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Total factor productivity growth and returns to investment in pearl millet (Bajra) crop research in Western Maharashtra

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Abstract
The attempt has been made to study the total factor productivity and returns to investment in pearl millet crop in Western Maharashtra. For the study, the time series data on cost of cultivation of pearl millet was collected from official records of state cost of cultivation scheme to fulfill the objectives. The output growth was highest (2.18) in second period in year 2004. The average output index for twenty one years was 1.53. In case of input index, there were heavy fluctuations, decreasing from 1.02in 1993-94 to 0.59in 2013-14.The average input index of pearl millet for twenty one years was 0.76.The Total Factor Productivity index of pearl millet grew at 3.88 per cent per annum. Research investment (0.27***), rainfall (0.04**), rural literacy (1.50**), N to P ratio (0.49*) and net irrigated area (0.69*) has significantly contributed to TFP growth in pearl millet. The additional investment of one rupee in pearl millet research generated additional income of ₹ 16.03, indicating substantial rate of returns to investment with internal rate of return of 34.76 on research in pearl millet in western Maharashtra. The empirical findings showed that the total factor productivity in pearl millet crop registered a substantial growth with profitable returns in Western Maharashtra. Hence the Government should allocate substantial funds to public research in pearl millet for productivity improvement and food security to masses.

Keywords: Total factor productivity, pearl millet, estimated value of marginal product, internal rate of return

Introduction
Pearl millet (*bajra*) is one of the three major millet crops grown in India. Millets are small seeded grasses which grow in a wide range of topographies and climates.
The area, production and productivity of pearl milletin Maharashtra during 1960-61 was 1635(‘000’ha), 489(‘000’ MT) and 299(Kg/ha) while in 2016-17 it was 837(‘000’ha), 800(‘000’ MT) and 955 (Kg/ha). Per cent change in area, production and productivity of pearl millet showed negative growth in area by 48.80, while positive growth was reported in production and productivity by 63.59 per cent 219.39 per cent, respectively.
Area under pearl millet in Maharashtra was 805 (‘000’ ha), while in India it was 7475 (‘000’ ha). In comparison with India area under pearl millet in Maharashtra was 10.8 per cent. (Area under principal crops, average for years 2012-13 to 2014-15, Economic Survey of Maharashtra, 2017-18).
A total 209 new varieties/hybrids tolerant to various biotic and abiotic stresses with enhanced quality have been developed for Cereals, Pulses, Oilseeds, Commercial and Forage crops.117 high yielding varieties/ hybrids of cereals comprising 65 of rice, 14 of wheat, 24 of maize, 5 of finger millet, 3 of pearl millet, 1 each of sorghum, barley, foxtail millet, Kodo millet, little millet and proso millet were released for cultivation in different agro-ecologies of the country during 2017. (Economic Survey, 2017-18).
TFP measures account for the use of a number of inputs in the production process and are therefore more suitable for performance measurement and comparison across firms and for a given firm over time (Coelli *et al*., 2005) [4].
Among these definitions, the later authors mention that the first one is the most commonly used. As per definition, TFP growth incorporates all the residual factors after accounting for input growth, and has also been hailed as an “index of ignorance” (Abramovitz, 1956).

The final aim of this research will be to provide suggestions for future investments in research for development of this sector
Total factor productivity concept implies an index of total output per unit of total factor inputs. There are two concepts of productivity: partial productivity and total factor productivity. Partial productivity measures the contribution of one factor (say labour or capital) to output

growth keeping the other factors constant. As such we have the concepts of labour productivity, capital productivity, which estimate the efficiency of resource use. But, partial productivity does not truly reflect whether it (productivity growth) is because of more use of inputs or improvement in the efficiency of their use or technology improvement. Further, it also ignores time, secondary products, inputs other than land, labour and capital and externalities, all of which should be included in a sustainability measure (Barnell *et al*., 1995). The best measure is one that compares output with the combined use of all resources" (cited in Chandel, 2007) [3].

Output Growth = Technical efficiency change + Technology change + Input growth

Further, following Kalirajan and Shand (2001) [7] the TPF growth consists of two components: technical efficiency change and technological change.

Pearl millet is an important food crop grown in India and well adapted to drought prone areas, low soil fertility, and high temperature situations. India is the largest producer of pearl millet. The low yield of pearl millet in India is primarily due to prolonged dry spells during its growing season.

Materials and Methods

Methodologies of measuring (TFP) total factor productivity

There are three main approaches for estimating the TFP, namely the Production Function Approach (PFA), Growth Accounting Approach (GAA) and the most recent one being the Non-parametric Approach. Growth Accounting Approach (GAA) was used to measure the TFPG.

Growth accounting approach (GAA)

Solow (1957) was the first to propose a growth accounting framework and then Denison (1967 and 1985) refined the approach. In this approach, TFP is measured as a residual factor, which attributes to that part of growth in the output that is not accounted for by the growth in the basic factor inputs. This approach approximates the technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices (Christensen, 1975). The TFP index is measured as the ration of the index of net output and the index of total factor inputs. The index of total factor inputs is derived as weighted average of indices of labour inputs, capital inputs and land inputs with relative income shares of the three factors as respective weights. The key feature of the GAA is separation of change in production on account of changes in the quantities of factors of production from residual influences, which include technological progress, learning by doing, etc.

Total factor productivity concept implies an index of total output per unit of total factor inputs. TFP growth measures the increase in output i.e. not accounted for by the increase in total inputs. Thus total factor productivity index that measure the growth in net output i.e. not accounted for by the growth in basic factor input such as land, labour, capital. It is superior to partial approach as it is composite measure of productivity, which related output to all inputs, simultaneously. (Kumar, 1994) [8].

For the productivity measurement over a long period of time, chaining indexes for successive time periods is preferable. With chain-linking, an index is calculated for two successive periods, t and t-1, over the whole period 0 to T (sample from time t=0 tot=T) and the separate indexes are then multiplied together.

The output index, input index and TFP index are constructed separately for Pearl millet crop. To construct output index the time series data (1993-94 to 2013-14) on main product, by product and prices used, where as to construct input index, the time series data with regard to inputs like seeds, manure, chemical fertilizer (NPK), human labour, bullock labour, machine labour, plant protection chemicals, irrigation and prices of inputs are used. Finally the TFP index is computed by dividing output index by input index. We have specified that the index is equal to 1.00 in a particular year i.e. here we considered 1993-94 as base year and TFP chain index constructed as it provides annual changes in productivity over a period of time.

The Chain-linking index takes into account the changes in relative values/costs throughout the period of study. This procedure has the advantage that no single period plays a dominant role in determining the share weights and biases are likely to be reduced. The TFP indices computed using the software TFPIP version 1.0, which developed by Tim Coelli, Centre for Efficiency and Productivity Analysis, University of Queensland, Australia. Time series data on Costs and returns of Pearl millet crop for the years 1993-94 to 2013-14 collected and compiled from the cost of cultivation scheme, Department of Agricultural Economics, MPKV, Rahuri. All the data was calculated in real terms by deflating the time series data on investment using the consumer price index with 2011-12 as a base year.

TFP indices computed as follows

Total output index

$(TOI) = TOI_t/TOI_{t-1}=\prod_j(Q_{jt}/Q_{jt-1})^{(Rjt+Rjt-1)1/2}$

Total input index:

$(TII) = TII_t/TII_{t-1}=\prod_j(Xjt/Xjt-1)^{(Sjt+Sjt-1)1/2}$

Total factor productivity index (TFPI) of t^{th} year is 100 times the ratio of TOI, to the TII and is given by,

$TFPI_t= (TOI_t/TII_t) \times 100$

Input price index is given by,

$$\frac{IPI_t}{IPI_{t-1}} = \prod_j \left[\frac{P_{it}}{P_{it-1}} \right]^{(S_{jt}+S_{jt-1})\frac{1}{2}}$$

Where

Rjt = Share of jth output in total revenue
Qjt = Output 'j'
Sjt = Share of ithinput in total input cost
Xit = input 'i'
Pit = Price of ith in period 't'

By specifying TOI t-1, TIIt-1 and IPIt-1 equal to 100 in the initial year, the above equation provides the total output, total input, total factor productivity and input price indices for the specified period 't'.

Chain-linking index takes into account the changes in relative values/costs throughout the period of study. This procedure has the advantage that no single period plays a dominant role in determining the share weights and biases are likely to be

reduced. The above equations provide the indices of total output, total input, and TFP for the specified year 't'.

The TFP is influenced by research, extension, human capital, intensity of cultivation, application of plant nutrients, infrastructural development and climatic factors. In order to assess the sources of TFP, the TFP index was regressed against the variables *viz*., research investment, rural literacy, rainfall, road density, N to P ratio and net irrigated area. The model specified in log-linear form as:

$$\text{Ln (TFP)} = a + b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6$$

Where

Y	=	Total factor productivity index (TFP)
a	=	Intercept/Constant term
X1	=	Research (lakh rupees)
X2	=	Rural literacy (%)
X3	=	Average rainfall (mm/year)
X4	=	Road density (km)
X5	=	N to P ratio
X6	=	Net irrigated area (%)
T	=	Time variable (years 1, 2, 3….n)
u	=	Error term

A common feature of the TFP index number is that the empirical estimation of different TFP indexes is based on different weighting methods of inputs and outputs. In most empirical studies, the Divisia, Solow, and the Tornqvist indexes are frequently used. Among index number methods, Tornqvist-Theil Index, which is an approximation to Divisia Index, was used in this study to construct aggregate output and aggregate input indexes. Explanation on theoretical properties and issues in measurement of the productivity through the Tornqvist Index can be found in Diewert (1980) and Coelli *et al*. (2005) [4].

Compared to other methods for TFP calculation, the advantage of the Tornqvist index is related to its capacity to decompose TFP growth into outputs and inputs growth indexes. Moreover, the Tornqvist index also consider the inputs and outputs values (prices) which is not the case for other non-parametric indexes such as the Malmquist index.

Estimated value of marginal return

The time series data from the different years was used. Using the elasticity of TFP with respect to research and development investment, one can estimate the value of marginal product of research and development investment.

$$\text{EVMP(R)} = b*(V*\text{TFP share}/R)$$

Where

R	:	Research investment
b	:	TFP Elasticity of research investment
V	:	Value of production associated with TFP
EVMP	:	Estimated value of marginal product

Internal rate of return to pearl millet research and development

Internal rate of return also known as Marginal efficiency of capital 'or' Yield on the investment. In economic terms, the IRR "is the interest rate earned on the unrecovered balance over an investment's life so that the unrecovered balance at the end of that time is zero. 'IRR' is the discount rate at which the NPV (Net present worth) of an investment becomes zero. In other words discount rate which equates the present value of future cash flows of an investment with the initial investment. It is one of the several measures used for investment appraisal. Formula used for internal rate of return:

IRR = (Lower Discount Rate) + (Difference Between The Two Discount Rates)* (Present Worth of Cash Flow At The Lower Discount Rate/Absolute Difference Between The Present Worth of the Cash Flow At The Two Discount Rates)

Result and Discussion

I. Input, Output and TFP Indices of Pearl Millet

Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production. The output, input and TFP indices of pearl millet crop are presented in Table 1.

From the Table 1, it is observed that the TFP for pearl millet increased from 1.00 in 1993 to 2.28 in 2014. During the later decade mean of input has declined, while increased output and TFP mean (1.68 and 2.49) shows the increased outputs and TFP growth, the efficient measure of productivity. However increased mean of TFP may take longer gestation to reflect into increased significant growth rates of TFP depending upon the scale and speed of varietal adoption by wider geographic farmer population.

Table 1: Total Factor Productivity of pearl millet during 1993 to 2014

Sr.no.	Year	Input	Output	TFP
1	1993	1.00	1.00	1.00
2	1994	1.02	1.35	1.33
3	1995	0.90	1.11	1.22
4	1996	0.88	1.86	2.12
5	1997	0.86	1.24	1.44
6	1998	0.84	1.57	1.87
7	1999	0.82	1.37	1.67
8	2000	0.80	1.34	1.68
9	2001	0.77	1.42	1.85
10	2002	0.75	1.51	2.01
Period I	**Mean**	**0.86**	**1.38**	**1.62**
11	2003	0.72	1.38	1.92
12	2004	0.70	2.18	3.11
13	2005	0.76	1.78	2.36
14	2006	0.73	2.16	2.98
15	2007	0.65	1.73	2.64
16	2009	0.72	1.42	1.99
17	2010	0.66	1.18	1.78
18	2011	0.65	1.91	2.94
19	2012	0.64	1.82	2.84
20	2013	0.60	1.53	2.56
21	2014	0.59	1.35	2.28
Period II	Mean	0.67	1.68	2.49
Overall	Mean	0.76	1.53	2.08

The highest TFP index (3.11) was observed in 2004-05. The average TFP index for 21 years was 2.08. The output growth fell to1.11 in 1995 and highest in second period in year 2004.The average output index for twenty one years was 1.53. In the case of input index, there were heavy fluctuations, decreasing from 1.02 in 1993-94 to 0.59 in 2013-14.The average input index of pearl millet for twenty one years was 0.76.

Share of input and TFP in total output of pearl millet

The main aim to analyzed the share of input and TFP was to assess the contribution of input and TFP in total output of pearl millet. The share of input was calculated by dividing input index to output. After subtracting input share from 100 it gives TFP share. It is observed from the table, that the contribution of technology increased from the year 2004-05 onwards. It may be due to University has released three high yielding varieties *viz*., Shanti, Dhanshakti and Adishakti.

Table 2: Share of input and TFP in total output of pearl millet

Year	(%)		
	Input Share	TFP Share	Total
1993	100.00	0.00	100.00
1994	75.38	24.62	100.00
1995	81.72	18.28	100.00
1996	47.20	52.80	100.00
1997	69.68	30.32	100.00
1998	53.45	46.55	100.00
1999	59.87	40.13	100.00
2000	59.64	40.36	100.00
2001	54.00	46.00	100.00
2002	49.74	50.26	100.00
2003	52.15	47.85	100.00
2004	32.18	67.82	100.00
2005	42.35	57.65	100.00
2006	33.55	66.45	100.00
2007	37.83	62.17	100.00
2009	50.36	49.64	100.00
2010	56.12	43.88	100.00
2011	33.97	66.03	100.00
2012	35.17	64.83	100.00
2013	39.00	61.00	100.00
2014	43.80	56.20	100.00

In order to assess productivity performance of TFP of pearl millet in western Maharashtra, the compound growth rates of output, input and TFP indices were estimated for 21 years *i.e.* from 1993-94 to 2013-14 and for two sub-periods, *viz*., period I (1993-94 to 2002-03) and period II (2003-04 to 2013-14).

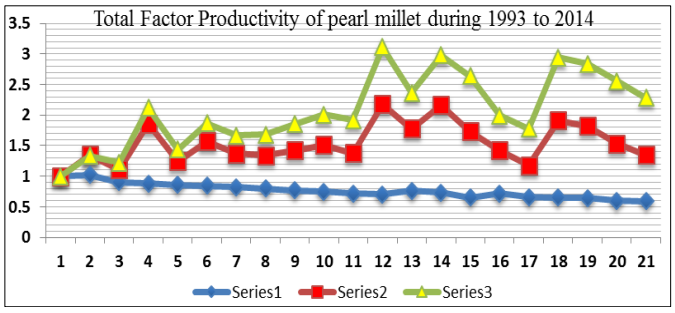

Fig 1: Growth of Total Factor Productivity of pearl millet

Compound growth rates of input, output and TFP Index of pearl millet

A perusal of Table 3 reveals that over the entire period of study (1993-94 to 2013-14), TFP grew at the rate of 3.88 per cent per annum. During the same period, output index increased by 1.39 per cent per annum and input index decreased by 2.4 per cent per annum. In sub periods, the results are also more revealing. The input index declined at the rate of 3.23 per cent per annum during period I, while output index increased at the rate of 2.66 per cent per annum.

The TFP index increased at the rate of 6.08 per cent during period I. During, period II, the input index continued to decline at the rate of 2.14 per cent per annum, whereas output index decreased at the rate of 1.93 per cent per annum. The TFP index witnessed an impressive growth of 6.08 per cent per annum during period I. Non-significant TFP growth (0.22) in period II might be a reflection of longer gestation in varietal adoption by farmers on wider scale, saturation of direct input-output productivity, initiating thereon the increased contribution of TFP in productivity improvement.

The private seed companies as well as Pearl millet Research Station, Dhule, MPKV, Rahuri has released a number of new hybrid varieties to increase productivity which are high yielding and tolerant to drought. The university released varieties *viz*., Shraddha (Rhrbh 8609) and Saburi (Rhrbh 8924) varieties of pearl millet were the prominent and highly preferred by the pearl millet cultivators over a period of time. Hence, agricultural universities played a vital role in growth of total factor productivity of pearl millet crop.

Table 3: Compound growth rates of input, output and TFP of pearl millet

Period	CGR (%)		
	Input	Output	TFP
Period I(1993-2002)	-3.23***	2.66	6.08**
Period II(2003-2013)	-2.14***	-1.93	0.22
Overall Period (1993-2013)	-2.4***	1.39*	3.88***

*,** and *** indicate significance at 10,5 and 1 per cent level

Sources of total factor productivity (TFP) growth of pearl millet

The results of TFP analysis are presented in Table 4. Estimates of regression coefficients which measure the effect of various sources of TFP were used to compute elasticity of TFP with respect to research stock and to assess the impact of research. The results indicate that research investment (0.27), rainfall (0.04), rural literacy (1.50), N to P ratio (0.49) and net irrigated area (0.68) has significantly contributed to TFP growth in pearl millet.

The findings corroborated with the findings of [5]. The rainfall is a crucial determinant of TFP in pearl millet. The ratio of nitrogen to phosphorus nutrients (0.49) was taken as proxy for the balanced use of fertilizer. The road density was considered as a proxy for infrastructure. The coefficient of this variable was positive and significant. The estimated R^2value was 0.85 indicating that 85 percent of variation in TFP explained by the factors included in the model and F value was statistically significant at 12.42 indicating a good fit to the model.

Table 4: Total factor productivity (TFP) analysis of pearl millet

Variables	Coefficients
Intercept	-0.79 (3.31)
Research (₹)	0.27*** (0.06)
Rural literacy (%)	1.50** (0.59)
Rainfall(mm/year)	0.044** (0.02)
Road Density(km)	-0.87 (1.05)
N to P ratio	0.49* (0.26)
Net irrigated area (%)	0.69* (0.56)
R^2	0.85
F value	12.42**
N (No. of observations)	21

*,** and *** indicate significance at 10,5 and 1 % level

Figures in parenthesis are standard errors

Estimated value of marginal product of research investment and internal rate of return to research in Pearl millet in Maharashtra: 1993-94 to 2013-14

The estimated value of marginal product of research investment on pearl millet and internal rate of return is given

in Table 5. Using TFP decomposition results, the technical coefficient of research stock (Restock) representing production elasticity, was multiplied by growth rate of research stock to determine its contribution in the growth of TFP index. Thus, share of TFP growth explained by research is equal to product of growth rate and value of technical coefficient of research stock in percentage terms. The research-induced value of production (V) could be estimated when value of percentage share of research in TFP growth multiplied with average value of production (product of production and price). The 'V' is used to derive estimated value of marginal product (EVMP) of research, where EVMPr = br (V/R). br is elasticity of research stock and R is average value of research stock (B.S. Chandel, 2007) [3].

To estimate the marginal value product the regression coefficients should be positive and statistically significant. Thus, in this study, the regression coefficient of research expenditure of pearl millet was found significant.

The estimated value of marginal product by considering the regression coefficient of research investment is 16.03 (Table 5). It indicates that an additional income of one rupee in pearl millet research generated additional income of ₹ 16.03.The inverse of TFP elasticity with respect to research gives flexibility to research expenditure. The estimated value was 3.85 which mean that to achieve one percent increase in TFP, the investments in research need to be increased by 3.85 per cent for pearl millet in western Maharashtra

The Internal Rate of Return (IRR) is the rate of an investment which we equate the present value of benefits and costs. IRR was estimated as below:

IRR = (Lower Discount Rate) + (difference between the two discount rates)*(present worth of cash flow at the lower discount rate/absolute difference between the present worth of the cash flow at the two discount rates).

The marginal internal rate of return for pearl millet crop during the period 1993-94 to 2013-14 was 34.76 per cent. It means that every rupee invested in pearl millet research yielded return of 34.76 per cent annually which implies that if we invest hundred rupees in pearl millet research we will get 134.76 rupees in return and results clearly implied that investment in pearl millet research is highly profitable.

Table 5: Estimated value of marginal product of research investment and internal rate of return to research in pearl millet in western Maharashtra (1993-94 to 2013-14)

Period	EVMP (₹)	IRR (%)	Research Expenditure Flexibility (%)
1993-94 to 2013-14	16.03	34.76	3.85

Conclusions

1. Index
2. Share
3. Factors
4. EVMP
5. IRR
6. The total factor productivity in pearl millet crop registered a substantial growth in Western Maharashtra
7. An additional income of one rupee in pearl millet research generated additional income of ₹ 16.03.
8. The internal rate of return for pearl millet crop during the period 1993-94 to 2013-14 estimated to be 34.76 per cent. Research expenditure flexibility estimated to be 3.85 which mean that to achieve one per cent increase in TFP, the investments in research need to be increased by 3.85 per cent for pearl millet in Western Maharashtra.
9. Public research recorded to bevital and significant source of TFP growth in staple food crop like pearl millet. However increased mean of TFP may take longer gestation to reflect into increased significant growth rates of TFP depending upon the scale and speed of varietal adoption by wider geographic farmer population.

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