karnataka. The data on cost and returns of major field crops 1980-81 to 1994-95 were collected from the Farm Management Survey reports published by the Directorate of Agriculture, Government of Karnataka. The data on the prices of inputs and agricultural commodities have been collected from various secondary sources for the period 1970-71 to 1994-95 to construct the indices.

2.2 Methods of Analysis

The impact of research investment on technology development was assessed by considering the number of crop varieties and technologies relating to non-varieties developed and released by the two SAUs for major field crops. The analysis has been

carried for the whole period (1970 –71 to 1994-95) and three sub periods viz., 1970-71 to 1979-80; 1980-81 to 1989-90 and 1990-91 to 1994-95 in order to capture the influence of research investments on technology development over different time periods.

The total factor productivity approach has been employed to capture the growth in productivity of selected crops. TFP is the ratio of total output index to the total input index or the value of total output to the total input cost multiplied by 100 or expressed in percentage over the years. The TFP concept, which implies an index of output per unit of total inputs, measures shifts in output appropriately, holding all inputs constant. Thus, TFP measures the amount of increase in total output, which is not accounted for, by the increase in total inputs (Kumar and Rosegrant, 1994). Farm harvest prices were used to aggregate the value of outputs. The inputs included to arrive at the input index are: human labor, bullock labor, seed, manure, fertilizers, pesticides, irrigation and depreciation. These inputs were aggregated using the factor shares with appropriate weights. Total output, total input, total factor productivity indices were calculated as follows.

Total output index (TOI) =

$$TOI_t / TOI\ t\text{-}1 = \pi_j \left(\frac{Qj_t}{Qj_{t-1}} \right)^{(Rj_t + Rj_{t-1})^{1/2}}$$

Total input index (TII_t)=
TOIt-1 and T

$$TII_t / TII\ t\text{-}1 = \pi_i \left(\frac{Xi_t}{Xi_{t-1}} \right)^{(Si_t + Si_{t-1})^{1/2}}$$

Total factor productivity index (TFPI)=

$$TFPI_t = \left(\frac{TOI_t}{TII_t} \right) X\ 100$$

Where,

R_{jt}	=	the share of output 'j' in total revenue
Q_{jt}	=	output 'j'
S_{it}	=	the share of input 'i' in total input cost
X_{it}	=	input 'i'

By specifying IIt-1 equal to 100 in the initial year, the above equations provide the total output, total input and total factor productivity indices for the specified period 't'.

The returns to research investment were assessed by computing the internal rate of return (IRR) using the TFP estimates. Changes in output, other than that generated by changes in inputs are induced by research, extension, human capital, infrastructure, price policy and climatic factors. In order to assess the determinants of TFP, the TFP index was regressed on crop research investment per hectare of area per year, which is a linear trend variable. The time series data on research investments were arrived by pooling the data from different categories of expenditure incurred for each crop. Estimation was undertaken using a fixed effects approach for the cross section and time series data set. Using the elasticity of TFP with respect to research investment, one can easily estimate the value of marginal product (additional product value) of research investment (R) as:

$$VMP\ (R) = b\ x\ (V/R)$$

Where,

R	=	the research investment
V	=	the value of the production associated with TFP
b	=	the TFP elasticity of research investment

Estimated in the TFP determinant equation above, the benefit stream generated under the assumption that the benefit of investment made in research period (t-1) will start

generating benefits after years of lag at an increasing rate in the beginning, remain constant for a period of time and thereafter declines following the typical inverted 'V' shape curve. A rupee invested in year (t-1) will generate a benefit equal to 0.1 VMP in year (t+1) and so on. The rate of return to investment was obtained by calculating the internal rate of return (IRR) using the discounted cash flow measure as detailed below:

$$\text{Research contribution/incremental production for year i} = \frac{\text{TFPi X Current year production}}{100} - \text{Base year production}$$

$$\text{Internal Rate of Return (IRR)} = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} = 0$$

Where,

B_t = Benefit in year't'

C_t = Cost in year't'

r = Internal rate of return and is considered as the marginal rate of return to public research investment.

3. Results and discussion

3.1 Trend in agricultural research investment in Karnataka

There has been a steady increase in the total research investment made in agriculture in Karnataka, which increased, from Rs 3.39 million in 1970-71 to Rs 90.30 in 1994-95 (table 1). The comparison of research investment across crops indicate that in respect of rice, ragi, and redgram the investment is almost on par with the proportion of area under these crops (table 2). The research investment on cotton and sugarcane is relatively higher compared to their area share. Growth in research investment in nominal terms has shown a marginal rise but has stagnated around 7 percent when assessed in real terms. Crop wise analysis indicated highest growth rate for redgram (15.1 percent per annum) and lowest for cotton (2.7 percent). Among the staple food crops, ragi recorded

high growth in terms of research investment at 7.5 percent per annum as compared to sorghum (4.2 %) and rice (5.2 %)

3.2 Impact of research investment on technology development

The two SAUs in Karnataka have developed and released 90 crop varieties in eight major field crops considered for the analysis during the period 1970-71 to 1994-95 as detailed in Table 3. Of these, cereals - rice, ragi and sorghum together accounted for 63 per cent of total varieties developed and released. During the first period (1970-71 to 1979-80), 49 varieties were released of which cereals accounted for 57 per cent. During the first period no variety was released in case of red gram and very few varieties were released in case of groundnut, sunflower and sugarcane. During the third period, a total of 10 varieties were released; of which rice accounted for five, sorghum and ragi two each. In addition to release of crop varieties, the focus of research has been to evolve appropriate location specific production technologies in order to realize the full potential of the crop in terms of productivity. During the period of analysis (1970-71 to 1994-95) 3437 non-varietal technologies pertaining to nine major disciplines have been released (table 3). Of these, 1144 have been released during the first period, 1413 technologies during the second period and 880 during the third period. In all the three periods, food grains comprising of rice, sorghum, ragi and red gram accounted for the major share (63 percent) of technologies released followed by commercial crops. This is understandable since the state and the nation as a whole had placed thrust on food security and thereby increasing food grain production through improved technologies received higher attention. In both the SAUs, 9 major disciplines were associated in evolving 3437 technologies other than crop varieties in 8 major field crops of the state. (table 4). Of them, the crop improvement program carried out by the disciplines of agronomy, genetics

and plant breeding and seed technology together accounted for 62 per cent of the technologies released. The crop protection program involving disciplines of entomology and plant pathology accounted for 17 per cent with similar emphasis in crop physiology and soil science.

The agricultural research investment had considerable impact on the release of crop varieties and other technologies, which led to improvement in productivity of the crops in the state during the period of analysis. In all the three periods, food grains comprising of rice, sorghum, ragi and red gram accounted for the major share of technologies released followed by commercial crops. The pace of development and release of crop varieties was relatively higher in the seventies which declined considerably in the eighties and more so in the nineties. There was a reversal pattern in the release of technologies other than the varieties, which were lower in number in the seventies and eighties as compared to nineties particularly in cereals. This is attributed to the fact that as the cultivation of improved varieties increased due to higher adoption, new problems in crop management relating to soil, pests and diseases emerged requiring development of non-varietal technologies to tackle these problems

3.2 Growth in total factor productivity and rate of return on research investment

The increase in productivity mainly attributable to the research effort has been quantified through the growth in total factor productivity index. This analysis was extended to the total area under the crops to obtain the gross benefit of the research endeavor. The analysis was carried out for three sub-periods viz., pre-stagnation period of productivity (1981-82 to 1985-86) stagnation period of productivity (1986-87 to 1990-91) and post-stagnation period of productivity (1991-92 to 1994-95). These three sub periods were identified based on the Report of the Expert Committee, Government of Karnataka (1993) on Stagnation of Agricultural Productivity in Karnataka during1980s.

Total factor productivity for eight major field crops in Karnataka was calculated for the above three periods and the results are presented in Table 5. During the pre-stagnation period, TFP growth was over one per cent per annum in case of ragi, rice and cotton; around one per cent per annum in case of sorghum and sugarcane and much lower in case of sunflower, groundnut and red gram. During the stagnation period, TFP growth was higher at 1.4 per cent per annum in case of sugarcane and 1.3 percent for rice and just over one per cent in case of cotton, sorghum, and sunflower. The TFP growth was as low as 0.6 to 0.8 percent per annum in case of the other crops viz., groundnut, ragi and red gram crops in the state. During the post-stagnation period, highest TFP growth rate of 1.3 per cent per annum was witnessed in case of sugarcane and rice. The TFP growth was one per cent per annum in sorghum crop and below one percent (ranged between 0.4 and 0.6 per cent per annum) in rest of the crops viz., ragi, red gram, groundnut, sunflower and cotton. This indicates that TFP growth declined perceptibly during post-stagnation period in the state. The TFP growth was around one per cent during the three periods in case of rice, sorghum, cotton and sugarcane, but less than one per cent in case of red gram, groundnut, ragi and sunflower in the state as a whole. The decline in the TFP as well as low growth in TFP in different crops in different periods is explained by the fact that there is no commensurate increase in productivity, particularly in case of red gram and sunflower. During the same period, the area under the crops has increased, barring the marginal decline in case of ragi and sorghum. Also, there has been an increase in the use of purchased inputs like fertilizers and hired labor, which has resulted in increase in cost of cultivation even under rainfed conditions. However, the increase in productivity in most of the crops is not in tune with the proportionate increase in cost resulting in lowering of TFP.

The rate of return (IRR) to research investment worked out for individual crops indicates that it was the highest in case of rice (251%) followed by sugarcane (59.82%), ragi (16.79%), cotton (14.68%) and sorghum (11.03%). The returns were negative in respect of red gram, groundnut and sunflower. It is clearly borne from the analysis that the internal rate of return was high for the crops that received higher research investments. For example, Rice received a very high share of research investment, also recorded a very high internal rate of return. If the present declining trend in TFP observed in most crops is not arrested, the rate of return to research investment in future will be much lower. This implies that there is a need for achieving higher yield levels in case of crops with low productivity levels such as red gram, groundnut and sunflower by targeting the research investments for developing new technologies while maintaining current trend for cereals and sugarcane.

4. Conclusions

This paper presents the impact of research investment in terms of technology development and rate of return based on 25 years data relating to eight major field crops in Karnataka state located in peninsular India. The results show that agricultural research investment had considerable impact on release of crop varieties and other technologies. Food grains comprising of rice, sorghum, ragi and red gram accounted for a major share of technologies released followed by commercial crops. The thrust on food grains is understandable since the state and the nation, as a whole had accorded priority in achieving food security. The rate of return to agricultural research estimated using the total factor productivity approach shows high rate of return in case of rice and sugarcane, moderate for finger millet, cotton and sorghum, negative in red gram, groundnut and sunflower. The growth in TFP was higher in the crops, which attracted higher research investments, in turn attributed to growth in yield due to continuous up gradation of

technologies. The state has achieved self-sufficiency in food grains but to meet the nutritional needs, it is imperative that the investments in pulses and oil seeds need to be augmented while continuing the present trend for cereals and sugarcane.

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Table 1. Trend in total agricultural research investment in Karnataka
(Million Rs at current prices)

Year	Crops								Total
	Rice	Sorghum	Ragi	Red gram	Ground nut	Safflower	Cotton	Sugar cane	
1970-71	0.83	0.83	0.23	0.01	0.13	0.10	0.85	0.41	3.39
1975-76	1.58	1.67	0.73	0.25	0.31	0.43	1.54	1.05	7.53
1980-81	2.56	2.72	1.10	0.54	0.88	0.88	2.25	1.64	12.57
1985-86	6.73	4.35	2.36	1.17	1.61	1.97	3.75	2.45	24.39
1990-91	11.03	9.72	5.64	2.13	6.70	6.70	6.56	6.22	52.20
1994-95	18.22	17.52	10.07	3.59	7.59	9.13	12.70	11.48	90.30

Source: Annual reports and other documents of UAS, Bangalore and UAS, Dharwad.

Table 2. Crop wise annual compound growth in of research investment in Karnataka (1970-71 to 1994-95)

Crops	Proportion of area under crop (%)	Proportion of research investment (%)	Productivity growth rate (%)	Growth rate (percent) (1970-71 to 1985-86)		(1986-87 to 1994-95)		(1970-71 to 1994-95)	
				Real	Nominal	Real	Nominal	Real	Nominal
Rice	15.5	19.7	1.1	6.2	15.6	5.1	14.8	5.2	14.1
Sorghum	26.5	19.9	0.2	4.1	13.3	14.6	25.2	4.2	12.9
Ragi	12.8	11.4	1.2	7.2	16.6	8.6	18.7	7.5	16.5
Red gram	5.2	4.2	2.4	27.7	39.0	5.8	15.6	15.1	24.7
Groundnut	15.5	7.6	1.3	9.8	19.5	11.4	21.7	8.8	17.9
Sunflower	13.5	10.3	3.8	11.5	21.4	9.3	19.4	10.4	19.7
Cotton	7.4	14.2	4.9	2.0	11.0	10.9	21.2	2.7	11.3
Sugarcane	3.6	12.7	0.4	4.9	14.2	12.3	22.7	5.1	14.0
Total	100.00	100.00	1.9	7.0	16.4	6.9	16.9	6.9	14.7

Source: Annual reports and other documents of UAS, Bangalore and UAS, Dharwad

Table 3. Number of technologies (varieties and non varieties) developed and released in major field crops by the state agricultural universities in Karnataka (1970-71 to 1994-95)

Crops	Period-I (1970-71 to 1979-80)	Period-II (1980-81 to 1989-90)	Period-III (1990-91 to 1994-95)	Overall period (1970-71 to 1994-95)	Per cent to total
a) Number of varieties developed and released					
Rice	14	9	5	28	31.11
Sorghum	4	6	2	12	13.33
Ragi	10	5	2	17	18.89
Red gram	-	1	-	1	1.11
Groundnut	4	1	-	5	5.56
Sunflower	2	-	1	3	3.33
Cotton	10	6	-	16	17.78
Sugarcane	5	3	-	8	8.89
Total	49	31	10	90	100
b) Number of non varietal technologies developed and released					
Rice	255	329	193	777	22.60
Sorghum	196	219	121	536	15.60
Ragi	164	161	91	416	12.51
Red gram	66	155	108	329	12.19
Groundnut	144	164	122	430	12.10
Sunflower	97	154	97	348	10.13
Cotton	161	155	103	419	9.57
Sugarcane	61	76	45	182	5.30
Total	1144	1413	880	3437	100

Source: Annual reports and other documents of UAS, Bangalore and UAS, Dharwad

Table 4. Discipline wise number of technologies, other than crop varieties developed and released in major field crops by the SAUs of Karnataka (1970-71 to 1994-95)

Discipline	Rice	Sorghum	Ragi	Red gram	Ground nut	Sun flower	Cotton	Sugar Cane	Total	%
Genetics and Plant Breeding	29	73	125	70	99	81	93	52	622	19.22
Crop Physiology	38	42	40	11	33	44	35	-	243	7.51
Entomology	82	72	10	40	45	10	55	11	325	10.04
Plant Pathology	59	46	56	21	37	25	25	7	276	8.53
Agricultural Microbiology	25	9	13	36	20	6	10	5	124	3.83
Agricultural Engineering	20	15	11	3	21	12	4	-	86	2.66
Soil Science and Agricultural Chemistry	69	57	27	15	37	23	22	2	252	7.78
Seed Technology	21	27	5	5	11	18	6	-	93	2.87
Total	577	536	416	329	430	348	419	182	3237	100

Source: Annual reports and other documents of UAS, Bangalore and UAS, Dharwad

Table 5.Total factor productivity growth and internal rate of return for major crops in Karnataka (1980-81 to 1994-95)

Crop	Period	Average total area (m. ha)	Average total production (m. tons)	Average productivity (kg/ ha)	Average total research expenditure (million Rs.)	Average research expenditure (Rs/ ha)	Additional Value (million Rs.)	Average TFP Growth	IRR (%)
	Pre-stagnation	1.16	2.23	2035	5.15	4.47	1.80	101.54	
Rice	Stagnation	1.16	2.54	2292	8.12	6.96	15.77	132.10	251.00
	Post-stagnation	1.32	4.20	3354	14.74	11.20	23.22	133.35	
	Pre-stagnation	2.26	1.63	764	4.39	1.94	3.59	98.51	
Sorghum	Stagnation	2.34	1.59	714	6.51	2.88	6.82	109.40	11.03
	Post-stagnation	2.17	1.78	864	15.25	7.06	5.46	101.21	
	Pre-stagnation	1.10	1.23	1176	1.94	1.77	6.63	125.91	
Ragi	Stagnation	1.13	1.20	1112	4.22	3.76	4.98	74.42	16.79
	Post-stagnation	1.03	1.48	1517	8.68	8.49	15.83	44.06	
	Pre-stagnation	0.39	0.18	473	0.91	2.32	0.77	88.81	
Red gram	Stagnation	0.47	0.18	409	1.41	3.71	1.39	80.73	Negative
	Post-stagnation	0.41	0.14	385	2.51	8.41	4.45	56.89	
	Pre-stagnation	0.92	0.70	798	1.21	1.32	3.31	81.39	
Groundnut	Stagnation	1.16	0.87	795	2.65	2.26	9.57	61.82	Negative
	Post-stagnation	1.27	1.10	909	5.67	4.52	19.78	52.15	
	Pre-stagnation	0.29	0.14	498	1.46	5.96	-	79.23	
Sunflower	Stagnation	0.72	0.28	414	4.14	6.17	0.63	108.94	Negative
	Post-stagnation	1.15	0.45	413	7.47	6.94	0.54	59.10	
	Pre-stagnation	0.88	0.65	134	3.20	3.80	4.91	110.88	
Cotton	Stagnation	0.57	0.69	219	4.62	8.02	8.86	118.62	14.68
	Post-stagnation	0.61	0.85	252	10.84	17.86	25.65	48.70	
	Pre-stagnation	0.18	13.72	82	2.40	13.65	31.90	97.47	
Sugarcane	Stagnation	0.23	18.55	84	4.07	17.07	172.80	141.87	59.82
	Post-stagnation	0.30	26.54	93	9.73	32.73	224.33	134.48	

Note: Pre -stagnation period (1981-82 to 1985-86); stagnation period (1986-87 to 1990-91); Post-stagnation period (1991-92 to 1994-95);
Productivity = tons per hectare in case of Sugarcane.
Source: Annual reports and other documents of UAS, Bangalore and UAS, Dharwad