Agricultural Economics Research Review
Vol. 29 (No.1) January-June 2016 pp 41-51
DOI: 10.5958/0974-0279.2016.00017.3

Total Factor Productivity Growth and Returns from Research Investment on Soybean in India

Purushottam Sharma* and B.U. Dupare

ICAR-Indian Institute of Soybean Research, Khandwa Road, Indore-452 001, Madhya Pradesh

Abstract

The study has estimated total factor productivity growth of soybean and returns to research investment on the crop in India. For study, time-series data on cost of cultivation of soybean in major states were collected from the reports of Commission on Agricultural Costs and Prices for the period 1980-81 to 2011-12. The Tornqvist-Theil index has been used to compute input, output and TFP indices and compound annual growth rates on triennium average datasets were estimated. The regression analysis was carried out to identify the sources of TFP growth. The study has indicated moderate growth of TFP in soybean (1.2% per year) with 10.5 per cent share in output growth. The decade-wise analysis has revealed that TFP growth and the share of TFP in growth of output is increasing in the recent decade. The research investment and irrigation have turned out to be the significant variables affecting TFP positively. Although, marginal value output of research has been found less than one, the internal rate of return for research investment is increasing in recent decades, suggesting enhancement in research allocation and irrigation infrastructure for productivity improvement and edible oil security in the country.

Key words: Total factor productivity, Tornqvist-Theil index, returns to research investment, soybean, India

JEL Classification: Q16, Q13, D24

Introduction

Productivity growth in agriculture is of paramount importance as higher yields are associated with declining rural poverty, suggesting that impact of growth in agricultural production on poverty remains high (Himanshu *et al.,* 2010). The agricultural productivity continues to be an important driver of rural poverty reduction, especially it helps rise agricultural wages. The slow agricultural growth could be due to reduced demand for food, slow technological change in agriculture, lack of employment opportunities for part time smallholders, limited technology adoption by full-time farmers (Binswanger-Mkhize, 2012). In India, the productivity of oilseed crops is low because the crops are largely grown on marginal lands with minimal use of inputs.

The oilseed crops play an important role in agricultural development of India, sharing 14 per cent of the country's gross cropped area and accounting for about 3 per cent of the gross domestic product and nearly 6 per cent of the value of all agricultural products (ICAR-IIOR, 2015). Soybean, introduced for commercial cultivation in India in 1970-71, has established itself as a leading oilseed crop in the rainfed agro-ecosystem of central and peninsular India (Bhatia

* Author for correspondence
Email: purushottamji@gmail.com

§ The paper is drawn from the larger institutional research study on 'Socio-Economic Analysis of Growth in Soybean Crop Productivity and Impact of Research' conducted by authors at ICAR-Indian Institute of Soybean Research, Indore, Madhya Pradesh. Authors would like to thank anonymous referees of the journal for providing valuable comments on the earlier version of the paper.

et al., 2008). The crop has gained tremendous strides in terms of growth in area and production in the country. The area under soybean has increased at an annual growth rate of 13.74 per cent and production by 15.1 per cent during 1970-71 to 2013-14 (based on five-year moving average data), whereas the growth in productivity has been merely at 1.19 per cent only. The government policies and research support from National Agricultural Research System (NARS) paved the way for more than trebling the average productivity of soybean in the country, from 436 kg/ha in 1970-71 to 1353 kg/ha in 2012-13 (GoI, 2015b).

The soybean is the largest oilseed crop in the country sharing 38 per cent of total oilseeds crop area and 42 per cent of total oilseeds production during TE 2012-13, contributing about 28 per cent to the total vegetable oils and two-thirds of the oil meals supplies during this period. However, the country has been meeting its edible oil demand by importing more than 50 per cent of its requirement. The per capita consumption of vegetable oil is increasing very rapidly in the country due to increasing population and improving economic status of the consumers. The per capita availability for edible oils has increased to about 16.8 kg/year compared to 3.2 kg/year in 1960-61 (GoI, 2015a). The consumption of edible oils reached 21.06 million tonnes in 2013-14 (Nov- Oct) and is likely to increase further with changing dietary habits, enhancing income levels and increasing population (Sharma and Bhatia, 2015). The per capita consumption of edible oils increased faster (5.65 %) than the production of oilseeds (4.55 %) during the previous decade, leading to a higher growth rate in imports of edible oils (7 %) (Reddy and Bantalian, 2012). It is, therefore, necessary to utilize the domestic resources fully to maximize production and ensure edible oil security for the country.

The change in soybean production in the country was mainly contributed by the area expansion and the yield expansion contributed less than one-fifth share. The area expansion in oilseeds was facilitated by the encouraging results achieved on introducing new varieties/crops and reducing yield variability (Chandel and Rao, 2003). But now the chances of area expansion are limited, and hence, yield increase is the best alternative to boost supply of edible oils and improve farmers' income. Under this backdrop, the present study was undertaken with the following objectives: (i) to analyse the total factor productivity growth of soybean in India and its determining factors, and (ii) to estimate the returns from research investment in soybean in the country.

Data and Methodology

Time-series data on item-wise cost of cultivation, use of inputs and their prices for soybean grown in major states of India were collected for the period 1980-81 to 2011-12 from the reports of '*Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops*', Commission on Agricultural Costs and Prices, Ministry of Agriculture, Government of India. Time-series data on public funding on soybean research were collected from the ICAR-Budget Books, annual reports of ICAR-Directorate of Soybean Research and All India Coordinated Research Project on Soybean. Also, time-series data on infrastructural variables (market density), *kharif*-rainfall, price parity, and proportion of irrigated area were collected from various publications of central and state governments of soybean-producing states.

The total factor productivity measures the growth in total output which is not accounted for by the increase in total inputs. The TFP index is computed as the ratio of index of aggregate output (output index) to the index of aggregate inputs (input index). Therefore, growth of TFP index is the growth of output index less the growth of input index.

To calculate input and output index, Tornqvist-Theil index was used for data on output and inputs of soybean crop. The Tornqvist index of TFP is the frequently used index to compute TFP growth. It does not require the assumption of neutral technical change and allows for variable elasticity of substitution (Evanson *et al.*, 1999). Another advantage of this index is that it accounts for the change in quality of inputs because current factor prices are used in constructing the weights. The quality improvements in inputs are incorporated to the extent that these are reflected in higher wages and rental value (Capalbo and Vo, 1988). The output and input indexes were calculated for the soybean crop in major states and at all-India level using TFPIP program developed by Coelli *et al.* (1998; 2005).

The Tornquist-Theil index is a superlative index, which is exact for the linear homogeneous translog production function (Diewart, 1976). The TFP growth is measured from the Tornquist-Theil TFP index (Desai, 1994). The logarithmic form of the Tornquist-Theil TFP index is given by Equation (1):

$$I_t = I_{t-1} \Pi^{n(m)}_{j=1} (Q_{j,t}/ Q_{j,t-1})^{1/2(Sj,t + Sj,t-1)} \quad \ldots(1)$$

where, $S_{j,t} = Q_{j,t}*P_{j,}t/ [Ó^{n(m)}_{j=1} Q_{j,t}*P_{j,t}]$

Here, I_t is the index value of output/input for the current year 't'; I_{t-1} is the index value of output/ input for the previous year 't-1'; $Q_{j,t}$ is the quantity of j^{th} output/ input for the year 't', when 'j' varies from 1 to 'n' for outputs and from 1 to 'm' for inputs used in the production of soybean; $Q_{j,t-1}$ is the quantity of j^{th} output/ input for the crop for the previous year 't-1'; $S_{j,t}$ is the share of j^{th} output value in total value of production (VOP) or j^{th} input in total cost; and $P_{j,t}$ is the current price of j^{th} output/ input.

The total factor productivity is calculated using index for input-use and output. If Q_{It} is the index for output in year 't' and X_{It} is the index for inputs for the same year, the total factor productivity (TFP) index is equal to Q_{It}/X_{It}. Thus, TFP index was computed as the ratio of an index of aggregate outputs to an index of aggregate inputs. Specifying the index equal to 100 in a particular year (1980-81 in the present study) and accumulating the measure based on Equation (1) provides the TFP index for soybean in India. The annual growth rates of triennium moving average data of output index and input index were calculated fitting the exponential trend equation. The growth rate of TFP was worked out by deducting growth rate of input index from the growth rate of output index.

Both grain and straw yields were included in output index of soybean. The quantity of straw yield was calculated from grain yield using harvest index as per Chandel (2003). The shares in total revenue estimated using farm harvest prices were applied as the weights to aggregate the outputs. Inputs included in input index were land, seed, fertilizers and manure, plant protection chemicals, human labour, animal labour, machine labour and irrigation. Inputs were aggregated using their shares in total cost of cultivation as weights. The total factor productivity of soybean for all India was worked out from area weighted average input costs and returns for different states including Madhya Pradesh, Maharashtra, Rajasthan, Chhatisgarh and Uttar Pradesh for available data.

Total Factor Productivity Decomposition

The total factor productivity is influenced by research, extension services, human capital, infrastructural development, price policy and weather (Chand *et al*., 2011). As an input to public investment decision, it is important to understand the relative importance of these productivity-enhancing factors in determining TFP growth. The sources of TFP growth were estimated and, based on these estimates, the relative TFP growth accounting and marginal rates of return on investment of these productivity-enhancing factors were computed.

To identify the determinants of total factor productivity, the TFP index was estimated as a function of productivity-enhancing factors representing research, infrastructural development, price policy and rainfall. The five parameters namely research stock (Res_Stock), *kharif*-rainfall (Rf_kharif), density of regulated markets in soybean-growing states (Market), price parity with the competing crop (Price_Parity) and percentage irrigated area under the crop (Area_Irrig) were regressed against TFP index. All the parameters were in log form except those present in percentages. The other parameters tried in the model were rural literacy rate, road density, cropping intensity, but were dropped as they showed high multicollinearity with other variables. To assess the determinants of TFP, the regression Equation (2) was specified as:

$$TFP_I = f(Res\_Stock, Rf\_kharif, Market, Price\_Parity, Area\_Irrig) \quad \ldots(2)$$

The research stock was constructed using a lagged scheme following Evenson (1991) and Chand *et al*. (2011) by summing up research investment of five years by assigning weights as 0.2 in the year t-2, 0.4 in the year t-3, 0.6 in the year t-4, 0.8 in the year t-5 and 1.0 in the year t-6. These coefficients were used to estimate TFP growth and the estimated values of marginal product (EVMP) were ultimately used to compute marginal internal rate of return to investment on oilseeds research.

Returns to Research Investment

The value of marginal product for soybean research was estimated as per Equation (3):

$$EVMP\ (Research\_Stock) = b_i\ (V/Res\_Stock) \quad \ldots(3)$$

Table 1. Growth in yield of soybean in major states of India

Period	Andhra Pradesh	Madhya Pradesh + Chhatisgarh	Karnataka	Maharashtra	Rajasthan	Uttar Pradesh + Uttarakhand	Gujarat	India
				Yield (kg/ha)				
TE 1980	-	777.3	-	-	-	467.5	-	766.0
TE 1990	970.0*	760.2	560.3	623.2	887.9	902.6	696.4	764.4
TE 2000	953.8	1053.6	901.7	1280.6	1272.5	717.6	813.2	1106.0
TE 2010	1285.0	1125.8	626.5	1021.0	1160.5	1276.0	647.1	1096.4
TE 2013	1719.4	1188.1	939.5	1446.3	1469.8	1439.6	855.5	1296.7
				Compound annual growth rate (%)				
1980s	-	0.01	-	-	8.0	7.4	7.3	0.6
1990s	-2.7	1.9	7.0	5.2	2.6	-8.5	-0.8	2.6
2000s	2.3	5.3	-3.8	-3.4	5.1	8.1	-2.7	3.0
1980-2013	2.5	1.6	2.2	3.1	2.5	1.5	2.0	1.8

*Data pertains to TE 1992-93

where, V is the value of soybean production associated with total factor productivity (value of soybean output multiplied by the share of TFP in total output), Res_Stock is the research stock and b_i is the TFP elasticity of research stock estimated from Equation (2).

The stream of benefits was generated under the assumption that the investment made in research in the period t-i will start generating benefits after a lag of 5 years and the benefits will increase during the next nine years, remain constant for next nine years and will start decreasing thereafter. Following Evenson (1991) and Chand *et al.* (2011), an investment of one rupee in the year t-i will generate a benefit equal to 0.1 EVMP in the year t-i+6, 0.2 EVMP in the year t-i+7, and so on till t-i+13, and it will be 0.9 EVMP in the year t-i+14. After this, the benefits will be equal to EVMP up to the year t-i+23. Thereafter, the benefits will start declining and will be 0.9 in the year t-i+24 and so on. This stream of benefits can then be discounted at the rate 'r' at which the present value of benefits is equal to one. Thus, 'r' was considered as the marginal internal rate of return (MIRR) to soybean research investment.

Results and Discussion

In this paper, growth in total factor productivity of soybean in India has been worked out along with its determining factors. The returns from investment in soybean research in India have also been computed. To understand the change in cost structure of soybean cultivation, the growth in different components of soybean cultivation has been analysed.

Growth in Yield of Soybean in Major States of India

During the initial phase of commercial cultivation of soybean in the country, its productivity was 425 kg/ha (during 1970-71), which increased to 766 kg/ha during TE 1980, and 1297 kg/ha during TE 2013, indicating almost tripling of yield from the initial years (Table 1). The highest productivity of soybean was found in Andhra Pradesh at 1719 kg/ha during TE 2013, which had increased from 954 kg/ha during TE 2000. Other states with higher productivity are Rajasthan, Maharashtra and undivided Uttar Pradesh. The soybean yield levels had shown a decline in the states like Andhra Pradesh, undivided Uttar Pradesh and Gujarat during TE 2000 compared to in TE 1990. Overall, there has been an increasing trend in soybean productivity, and the rate of growth in yield is picking-up with the concerted efforts of research, extension and farmers of the country.

Between 1980-81 and 2012-13, the yield of soybean has increased at the annual rate of 1.8 per cent per annum. It was lower during the initial decade and has picked up in the recent decade. The growth in soybean yield was observed highest in the state of

Maharashtra (3.1%), followed by Rajasthan (2.5%), Andhra Pradesh (2.5%), Karnataka (2.2%) and Gujarat (2%). During the recent decade, the soybean yield growth rate was seen picking up in undivided Madhya Pradesh, Rajasthan, undivided Uttar Pradesh, and Andhra Pradesh.

There has been a tremendous growth in production of soybean in India mainly due to expansion in area, whereas contribution of yield is minimal with the slow growth in productivity. Post-introduction of soybean, the cropping system has shifted from rainy season fallow followed by winter season wheat or chickpea system to soybean followed by wheat or chickpea (Bhatia *et al.,* 2008). This has enhanced the cropping intensity which has resulted in profitability per unit area.

Changes in Cost of Cultivation of Soybean in India

The real cost of soybean production, cost incurred on major inputs, and real returns (at 2004-05 constant prices) along with the proportion of different inputs in total cost of cultivation of soybean were worked out to understand the changes in cost and profitability over time. The traditional inputs make up about three-fourths of the total cost of soybean cultivation in India. The proportion of modern inputs have increased from mere 10 per cent during the decade of 1981-1991 to about 18 per cent in the recent decade (Table 2). A higher proportion of labour inputs and a lower share of productive and protective inputs was observed in the cost of soybean cultivation. This signifies that there was increase in operational inputs due to rise in wage rate, hiring charges of tractor and hike in diesel price, leading to a curtail in expenditure on productive or protective inputs or higher dependency on farm-saved inputs (especially seeds) due to poor resource base. This phenomenon might also be adding to the slow growth in soybean productivity.

The real average cost incurred on different components of soybean cultivation and real gross returns over the years are presented in Table 3. It is evident from Table 3 that the real operational cost of soybean cultivation has increased gradually. The operational cost of soybean cultivation (at 2004-05 constant prices) has increased from ₹ 3637/ha in TE 1982-83 to ₹ 10882/ha in TE 2011-12, at annual compound growth rate of 3.63 per cent.

Table 2. Trends in cost structure of soybean production in India: 1980-81 to 2011-12

(% of total cost)

Components	1981-91	1991-01	2001-11
Traditional inputs	76.6	74.7	71.9
Land	31.7	28.3	24.7
Seed	14.1	13.6	11.1
Human labour	16.9	22.5	22.6
Animal labour	10.4	8.2	10.8
Manure	3.5	2.1	2.7
Modern inputs	9.6	14.5	17.8
Fertilisers	5.5	6.5	4.2
Pesticides	0.2	0.9	2.3
Irrigation	0.5	0.3	0.4
Machine labour	3.4	6.8	10.9
Others[a]	13.8	10.8	10.3

Source: Calculated by authors from data collected from reports of CACP.

[a]denotes cost items such as interest on working and fixed capital, depreciation, and other miscellaneous items.

The total real cost of soybean cultivation in India has increased from ₹ 7231/ha in TE 1982-83 to ₹ 16431/ha. The real gross returns have increased to ₹ 19903/ha recently from ₹ 10727/ha during TE 1982-83. The growth was found to be faster in real total cost (2.62%/annum) as compared to in real gross returns (2%/annum), resulting in lower profits for farmers from the crop. The growth in real cost of inputs such as plant protection chemicals and machine use has been found to be faster. The real cost of human labour in cultivation of soybean has increased fast (3.94 % per annum), even though the use of human labour (hours/ha) has declined significantly.

The growth has increased faster in real operational cost (3.63 % per annum) than in fixed cost (1.12 %) and gross returns (1.99 %), indicating that input-use has increased faster than productivity. This implied that soybean production is increasingly becoming input-intensive with low yield response. This may be due to the factors such as following a mono-cropping system (Soybean- wheat/ chickpea) for a longer duration in the major producing areas leading to fast depletion of soil health and increased incidence of insects and pests (Dupare *et al.*, 2010), inadequate and imbalanced soil

Table 3. Average real cost and returns in soybean production in India, TE 1982-83 to TE 2011-12

(₹/ha)

Real cost and returns	TE 1982-83	TE 1991-92	TE 2001-02	TE 2011-12	CAGR (%)
Gross returns	10727	13988	12792	19903	1.99
Operational cost	3637	6139	8166	10882	3.63
- Human labour	1297	1828	3071	3917	3.94
- Animal labour	813	784	1326	1264	2.53
- Machine labour	90	584	1000	2051	10.78
- Seed	805	1531	1382	1743	1.94
- Fertilizers & manure	523	1144	1009	997	1.93
- Plant protection chemicals	13	37	107	598	23.64
- Irrigation charges	10	63	70	32	7.63
Fixed cost	3595	4663	3937	5550	1.12
Total cost	7232	10802	12103	16432	2.62
Net returns	3495	3186	689	3471	
Returns over operational cost	7091	7849	4627	9021	

Source: calculated by authors from data collected from reports of CACP.
Note: Growth is annual compound growth rates for the period 1980-81 to 2011-12. All India item-wise cost and returns have been worked out as area weighted average input costs and returns data for different states including Madhya Pradesh, Maharashtra, Rajasthan, Chhatisgarh and Uttar Pradesh for available data.

nutrition (Sharma *et al.*, 1996; Tiwari, 2001; Hegde and Sudhakara Babu, 2009), low production technology adoption (Sharma *et al.,* 2006; Dupare *et al.*, 2011; Kumar *et al.*, 2012; Singh *et al.*, 2013), water stress at critical crop growth stages (Tiwari, 2001; Bhatia *et al.*, 2008), and so on. Oilseeds are energy-rich crops while in India these are grown under energy-starved conditions (Hegde and Sudhakara Babu, 2009) and the low response of oilseeds to fertilizer application may be due to hidden hunger for secondary and micro-nutrients.

Total Factor Productivity Growth of Soybean in India

The increase in input use, to a certain extent, allows the agricultural sector to move along the production surface. The balanced use of modern inputs is expected to induce an upward shift in the production function to the extent that a technological change is embodied in them. The TFP measures the extent of increase in the total output, which is not accounted for by increases in the total inputs.

The input, output and TFP index of soybean in India was worked out and is depicted on Figure 1. It is evident from Figure 1 that there was a robust growth in output index of soybean from 1980-81 to 2011-12, but it was mainly because of increased inputs-use which brought into inefficiencies in their use. A higher growth in output index coupled with almost parallel growth in inputs-use index led to near stagnant total factor productivity of soybean in India (Figure 1). However, the output index in recent years was found to be higher than the index of inputs-use.

Annual growth rates in output, input and TFP indexes (compound annual growth rate based on three-year moving averages) of soybean in India are presented in Table 4. The total period was divided into three different decades to understand the dynamics of TFP over time. The analysis has revealed that the annual growth in output as well as inputs-use index has slowed down in the recent decade. However, the growth was found to be higher in output index than the inputs-use index, leading to a positive growth in TFP for soybean in recent decades (Table 4). The higher output growth triggered by technological change has resulted in positive soybean TFP growth in the recent period. Overall, TFP index of soybean has grown moderately (1.2 % per annum) in India. Also, the contribution of TFP to total output growth was negligible during 1980s,

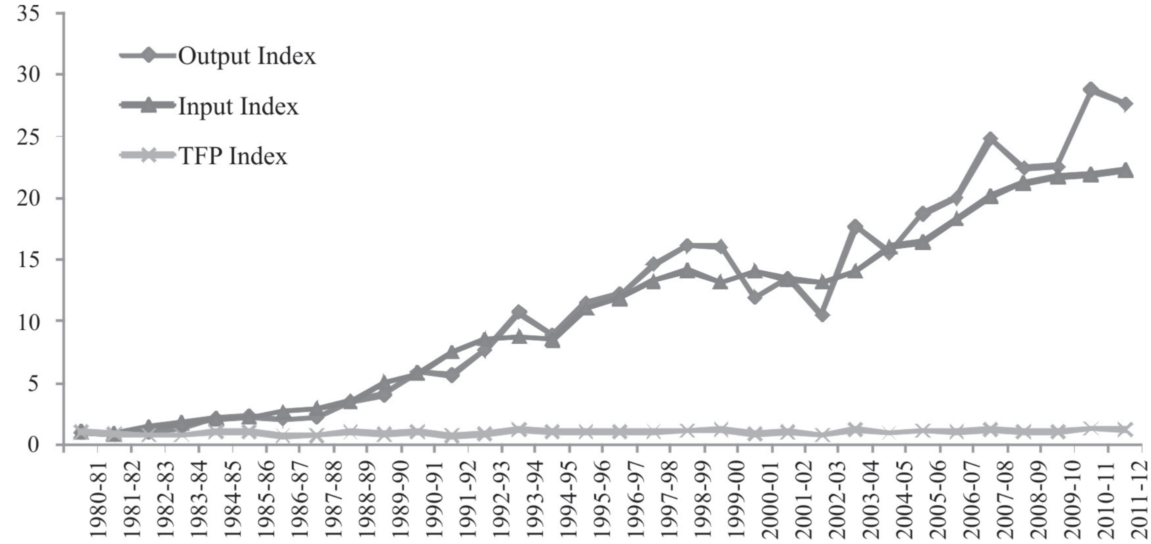

Figure 1. Input, output and TFP index of soybean cultivation, 1980-81 to 2011-12

Table 4. Annual growth rates of input-use, output and TFP index of soybean in India: 1980-81 to 2011-12

Decade	Output	Input-use	TFP index	Share of TFP in output growth
Madhya Pradesh (1981-2012)	9.94	8.28	1.66	20.11
Maharashtra (1995-2012)	10.19	10.79	-0.60	-5.61
Rajasthan (1997-2012)	5.82	4.23	1.59	37.63
All India				
1982-1991	19.60	19.44	0.16	0.83
1992-2001	9.52	7.89	1.62	17.06
2002-2012	9.08	6.47	2.61	28.72
1982-2012	11.40	10.20	1.20	10.52

Note: TFP for all India have been worked out from area weighted average input costs and returns data for different states including Madhya Pradesh, Maharashtra, Rajasthan, Chhatisgarh and Uttar Pradesh for available data.

which increased fast and reached about 29 per cent in the recent decade. This indicates that the productivity growth rather than the input growth has been the main driver of soybean production in India during the recent period. For the overall period under analysis, nearly 10.5 per cent of the total soybean output growth was contributed by TFP in India. The TFP growth of soybean in Madhya Pradesh and Rajasthan was found positive, while in Maharashtra, it was negative on higher input-use.

Determinants of TFP of Soybean in India

To analyse the determinants of total factor productivity of soybean in India, the aggregate/ area weighted average data of the districts, covering more than 90 per cent of soybean area, were used for the independent factors such as *kharif* rainfall and density of regulated markets. For TFP growth, the various factors are responsible are technology improvement, infrastructural development, weather, price policy and human capital. Thus, TFP index was decomposed against five explanatory variables related with these factors, viz., research (Res_Stock), infrastructure (Market, Area_Irrig), price policy (Price_Parity) and weather (Rf_Kharif). The dependent variable was taken in natural log of TFP index. All explanatory variables were specified to the base of natural logarithms, except the variable defined in percentage/ ratio terms such as proportion of soybean area irrigated and price parity. Maize was taken as a competitive crop of the soybean

Table 5. Determinants of TFP of soybean in India, 1980-81 to 2011-12

Variable	Regression coefficient	Pr > |t|
Intercept	3.114**	0.0230
Res_Stock	0.227*	0.0090
Rf_kharif	0.152	0.4285
Market	0.081	0.8806
Price_Parity	-0.082	0.2686
Area_Irrig	0.055**	0.0267
R^2	0.44	
Durbin-Watson D	2.04	

for price parity variable. The estimated regression results are presented in Table 5. Although, some other factors such as extension stock, road density, cropping intensity, rural literacy, etc. were also included in the model, but were not considered due to multicollinearity. Also, the exclusion of these variables did not much affect R^2 value.

The regression results indicated that expenditure on soybean research had a positive and significant impact on total factor productivity of soybean, implying thereby that public expenditure on soybean research assumes a greater role in accelerating the productivity of soybean in the country. The per cent soybean area irrigated had a positive and significant effect on TFP. Irrigation played a crucial role in *kharif* crops, particularly under prolonged drought situations. Thus, providing irrigation at the crucial stage can boost the productivity of the crop.

Returns from Research Investment in Soybean in India

The impact of soybean research was measured in terms of economic returns to investment. Measuring economic returns of agricultural research comprises two steps; the first step includes decomposing the growth of TFP to various factors including research, and the second step includes estimating the marginal product for investment on research by the product of research stock elasticity and average product value to research. The results of regression were used to determine the relative contribution of research investment in TFP growth of soybean. Since the function fitted was semi-log linear, the technical coefficients of the variables gave the production elasticities. Using the elasticity of TFP with respect to research stock variable, the value of marginal product and marginal internal rate of returns from soybean were calculated and are presented in Table 6.

The analysis has revealed that marginal returns to investment on soybean research in India were very low. For the overall period, 1980-81 to 2011-12, increment of one rupee in research stock generated, on an average, additional income of ₹ 0.26 only, indicating very low rate of returns to public research investment. The decade-wise analysis has indicated that the marginal rate of returns from soybean research has improved in the recent decade (Table 6). Less than one marginal value product of research for groundnut, and rapeseed & mustard was also reported by Chand *et al.* (2011). Similarly, the internal rates of returns to soybean research investment are moderate (10 %).

The ratio of soybean research investment to the value of output from soybean at nominal prices has indicated that not even 0.001 per cent of value of output from crop was invested in research. The results suggest that further higher investment on soybean research will generate soybean supply at a faster rate. Hence, to meet the fast growing demand for edible oils and in turn oilseeds, the policy signals are clear; ‘Invest more on

Table 6. Estimated value of marginal product of research stock and marginal internal rate of returns to research investment in soybean in India: 1980-81 to 2011-12

Decade	EVMP	IRR (%)	Average research investment (in lakh ₹)	Research investment to value of output ratio
1981-1991	0.008	Negative	72.57	0.0016
1991-2001	0.39	13.1	227.77	0.0005
2001-2011	0.71	18.2	634.39	0.0004
1981-2011	0.26	10.0	314.19	0.0005

Note: VMP less than ‘1’ indicates that research in the commodity is not generating enough output to justify investment.

research and create irrigation infrastructure', may be through localized water harvesting to boost domestic production of the crop and the edible oil pool.

Low or stagnant growth in TFP of soybean crop was reported earlier by Chandel (2007) and Chand *et al.* (2011). Chandel (2007) has reported that the input index increased marginally faster (18.29 %) than the output index (18.23 %), leading to marginally negative TFP growth. Similarly, Chand *et al.* (2011) have revealed that the total factor productivity (TFP) growth for soybean was 0.83 during post-TMO period and declined to 0.62 during post-WTO period. The value of marginal product of oilseed research stock was found to be less than ₹ 1 during all the periods, and started declining during post-TMO and continued to decline during post-WTO periods. The internal rate of returns through oilseeds research investment was around 18 per cent for groundnut during all the periods, while it continuously declined for mustard crop from 27 per cent during pre-TMO period, 17 per cent during post-TMO period and 13 per cent during post-WTO period (Chand *et al.,* 2011).

The lower growth in total factor productivity for oilseeds can be attributed to lower investment in oilseeds research. Indian research system invests merely 4.2 per cent of total agricultural research investment on oilseeds research (Chandel and Rao, 2003), whereas oilseeds contribute about 10 per cent of total value of output from agriculture crops. Even within oilseed crops research, resource allocation was found to be disproportionate. The share of research investment for mustard and sesame had increased, while share of all other oilseed crops had declined. The research investments for crops like rapeseed and mustard, groundnut and soybean were lower than their contribution in the value of output (Chandel and Rao, 2003). Rao *et al.* (2000) have also reported R&D input index of 0.36, reflecting more budget and manpower for the soybean crop for which R&D output index was moderately high (0.56). Some studies have reported low adoption of soybean production technology (Sharma *et al.,* 2006; Dupare *et al.,* 2010; 2011; Kumar *et al.,* 2012; Singh *et al.,* 2013) leading to realization of lower yield, calling for concerted efforts on extension services along with policy support for timely availability of quality inputs to the farmers.

Most of the change in total soybean production in the country was mainly contributed by area expansion with 18 per cent contribution of yield increase. The chances of area expansion are limited now and hence, efforts need to be enhanced towards yield increase and resource conservation. The modern research tool such as biotechnology, nanotechnology, etc., need to be deployed to improve the genetic potential of crop and input-saving technologies aiming at enhancing soybean production per unit of factors of production. This requires putting higher research investment in soybean with well-defined and goal-oriented efforts. The concerted efforts towards this direction will improve not only farmers' income, but will also help realize higher production of soybean in the country and in turn, higher capacity utilization of ailing oil processing units, saving foreign exchange through reduced burden on edible oil imports and even earning significant amount of foreign exchange through exporting soy products.

Conclusions

The study has analysed the growth in total factor productivity of soybean in India using Tornqvist-Theil index approach from the data collected from reports of Commission on Agricultural Costs and Prices, New Delhi. Efforts have also been made to workout returns from research investment in soybean in the country. The analysis has indicated that the annual growth in output index is higher than the inputs-use index, leading to positive moderate growth in TFP for soybean in India (1.2 % per annum) and higher in the recent decade. The contribution of TFP to total output growth was nearly 10.5 per cent.

The analysis of determinants for TFP has indicated that expenditure on soybean research and proportion of irrigated area under soybean have a positive and significant impact on total factor productivity, implying thereby that public expenditure on soybean research and irrigation assumes a greater role in accelerating the productivity of soybean in the country. The internal rates of returns to soybean research investment are moderate (10 %). The returns to research have increased over time with increase in soybean research investment, implying that higher investment on soybean research will facilitate soybean supply at a faster rate. Hence, to meet the fast growing demand for edible oils and in turn oilseeds, higher investments on research and creating irrigation infrastructure are needed.

References

Bhatia, V.S., Singh, P., Wani, S.P., Chauhan, G.S., Kesava Rao, A.V.R., Mishra, A.K. and Srinivas, K. (2008) Analysis of potential yields and yield gaps of rainfed soybean in India using CROPGRO-Soybean model. *Agricultural and Forest Meteorology*, **148**: 1252-1265.

Binswanger-Mkhize, H.P. (2012) India 1960-2010: Structural change, the rural nonfarm sector, and the prospects for agriculture. In: *Stanford Symposium Series on Global Food Policy and Food Security in the 21st Century*. Accessed from https://woods.stanford.edu/sites/default/files/files/India1960-2010.pdf.

Capalbo, S.M. and Vo, T.T. (1988) A review of the evidence on agricultural productivity and aggregate technology. In: *Agricultural Productivity: Measurement and Explanation*, *Resources for the Future*, Eds: Susan M. Capalbo and John M. Antle. Washington, DC, USA.

Chand, Ramesh, Kumar, P. and Kumar, S. (2011) *Total Factor Productivity and Contribution of Research Investment to Agricultural Growth in India*. Policy Paper No. 25, ICAR-National Centre for Agricultural Economics and Policy Research, New Delhi.

Chandel, B.S. (2003) *Impact Assessment of Oilseeds Research in India.* Institute Project Report, National Academy of Agricultural Research Management, Hyderabad.

Chandel, B.S. (2007) How sustainable is the total factor productivity of oilseeds in India?, *Indian Journal of Agricultural Economics*, **62**(2)**:** 244-258.

Chandel, B.S. and Rama Rao, D. (2003) Investment in oilseeds research in India. *Economic and Political Weekly*, **38**(43): 4618-4622.

Coelli, T., Rao, D.S.P. and Battese, G.E. (1998) *Introduction to Efficiency and Productivity Analysis*. Kluwer Academic Publishers, Boston.

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J. and Battese, G.E. (2005) *An Introduction to Productivity and Efficiency Analysis*. Second Edition, Springer, USA.

Desai, B.M. (1994) Contributions of institutional credit, self-finance and technological change to agricultural growth in India. *Indian Journal of Agricultural Economics*, **49**(3): 457-475.

Diewert, W.E. (1976) Exact and superlative index numbers. *Journal of Econometrics*, **4**(2): 115-145.

Dupare, B.U., Billore, S.D. and Joshi, O.P. (2010) Farmer's problems associated with cultivation of soybean in Madhya Pradesh, India. *Journal of Agricultural Sciences and Technology*, **4**(6): 71-78.

Dupare, B.U., Billore, S.D., Joshi, O.P. and Verma, S.K. (2011) Adoption of improved soybean production technology in Madhya Pradesh: A critique. *Journal of Oilseeds Research*, **28**(2): 125-130.

Evenson, R.E. (1991) Agricultural technology, population growth, infrastructure and real incomes in north India. In: *Research and Productivity in Asian Agriculture*, Eds: R.E. Evenson and C.E. Pray. Cornell University Press, Ithaca, USA.

Evenson, R.E., Pray, C. and Rosegrant, M.W. (1999) *Agricultural Research and Productivity Growth in India*. Research Report No. 109. International Food Policy Research Institute, Washington, D.C.

GoI (Government of India) (2015a) *Economic Survey-2014-15*. Ministry of Finance, New Delhi.

GoI (Government of India) (2015b) *Agricultural Statistics at a Glance 2014*. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi.

Hegde, D.M. and Sudhakara Babu, S.N. (2009) Declining factor productivity and improving nutrient-use efficiency in oilseeds. *Indian Journal of Agronomy*, **54**(1): 1-8.

Himanshu, Lanjouw P., Mukhopadhyay A. and Murgai R. (2010) *Non-farm Diversification and Rural Poverty Decline: A Perspective from Indian Sample Survey and Village Study Data.* Working Paper 44. Asia Research Centre, London School of Economics and Political Science, London, UK.

ICAR-IIOR (2015) *Vision 2050*. ICAR-Indian Institute of Oilseeds Research, Hyderabad.

Kumar, A., Rathod, M.K. and Kalantri, L.B. (2012) Behaviour of farmers in adoption of recommended technology for soybean. *Indian Research Journal of Extension Education*, Special issue (II): 223-227.

Rao, D.R., Shastry, K.R. and Kiresur, V.R. (2000) *Technological Forecasting of Future Oilseeds Scenario in India*. Project Report, National Academy of Agricultural Research Management, Hyderabad.

Reddy, A.A. and Bantilan, M.C.S. (2012) Competitiveness and technical efficiency: Determinants in the groundnut oil sector of India. *Food Policy*, **37**(3): 255-263.

Sharma, H.O., Nahatkar, S.B. and Patel, M.M. (1996) Constraints of soybean production in Madhya Pradesh: An analysis. *Bhartiya Krishi Anusandhan Patrika*, **11**(2): 79-84.

Sharma, H.O., Patidar, M. and Nahatkar, S.B. (2006) Constraints of soybean production technology in Vindhyan Plateau agro-climatic region of Madhya Pradesh. *Research on Crops,* **7**(1): 100-110.

Sharma, P. and Bhatia V. S. (2015) Oilseed and edible oil economy in India: Enhancing supplies through augmenting productivity. In: *Souvenir 53rd All India Convention on Oilseeds, Oils Trade and Industry*, organized by The Central Organization for Oil Industry and Trade (COOIT) during 24-25 October, at Nagpur.

Singh, M., Dwivedi, A.P., Mishra, A., Singh, R.P., Singh, D., Singh, S.R.K. and Chand, P. (2013) Adoption level and constraints of soybean production technology in Sagar district of Madhya Pradesh. *Journal of Community Mobilisation and Sustainable Development*, **8**(1): 94-99.

Tiwari, S.P. (2001) Shattering the production constraints in soybean-based cropping systems. *JNKVV Research Journal,* **35**(182): 1-10.

Received: January, 2016; Accepted: April, 2016