Impact of Government Initiatives on Total Factor Productivity of Pigeon Pea Cultivation in India

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ABSTRACT

Background: India is the largest producer as well as consumer of pulses in the world in terms of both quantity and value, it is also the largest pulses producing country in the world with its share at 77% (4.16 million tonne during TE 2018-19; FAO, 2020). The high consumption of pulses by Indian population is mainly due to very large proportion of its vegetarian population (29%; Census of India-2011) who have pulses as their principal source of proteins (Martolia and Rana, 2016). Further, even the non-vegetarian Indian population eat inadequate proportion of non-vegetarian food and partially rely upon pulses as their source of proteins.

Pulses production is quite localized in some states of India and even some geographies within the states. Madhya Pradesh (MP) is the largest producer of pulses in India contributing 27% of the national production followed by the Rajasthan (17%) and Maharashtra (12%). Chickpeas is the most produced pulse in India with its 45%, followed by the pigeon peas (15%); Black Gram (14 %) and green gram (11%) (Indiaagristat.com). Maharashtra (26%) is the largest producer of pigeon pea in India followed by MP (20%) and Karnataka (18%). Gujarat is the number one in terms of productivity of pigeon pea in India (1203 kg/ha) followed by Uttar Pradesh (UP) (1111 kg/ha) and MP during triennium ending (TE) 2018-19. India is the principal pigeon pea producing country in the world with its share at 77% (4.16 million tonne during TE 2018-19; FAO, 2020).

Production of pulses in India being less profitable venture, is subjected to tremendous risk and fluctuations due to their cultivation on marginal lands under rainfed conditions. (Ali et al., 2012). Resultantly, we have been depending on import of pulses over long period of time for meeting huge domestic demand for them (Ahlawat et al., 2016; Shukla and Mishra, 2020). Pulses being not a preferred source of proteins in many of the countries, especially in the developed world, the international market for pulses is not very robust. There have been incidences that the Indian demand has created unreasonable hike in the world prices of pulses.

Government of India seriously considered making India self-reliant on pulses so that consumers are saved from unduly high prices in some of the years. Accelerated Pulses Production Program (A3P) under the National Food Security Mission (NFSM) was implemented during 2010-11 to

INTRODUCTION

India is the largest consumer (28% of global production) as well as producer (25% of global production) of pulses in the world (FAO, 2020). The high consumption of pulses by Indian population is mainly due to very large proportion of its vegetarian population (29%; Census of India-2011) who have pulses as their principal source of proteins (Martolia and Rana, 2016). Further, even the non-vegetarian Indian population eat inadequate proportion of non-vegetarian food and partially rely upon pulses as their source of proteins.

Pulses production is quite localized in some states of India and even some geographies within the states. Madhya Pradesh (MP) is the largest producer of pulses in India contributing 27% of the national production followed by the Rajasthan (17%) and Maharashtra (12%). Chickpeas is the most produced pulse in India with its 45%, followed by the pigeon peas (15%); Black Gram (14 %) and green gram (11%) (Indiaagristat.com). Maharashtra (26%) is the largest producer of pigeon pea in India followed by MP (20%) and Karnataka (18%). Gujarat is the number one in terms of productivity of pigeon pea in India (1203 kg/ha) followed by Uttar Pradesh (UP) (1111 kg/ha) and MP during triennium ending (TE) 2018-19. India is the principal pigeon pea producing country in the world with its share at 77% (4.16 million tonne during TE 2018-19; FAO, 2020).

Production of pulses in India being less profitable venture, is subjected to tremendous risk and fluctuations due to their cultivation on marginal lands under rainfed
augment production of pulses in India (DAC, 2010). These big-push initiatives have certainly increased production of pulses in India including the pigeon pea. As large proportion of this enhancement in pulse production was due to higher use of area and inputs the sustainability of this growth was questioned too. An assessment of total factor productivity (TFP) of pigeon pea is imperative to understand the source of production growth in pigeon pea in India and to ensure sustainability through formulating future development plans on this pulse with credible evidence.

**MATERIALS AND METHODS**

The current study on TFP of pigeon pea cultivation in India is mainly based on the secondary data on “Comprehensive Scheme on Cost of Cultivation of Principal Crops in India”, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, GOI, New Delhi. As five states viz. Gujarat, Karnataka, MP, Maharashtra and UP cover more than three-fourth of pigeon pea production in India, these five states were considered representative at national level. Further, data on area, production and productivity of pulses in India and in the world were collected from https://www.indiaagristat.com/ and FAOSTAT. The time series data on cost of cultivation of pigeon pea in major producing Indian states and at national level were smoothed with the help of Hodrick-Prescott (HP) filter. The smoothed data were used for estimation of MPI and averages as well as growth rate calculations.

For this study, yield of pigeon pea (output variable) was considered in terms of kg per hectare while seven input variables viz. usage of seed (kg/ha), chemical fertilizers (NPK, kg/ha), farm yard manure (q/ha), animal (bullock) labour for a pair (hours/ha), human labour (hours/ha) and real costs of machine usage and irrigation were deflated by price index of diesel and electricity, respectively. Triennial ending averages were used to have smooth levels of the targeted data. The analysis of TFP and its decomposition into efficiency change and technical change was carried out using Malmquist Productivity Index (MPI) method [as proposed by Malmquist (1953) and standardized by Caves et al. (1982); Nishimizu and Page (1982); Fare et al. (1989)] with version 2.1 of the Data Envelopment Analysis Program (DEAP) software (Coelli, 1996).

The analysis of the collected data was carried out for an overall period of 2002-03 to 2017-18 and its two sub-periods viz. 2002-03 to 2009-10 (period-I) and 2010-11 to 2017-18 (period-II) with a structural break year of 2010-11. There were two strong reasons behind selection of 2010-11 as the structural break year; firstly, A3P, the first major exclusive initiative for the development of pulses in India, was initiated during 2010-11; secondly the pulses component of integrated scheme of oilseeds, pulses, oil palm and maize (initiated during 2004) was merged into the National Food Security Mission (NFSM) on 1 April 2010.

**Malmquist Productivity Index**

Malmquist Productivity Index (MPI) was initially given by Caves et al. (1982). This technique was much popularized by Coelli et al. 2005. The period \( t \) and \( t+1 \) MPI is represented by the equations 1 and 2 (taken from Coelli et al. 2005):

\[
M^t = \frac{D^t_0(x^{t-1},y^{t-1})}{D^t_0(x^t,y^t)} \quad \text{(1)}
\]

\[
M^{t+1} = \frac{D^{t+1}_0(x^{t+1},y^{t+1})}{D^{t+1}_0(x^t,y^t)} \quad \text{(2)}
\]

Fare et al. (1994) attempted to remove arbitrariness in the choice of benchmark technology by specifying their Malmquist Productivity Change Index as the geometric mean of the indices in the two-periods given in equation 3 (taken from Coelli et al. 2005):

\[
M_0(x^{t-1}, y^{t-1}, x^t, y^t) = \left[ \frac{D^1_0(x^{t-1},y^{t-1})}{D^0_0(x^t,y^t)} \cdot \frac{D^{t+1}_0(x^{t+1},y^{t+1})}{D^{t+1}_0(x^t,y^t)} \right]^{1/2}
\]

\[\text{(3)}\]

In above mentioned mathematical expressions \( x \) and \( y \) represent the vectors of inputs and outputs, \( D^0_0 \) denotes the distance and \( M \) the MPI. Fare et al. (1994) presented MPI as the product of two distinct components (equation 4), which represent Efficiency Change (EC) in equation 5 and Technical Change (TC) in equation 6, as under (taken from Coelli et al. 2005):

\[
M_0(x^{t-1}, y^{t-1}, x^t, y^t) = \left[ \frac{D^0_0(x^{t-1},y^{t-1})}{D^0_0(x^t,y^t)} \cdot \frac{D^{t+1}_0(x^{t+1},y^{t+1})}{D^{t+1}_0(x^t,y^t)} \right]^{1/2}
\]

\[\text{(4)}\]

Where,

\[
\left[ \frac{D^0_0(x^{t-1},y^{t-1})}{D^0_0(x^t,y^t)} \right] = \text{Efficiency Change (EC)} \quad \text{(5)}
\]

and,

\[
\left[ \frac{D^{t+1}_0(x^{t+1},y^{t+1})}{D^{t+1}_0(x^t,y^t)} \right] = \text{Technical Change (TC)} \quad \text{(6)}
\]

The MPI approach further decomposes EC into pure efficiency change and scale efficiency change.

The MPI was suggested by Malmquist in 1953 which was further refined with the passage of time. Zhang et al. (2015) suggested technique of bifurcating TFP into efficiency changes (EC) and technical changes (TC) with MPI. Important points of superiority of using MPI were described by Fare et al. (1994) as; (1) it requires physical data as input as financial data varies considerably across locations and years; (2) this technique being based on linear programming is free from the risk of violation of assumptions related to the error term in case of production function approaches; (3) this technique don’t has any pre-existing assumption on optimization in the process of decision making; and, (4) last but not least these techniques make decomposition of TFP into TC and EC possible. Suresh
(2013) and Das (2015) have also described superiority of MPI over Solow index and Tornqvist-Theil index while estimating TFP of rice; and Jowar and Bajra in India, respectively.

**RESULTS AND DISCUSSION**

Enhancement or diminution of area under any crop is a strong indicator of relative profitability of that crop. The area of pigeon pea in India had gradually increased from 34.38 lakh ha to 43.85 lakh ha from the TE average 2004-05 to TE average 2017-18. Except UP, area showed increasing trend in all major pigeon pea producing states. However, area under pigeon pea in UP and Gujarat has decreased over the periods under discussion. Maharashtra has the highest share of area i.e., 12.94 lakh ha followed by Karnataka (8.66 lakh ha) and MP (5.97 lakh ha) during TE 2017-18 (Fig 1).

The production performance of pigeon pea in India has significantly increased in recent past (TE average 2017-18) from 24.80 lakh tonne (TE average 2004-05) to 39.08 lakh tonne. Maharashtra was the highest pigeon pea producing state (10.60 lakh tonne) followed by MP (7.49 lakh tonne) and Karnataka (6.38 lakh tonne) as per TE average 2017-18. UP showed declining trend in production of pigeon pea where production decreased from 3.88 lakh tonne (TE 2004-05 average) to 2.92 lakh tonne as per TE average 2017-18 (Fig 2).

The productivity of Pigeon pea was the highest in Gujarat (1243 kg/ha during 2017-18) among all major

![Fig 1: Trend in area of pigeon pea of major producing states in India (in lakh ha).](image1)

![Fig 2: Trend in production of pigeon pea of major producing states in India.](image2)

![Fig 3: Trend in productivity (kg/ha) of pigeon pea for major producing states in India.](image3)
producing state in India. MP, on the other hand, witnessed an attractive increment from 619 kg/ha during 2003-04 to 1297 kg/ha during 2017-18 whereas the lowest productivity of pigeon pea for MP was reported in the year 2010-11 (337 kg/ha). In Karnataka the lowest productivity was reported in the year 2015-16 (368 kg/ha) while the highest productivity of pigeon pea was found in the year 2017-18 (861 kg/ha). At the national level the productivity of pigeon pea increased from 651 kg/ha during 2002-03 to 967 kg/ha during 2017-18.

Impact of government programs and initiatives targeted to accelerate production of pulses in India started during 2010-11 hence comparison of pigeon pea productivity before and after this time is very important in order to assess the success or failure of these programs. During period-I (2002-03 to 2009-10) the pigeon pea productivity growth was by and large positive in all states under consideration except the state of UP where the productivity actually decreased. As an indicator of desirable impact of the initiatives of the government to enhance pulses production in India through A3P and other initiatives, the productivity of pigeon pea showed an increasing trend in the producing states in India during the second period i.e., 2010-11 to 2017-18 (Fig 3).

Compound Annual Growth Rates (CAGRs) of area, production and productivity of pigeon pea in major producing states in India, have been presented in the Table 1. At the country level, the area under pigeon pea exhibited a CAGR of 1.96 per cent during the overall period of time i.e., 2002-03 to 2017-18. It is important to note that India achieved the overall higher growth rate due to the higher growth rate in Period-II. This is a very strong indicator about the success of the implementation of A3P and other initiatives under National Food Security Mission. Karnataka, MP and Maharashtra states experienced positive CAGRs for pigeon pea area (3.83, 5.89 and 1.43 per cent respectively), production (6.13, 9.07 and 2.26 per cent, respectively) and productivity (1.46, 3.00 and 0.81 per cent, respectively) in the overall period, as well as in both the sub-periods. The CAGRs of area, production and productivity were by and large much higher in period-II compared to the period-I except for few cases like in Gujarat for productivity, Karnataka for area and Maharashtra for production and productivity. The improvement in the CAGRs of pigeon pea production in India during second period over the first one was the highest in MP (20.09 percentage points) followed by UP (5.18 percentage points) and overall, India (4.90 percentage points). Similarly, the productivity improvement in the CAGRs of pigeon pea in second period over the first one was the highest in MP (16.44) followed by UP (5.18) and over Karnataka (4.16). The productivity enhancement in pigeon pea cultivation in India is mainly contributed by MP and Karnataka states (Table 1).

Table 1: Compound annual growth rate (CAGR) of area, production and productivity of pigeon pea in major producing states.

| Particulars | Period-I (2002-03 to 2010-11) | Period-II (2010-11 to 2017-18) | Overall Period (2002-03 to 2017-18) |
|-------------|-------------------------------|---------------------------------|------------------------------------|
| Gujarat     |                               |                                 |                                    |
| Area        | -1.69                         | 1.97**                          | -0.88*                             |
| Production  | 2.30**                        | 4.47***                         | 1.86**                             |
| Productivity| 4.05***                       | 2.45**                          | 2.76***                            |
| Karnataka   |                               |                                 |                                    |
| Area        | 2.74***                       | 2.55***                         | 3.83***                            |
| Production  | 5.46***                       | 7.17***                         | 6.13***                            |
| Productivity| 0.33                         | 4.49**                          | 1.46                               |
| MP          |                               |                                 |                                    |
| Area        | 1.55***                       | 4.42***                         | 5.89***                            |
| Production  | 3.54***                       | 23.63***                        | 9.07***                            |
| Productivity| 1.96                         | 18.40***                        | 3.00*                              |
| Maharashtra |                               |                                 |                                    |
| Area        | 0.33**                        | 0.74***                         | 1.43***                            |
| Production  | 2.42                          | 2.05                            | 2.26                               |
| Productivity| 2.09*                        | 1.30*                           | 0.81                               |
| UP          |                               |                                 |                                    |
| Area        | -2.36***                      | -1.94***                        | -2.07***                           |
| Production  | -6.96                         | -1.49*                          | -2.46*                             |
| Productivity| -4.72                        | 0.46                            | -0.39                              |
| India       |                               |                                 |                                    |
| Area        | 0.22***                       | 1.91***                         | 1.96***                            |
| Production  | 1.55***                       | 6.45***                         | 3.52***                            |
| Productivity| 1.32***                      | 4.47***                         | 1.53***                            |

Data source: https://www.indiaagristat.com/Note: ***, ** and * represent level of significance at 1, 5 and 10%, respectively.

Total factor productivity (TFP) of pigeon pea

TFP is one of the most important tools for assessing sustainability of agricultural systems (Evenson and Jha, 1973; Evenson et al., 1999). MPI has been the much-improved method of TFP estimation currently and there are some important studies on TFP estimation using MPI in India (Suresh et al. 2013; Rana and Anwer 2018; Monga and Sidana 2019, 2020; Monga and Rana 2020). These studies have showed varied results in different regions and periods for different crops.
Growth of Indian agriculture led just by higher use of inputs rather than backed by the use of technology is taking us towards the un-sustainable agricultural growth. As this is the biggest criticism for Indian national research and extension system it becomes imperative to study the nature of such growth. The current study is a thorough investigation on this aspect in which TFP of pigeon pea cultivation in major producing states of India has been estimated with the help of Malmquist Productivity Index (MPI).

The movement of TFP for pigeon pea cultivation in major Indian producing states was estimated for the overall period of the study i.e., 2002-03 to 2017-18 and the results have been presented in Table 3. As a significant finding of the study, it was found that the TFP change for pigeon pea cultivation in all studied states was solely due to the technical progress rather than the change in efficiency (which remained constant in all the cases along with its sub components viz. Pure Efficiency Change and Scale Efficiency Change). The TFP change for pigeon pea cultivation was 2.4 per cent per year during the overall period 2002-2018 at national level. Across the studied states, the highest change in the TFP was found in Gujarat (6.2 per cent) followed by MP (3.3 per cent) and all India level (2.4%). However, the state of Maharashtra exhibited a negative TFP growth of -2.1 per cent in the overall period of the study (Table 2).

The entire change in TFP was contributed by the technical progress and the efficiency remained unchanged for pigeon pea cultivation over the study period. However, major programs and initiatives of the Government of India to develop pulses production in India started during 2010-11 with the initiation of NFSM-Pulses and A3P. Hence, it is imperative to see the impact of these initiatives by analysing TFP growth of pigeon pea production in India before and after them.

The TFP change, solely led by the Technical Change as the Efficiency Change remained constant in all the cases, in period-II was invariably positive over the period-I in all studied states of India producing pigeon pea. The highest positive change was observed in the state of Maharashtra where TFP in first period (-0.3%) improved to 2.8% in period-II followed by Gujarat (TFP improved to 10.5% from 2.1%) and all India (TFP grew to 5.7% from -0.03%) (Table 3).

The TFP change varied considerably across states during period-I, as four out of the five states considered for this study (Gujarat, Karnataka, MP and UP) posted positive change while Maharashtra (the only state) posted negative TFP growth. Interestingly the Efficiency Change remained constant in both the periods i.e., period-I and period-II. The inadequate or no growth in efficiency change in Indian agriculture has also been discussed by Chand et al. (2011), Suresh (2013), Rana and Anwer (2018) and Monga and Rana (2020). Ultra-optimal use of inputs leading to the diminishing returns have been reported as the principal reason of inadequate or no growth along with the cases of negative growth in the efficiency change in Indian agriculture (Chand et al., 2011).

The TFP growth in period-II was the highest in the state of Gujarat (10.5%) followed by Karnataka at 6% and all India (5.7%). A TFP change of 5.7% in pigeon pea cultivation at national level provides very attractive growth and a confirmed indicator of strong positive impact of government programs and initiatives (A3P and NFSM-Pulses) for the development of Pigeon Pea in India. Another indicator of desirable impact of government programs for pulses production in India was reflected in case of pigeon pea crop in terms of very high TFP change in all major producing states of India (ranged from 2.8% in Maharashtra to 10.5%...
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Table 4: CAGRs in input use for pigeon pea production in the studied states (%).

| States   | Seed  | Fertilizer | Manure | Human Labour | Animal Labour | Machine Labour | Irrigation |
|----------|-------|------------|--------|--------------|---------------|----------------|------------|
| Gujarat  | -2.13** | -0.99      | -2.72  | -0.60        | -8.42***      | 10.41***       | 4.15**     |
| Karnataka| 4.99*** | -2.09      | -8.17* | -0.70        | -5.68***      | 12.01***       | 16.91**    |
| MP       | -2.90***| 13.89***   | -10.42*| -2.31***     | -6.87**       | 17.16***       | -3.62      |
| Maharashtra| 2.09*** | 9.18***    | 0.87   | 2.61***      | -2.98*        | 21.80***       | 11.96***   |
| UP       | 0.07   | 4.42       | -20.21**| 0.31         | -21.78***     | 7.47***        | 7.86**     |

Data source: DES, MoA&FW, GOI. Note: ***; ** and * represent level of significance at 1; 5 and 10%, respectively.

Table 5: Period wise growth in input use in pigeon pea production in study states.

| States   | Seed  | Fertilizer | Human Labour | Machine Labour | Irrigation |
|----------|-------|------------|--------------|----------------|------------|
| Gujarat  | -1.13 | -4.06      | -0.96        | -4.07          | -4.58***   | 3.45        | 3.05***    | 16.61**   | 0.06*     | 5.28      |
| Karnataka| -1.07 | 14.45**    | 1.07         | -12.22**       | 0.20       | -1.00       | 0.95**     | 16.37**   | 0.86*     | 20.90     |
| MP       | -2.31 | -8.00**    | 31.66        | 6.71           | -3.34*     | -3.05       | 11.05***   | 16.99***  | -18.94*   | 26.30     |
| Maharashtra| 1.18  | 2.56       | 18.49***     | 2.28           | 7.53***    | 0.10        | 14.85**    | 24.51***  | 7.85      | 12.26     |
| UP       | -0.30 | 1.03       | -6.80        | 18.31          | 1.00       | -1.69       | 4.14***    | 17.37***  | 5.73      | 11.28     |

Data source: DES, MoA&FW, GOI. Note: ***; ** and * represent level of significance at 1; 5 and 10%, respectively.

in Gujarat) (Table 3). This impact has also been indicated by Kumar and Raju (2017) on account of higher adoption of technologies in all major producing states of India.

To have better insight into the reasons of TFP change, the growth in input use was also analysed for primary inputs viz., seed, fertilizer, manure, irrigation, fertilizers, human labour and machine labour covering last 16 years under consideration (2002-03 to 2017-18) for Pigeon Pea production in India with the help of CAGRs. There was negative growth in use of manure and animal labour in all the studied states during the study period. However, machine labour use showed positive growth rate among all studied states indicating modernization of cultural practices adopted for pigeon pea production in the country. However, use of human labour, seed and manure as inputs showed a mixed trend among the major pigeon pea producing states (Table 4).

Period wise CAGRs of inputs use were also estimated and are presented in Table 5. The use of human labour declined in four out of five studied states in Period-II compared to the Period-I. However, Gujarat was the only state in which CAGR for human labour use was positive (3.45). Tremendous growth in the use of machine labour during period-II compared to the period-I in all studied states present strong evidence of the concerted efforts of the government of India to modernize the pulses production with the help of dedicated programs and initiatives like A3P and NFSM-Pulses. The change in growth rates for seed and fertilizer use during period-II over period-I showed a mixed trend in the studied states. However, all states under consideration have higher CAGRs for the real expenses on irrigation during period-II compared to the period-I.

As India can’t rely on international markets for supply of pigeon pea, special efforts are needed to further strengthen the production and productivity of this pulse in India. Integrated management of pulses cultivation in India has been highlighted as one of the key strategies for enhancement of their production and productivity in India (Ali and Gupta, 2012; Shukla and Mishra, 2020). Pigeon pea is a relatively long duration pulse crop and there is strong need of producing short duration but high yielding varieties of this crop for making the country self-sufficient (Sarkar et al., 2020). Further development of drought tolerant varieties of pigeon pea is another strong strategy for increasing pulses production in India (Gowda et al., 2013).

CONCLUSION

In order to improve self-reliance of the country in the field of pulses production, the Government of India implemented NFSM-Pulses and A3P during 2010 as the most important initiatives. The situation of pulses production in the country has definitely increased after these initiatives. A considerable improvement was noticed in the area, production and productivity of Pigeon Pea during the period-II (2010-11 to 2017-18) over the period-I (2002-03 to 2009-10). This study used MPI to analyse TFP of Pigeon Pea production in major producing states of India and it was found that the growth in the production of Pigeon Pea in India was technology led rather than just inputs led.

The impact of A3P and NFSM-Pulses has been clearly seen in terms of much improved TFP growth of pigeon pea during the period after these initiatives. In recent year, the process of modernization of pulses cultivation has been observed in terms of much better use of machines in this process. The entire contribution to the TFP growth in pigeon pea production in India during the study period was from technology change while the efficiency change remained constant in both the periods and in all the states. This is a testimony for the quality of pulses research in India. However, this momentum still needs the stimulus as the country has to strengthen pigeon pea production in the country as supply of this pulse from international market is not possible.
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