*e* **JADE**

*electronic* **Journal of Agricultural and Development Economics**

Agricultural and Development Economics Division (ESA) FAO
available online at www.fao.org/es/esa/eJADE

Vol. 2, No. 1, 2005, pp. 20-31

# Has the Green Revolution Bypassed Coarse Cereals? The Indian Experience

Aldas Janaiah, Lalith Achoth[1] and Cynthia Bantilan[2]

*Indira Gandhi Institute of Development (IGIDR),*
*Goregaon-Eas,; Mumbai-400 065, India*
*E-mail: ajanaiah@yahoo.com*

**Abstract**

*This paper analysed the growth performance of non-rice crop sectors by estimating total factor productivity (TFP) growth for the selected coarse cereals viz., maize, sorghum and pearl millet in India. The analysis indicates that the TFP growth contributed substantially to the output growth of coarse cereals over the past three decades. The TFP growth was higher in those states where coverage of irrigation was relatively high. TFP grew at an average of 1.4 percent per annum through out the Green Revolution (GR) period for sorghum in the sate of Maharashtra where about half of the India's sorghum area is concentrated mostly under rainfed conditions. Although small in absolute terms over the past three decades, the overall findings suggest that GR technologies have contributed considerably to output growth of coarse cereals. The contribution of technological progress was considerably higher in those regions where MVs were adopted under irrigated/semi-irrigated conditions. This TFP's contribution could further be seen more visibly if some irrigation and policy support are also provided to the coarse cereals.*

***Keywords:*** *Total factor productivity, coarse cereals, green revolution, adoption rate, India.*

[1] University of Agricultural Sciences, Hebbal, Bangalore (India)
[2] ICRISAT, Patencheru, AP, Hyderabad (India)

## 1. Introduction

The green revolution (GR) in India has a long history since the release of the first hybrid variety of maize in 1957. Subsequently, the first hybrid of sorghum was released in 1962. However, the development and release of first modern varieties (MVs) of wheat (Kalyansona) in 1967 and of rice (Jaya) in 1968 kicked off the beginning of GR in India. About 2500 MVs and hybrids of different food, fodder, fibre, and horticulture crops were released over the past four decades, of which nearly 50 percent were for cereals.

Several studies reported high payoffs to the GR technologies in India (Evenson and Jha, 1973; Mohan *et al*. 1973; Barker and Herdt, 1985; Evenson and McKinsey, 1991; Rosegrant and Evenson, 1992; Byerlee and Traxler, 1995; Pingali *et al.* 1997; Evenson *et al.* 1999). Most of these studies however, extensively covered rice and wheat crops, which were the forerunners of India's GR. Nevertheless, other cereals such as maize, sorghum and pearl millet (coarse cereals), which are popularly known as poor man's crops of India, might also have experienced the GR as suggested from the fact that these are cross-pollinated crops where hybrids were developed and released well before the introduction of MVs of rice and wheat (fine cereals). Moreover, the private sector participated largely in both R&D and seed production for coarse cereals, such as maize and sorghum, and did not participate in seed production of fine cereals, as they are self-pollinated crops.

It is often argued that GR technologies have not adequately benefited coarse cereals, which are grown extensively under marginal and dry land environments (Ramasamy, *at al.* 2002). In this context, the principal issues here are *whether GR missed coarse cereals or coarse cereals missed GR? Has GR bypassed these poor man's crops in India?* The principal objective of the paper is to find answers to these questions empirically.

The specific objectives of the study are to: (i) examine the growth performance of coarse cereals at desegregate level by various yield regimes (high, medium and low) across India, and (ii) assess the contribution of total factor productivity growth of these crops for the selected states between early and late GR periods. The study covers three major coarse cereals i.e. maize, sorghum and pearl millet, which accounts for nearly one third of total cereal cropped, but produces only 15 percent of cereal output. The paper is organised as follows: the data sources, and methodology are detailed in section 2, section 3 provides an overview of cereal crop sectors through GR in India. The growth performance of coarse cereals at desegregate level is described in section 4 along with the empirical results of the TFP growth. The last section concludes based on the overall findings of this paper.

## 2. Data base and methodology

Input-output data from the reports of a comprehensive scheme entitled *Cost of Cultivation of Principal Crops in India*, Ministry of Agriculture, Government of India, were used for measurement and analysis of TFP growth for the selected coarse cereal crops. The available time series data on the quantities and values of inputs for maize, sorghum and pearl millet were collected for the period 1970-71 to 1999-2000 for all the major states of India. District level statistics on area, production and yields of the selected crops were studied together with data on areas irrigated by crops using modern varieties and were compiled for the period 1966 to 1998 from the respective state's Bureau of Economics and Statistics.

In common parlance, productivity growth in agriculture crops is assessed through a change in crop yields measured as production per unit of land between two points of period. It has a clear physical connotation and allows for cross-section and time series comparisons. They are, however, incomplete as measures of economic efficiency, because they do not explicitly consider the growth in use of inputs other than land such as labour, fertilizer, animal power, etc. Changes in the use of these inputs over a period of time also bring a considerable change in yields, but at a cost (Evenson, *et al.*, 1999). Consequently, changes in physical yield are not true measures of productivity from efficiency perspective. Total factor productivity (TFP), some times referred to as multifactor productivity, is a true measure of economic efficiency. It can be interpreted as a measure of change in cost of producing a unit of product, holding all factor prices constant (Evenson and Pray 1991). Alternatively TFP growth provides changes in output growth that is not due to input growth.

The TFP can be estimated by the change in output relative to a weighted combination of all inputs, where the weights are factor shares. Here TFP has been defined as the ratio of aggregate output to aggregate input and thus TFP growth is widely considered as an indicator of technological progress. Estimation of the TFP can effectively captures the contribution of technology in crop production. In this paper, the Tornoqvist-Theil TFP indicies are computed as advocated by Rosegrant and Evenson (1992) using the available data for the selected coarse cereal crops in the major states.

## 3. Cereal crop sector in India: an overview

The cereal-crop sector has witnessed a remarkable progress over the GR period in India. Among cereals, rice and wheat crops continue to dominate the agricultural production systems, which accounts for nearly three-fourths of total cereal crop area and 40 per cent of gross cropped area in the country. Although the total area under all cereal has nearly stagnated at about 100 million hectares in India, total cereal output during the triennium ending (TE) of 1973 and 2001 rose from about 114 to 235 million tons. This was possible because of area expansion and yield improvements mainly in rice and wheat crops during this period. The incremental increases in rice and wheat areas have primarily come from reduction in area for coarse cereals and pulse crops as a result of crop diversification in favour of fine cereals. Consequently, share of coarse cereals to total cereal cropped area has declined from 44 to 30 percent during the period 1970-20001 in addition to their declining share in total cereal output from 24 to 15 percent during the same period.

The access to fertiliser and irrigation for semi dwarf MVs of rice and wheat crops backed by the favourable public policy support and infrastructure development since the 60s and 70s were the principal factors for rapid growth of cereal crop sector in India. Rice and wheat crops largely enjoyed most of the policy support in terms of subsidised fertiliser supply, support pricing, and assured procurement of output (Barker and Herdt, 1985; Rao and Gulati, 1994; Rosegrant and Pingali, 1994; Pingali, and Heisey 1999). Further rice and wheat crops occupied nearly two-thirds of gross irrigated area in India. Most of the additional irrigation infrastructure that was created over the past 40 years has been covered by rice and wheat, leaving little resources available for coarse cereals. For instance, total irrigated area has increased from about 43 million ha during the 70s to 68 million ha in the 1990s. The share of coarse cereals to the total irrigated area has reduced from about 8.2 to 5.0 percent between the 1970s and 1990s.

It is important to note that yields of coarse cereals were also substantially higher in the irrigated areas compared to the rainfed areas. Moreover, the adoption rate of MVs of coarse cereals has reached about 80-100 percent in the irrigated areas (Ramasamy *and Selvaraj,* 2002). The states in India with more coverage of irrigation for coarse cereals have recorded higher yields with higher rate of MV adoption (see Table 1).

**Table 1. Trends in yields, adoption rate of MV's and coverage of irrigation for major coarse cereals in the major states, India.**

| Crop/ State | Planted area, 2000-01 (m. ha) | Yield (kg/ ha) 19-- | | | % Share of HYVs/ Hybrid area to the total area 19-- | | | % Irrigated area |
|---|---|---|---|---|---|---|---|---|
| | | 70-73 | 80-83 | 98-01 | 70-73 | 80-83 | 90-93 | 1998-99 |
| **Maize** | | | | | | | | |
| Uttar Pradesh | 0.92 | 810 | 763 | 1365 | 12.8 | 18.5 | 48.5 | 26.9 |
| Karnataka | 0.57 | 3082 | 2981 | 2878 | 78.9 | 82.1 | 69.3 | 54.0 |
| Bihar | 0.62 | 792 | 989 | 1624 | 4.1 | 26.3 | 42.8 | 47.8 |
| Andhra Pradesh | 0.52 | 1201 | 2508 | 3047 | 21.2 | 22.3 | 68.6 | 33.8 |
| **Sorghum** | | | | | | | | |
| Maharastra | 5.1 | 373 | 845 | 1120 | 7.42 | 35.19 | 66.6 | 10.1 |
| Karnataka | 1.7 | 1119 | 1141 | 914 | 10.98 | 27.21 | 68.4 | 7.1 |
| Andhra Pradesh | 0.62 | 445 | 586 | 691 | 3.11 | 20.00 | 45.5 | 2.1 |
| **Pearl Millet** | | | | | | | | |
| Rajastan | 4.6 | 376 | 352 | 469 | 4.32 | 19.76 | 26.0 | 3.0 |
| Maharastra | 1.8 | 241 | 412 | 585 | 18.91 | 35.44 | 59.4 | 4.4 |

Surprisingly by the late 1990s, about 60 percent of total cropped area for coarse cereals had been covered with all MVs (both hybrids and high-yielding varieties or HYVs), even though the coverage of irrigation was much lower for coarse than for fine cereals. Therefore, as Table 2 clearly indicates, GR has begun initially in the irrigated regions where rice and wheat crops are grown intensively, and from there it started to spread into rainfed regions where coarse cereals are grown under marginal environments.

**Table 2. Trends in coverage of area under HYV and irrigation for major cereal crops in India**

| Period (TE) | Rice | Wheat | Maize | Sorghum | Peral millet |
|---|---|---|---|---|---|
| **Coverage under HYVs & Hybrids (%)** | | | | | |
| 1970-73 | 18.9 | 27. 0 | 37.0 | 5.5 | 7.3 |
| 1980-83 | 47.6 | 52.5 | 73.4 | 24.1 | 37.2 |
| 1990-93 | 65.1 | 87.9 | 45.7 | 52.4 | 53.7 |
| 1998-2001 | 74.1 | 90.1 | 59.8 | 68.8 | 57.8 |
| **Coverage under irrigation (%)** | | | | | |
| 1970-73 | 38.2 | 55.5 | 16.4 | 3.7 | 4.0 |
| 1980-83 | 41.4 | 73.2 | 20.5 | 4.5 | 5.8 |
| 1990-93 | 47.0 | 83.2 | 21.2 | 6.1 | 5.8 |
| 1998-2001 | 52.3 | 85.8 | 21.7 | 7.7 | 7.0 |

There were phenomenal increases in yields of fine cereals over the GR period (Table 3). It was reported that TFP was a principal source of yield growth for rice and wheat during the period 1965-86, which grew at the rate of about 1.0-1.2 percent per annum (Rosegrant and Evenson, 1993 and 1995; Kumar and Mrthyunjaya, 1992; and Kumar and Rosegrant, 1994). In case of coarse cereals, yield increases were also appreciable in relative terms over the past three decades (Table 3), although absolute yields are still at a low level, i.e., less than one ton per hectare except the yields for maize which have increased from about 1.1 ton per ha during 1970-73 ton 1.8 to per ha during 1998-2001. However, the issue is whether the output increases per unit land in coarse cereals are either due to increases in input uses or due to technological progress. The following sections address this issue.

**Table 3. Changes in yield levels of major cereal crops over the period in India**

| Period (TE) | All cereals | Rice | Wheat | Maize | Sorghum | Pearl millet |
|---|---|---|---|---|---|---|
| 1970-73 | 1.13 | 1.67 | 1.32 | 1.10 | 0.46 | 0.48 |
| 1980-83 | 1.40 | 2.04 | 1.73 | 1.16 | 0.68 | 0.47 |
| | (23.9) | (22.2) | (31.1) | (5.5) | (47.8) | (-2.1) |
| 1990-93 | 1.92 | 2.62 | 1.94 | 1.58 | 0.83 | 0.65 |
| | (37.1) | (28.4) | (12.1) | (36.2) | (22.1) | (38.3) |
| 1998-2001 | 2.32 | 2.91 | 2.80 | 1.80 | 0.83 | 0.71 |
| | (20.8) | (11.1) | (44.3) | (13.9) | - | (9.2) |

Fingers in the parentheses are the percentage changes over the previous TE period.

## 4. Growth performance at desegregate level

How have different regions with different levels of yields experienced GR for coarse cereals over the period? Have high productivity regions of coarse cereals benefited more from GR technologies? For this analysis, about 500 districts from all states were classified into three categories based on average yield levels of base period 1966-76, viz., high, medium and low yield regimes. Yield levels considered for the classification into high, medium and low yield regimes are greater than 1333 kg, 789-1332 kg, and lower than 788 kg per hectare, respectively, for maize, while the figures for sorghum and pearl millet respectively are greater than 804 kg, 447-803 kg, and lower than 446 kg; and greater than 788 kg, 403-787 kg, and lower than 402 kg.

Table 4 summarizes trends in mean yields of maize, sorghum and pearl millet for different yield regimes. Yields of all the crops, which were much higher during the 1970s, have marginally declined over the period in the high yield regimes. Thus, an important finding emerging out of this table is that high productive regions of coarse cereals have also experienced either yield stagnation or declining trends. In medium yield regimes, yield of maize and sorghum has increased by about 50 and 40 percent, respectively, during the 1970s and 1980s, while yield of pearl millet has substantially increased during a later period. Interestingly, yields of coarse cereals were very stagnant and remained low in the low yield regimes over the period under consideration.

**Table 4. Average yield levels of selected coarse cereals in different yield Regimes in India (Kg/ha)**

| Period | Yield Regimes | | |
|---|---|---|---|
| | High | Medium | Low |
| **Maize** | | | |
| 1970-73 | 2015 | 1024 | 510 |
| 1980-83 | 1618 | 1600 | 561 |
| 1990-93 | 1561 | 1638 | 552 |
| 1996-99 | 1766 | 1632 | 641 |
| **Sorghum** | | | |
| 1970-73 | 1135 | 601 | 281 |
| 1980-83 | 828 | 843 | 285 |
| 1990-93 | 936 | 905 | 292 |
| 1996-99 | 865 | 891 | 310 |
| **Pearl millet** | | | |
| 1970-73 | 1032 | 580 | 247 |
| 1980-83 | 769 | 788 | 270 |
| 1990-93 | 918 | 942 | 274 |
| 1996-99 | 915 | 1096 | 248 |

The adoption rate of MVs, as well as coverage of irrigation for coarse cereals, was substantially higher in high yield regimes than in low yield regimes (Table 5). There has been an increasing trend in adoption rate of MVs in high yield regime with higher MV adoption rate. The medium and low yield regimes also increased adoption rates after the 1980s.

These results shown in Tables 4 and 5 imply that the high productive regions, which experienced GR as early as the 1970s, have registered high yields but experienced a marginally declining trend through the GR period. Over the period, the medium yield regimes have performed appreciably well, and their yields are reaching close to those of high yield regimes by increased adoption rate of MVs over the entire period.

**Table 5. Adoption rate of modern varieties and coverage of irrigation for the selected coarse cereals by yield regimes in India**

| Period | Adoption rate (%) of modern varieties | | | Coverage of irrigation (%) | | |
|---|---|---|---|---|---|---|
| | High | Medium | Low | High | Medium | Low |
| **Maize** | | | | | | |
| 1970-73 | 12.6 | 8.0 | 5.8 | 39.7 | 13.1 | 4.6 |
| 1980-83 | 46.5 | 40.0 | 21.3 | 20.9 | 26.0 | 13.1 |
| 1990-93 | 73.9 | 58.1 | 36.8 | 20.9 | 30.2 | 10.4 |
| **Sorghum** | | | | | | |
| 1970-73 | 14.4 | 4.8 | 4.0 | 7.3 | 2.9 | 3.9 |
| 1980-83 | 32.1 | 29.4 | 9.4 | 5.3 | 3.3 | 5.5 |
| 1990-93 | 58.8 | 55.8 | 37.8 | 5.8 | 3.5 | 7.5 |
| **Pearl millet** | | | | | | |
| 1970-73 | 29.7 | 20.5 | 8.6 | 9.2 | 4.7 | 1.9 |
| 1980-83 | 53.3 | 52.8 | 20.0 | 6.4 | 8.6 | 2.9 |
| 1990-93 | 68.8 | 66.1 | 29.3 | 7.8 | 6.4 | 3.0 |

### *4.1 Total factor productivity growth*

The core research question of this study is to find out whether GR has made any impact on the output growth of the selected coarse cereal crops as measured by TFP growth over the period. Growth of TFP was analyzed for two periods 1971-86 (early GR) and 1986-1999 (late GR) for selected states. The first period corresponds to the period when widespread adoption of MVs took place in many of the cereal crops, which was referred to as the early green revolution period as it was a period when the intensive use of inputs was observed (Murgai, 2001). In the second period 1986-1999, input use tended to level off and reached a plateau, this was referred to as the late green revolution period. The TFP estimates were presented crop wise in the following section:

*(a) Maize*

TFP growth was computed for three major states i.e. Madhya Pradesh (MP), Rajasthan, and Uttar Pradesh for which time series input-output data were available for period 1971-99 (Table 6). The TFP growth rate was negative for MP during the early GR period, and it grew at the rate of 2.7 percent during the late GR period. This suggests that maize crop has experienced input-induced growth during the early GR period, while experiencing technology-induced growth during the late GR period in MP, where maize is grown extensively under semi-irrigated and/or rainfed conditions. In Rajashtan, the technological progress contributed to the output growth during the early GR period. For Uttara Pradesh, a major maize producer of India, technological progress contributed primarily to the reduction of production cost, as input growth has declined faster than the output growth during late the GR period.

**Table 6. Annual growth rates of output index, input index and total factor productivity growth of maize in the major states of India. (% per year)**

| State | Period | Output index | Input index | TFP |
|---|---|---|---|---|
| **Madhya Pradesh** | Early GR | -10.2 | -1.1 | -9.1 |
| | Late GR | 4.1 | 1.4 | 2.7 |
| | Overall period | 0.8 | 0.8 | -0.1 |
| **Rajasthan** | Early GR | 2.1 | 0.1 | 1.9 |
| | Late GR | 0.6 | 0.9 | -0.3 |
| | Overall period | 1.3 | 0.5 | 0.8 |
| **Uttar Pradesh** | Late GR | -0.6 | -1.9 | 1.6 |

*(b) Sorghum*

The TFP growth was estimated for four major states, Andhra Pradesh (AP), Madhya Pradesh (MP), Maharastra and Karnataka. These four states accounted for about 85 percent of India's sorghum area. The TFP has increased at the rate of 3.8 percent per annum during the early GR period in AP (Table 7), implying a significant contribution of technological progress to output growth. It is noteworthy to mention here that the first sorghum hybrids that were widely adopted by farmers were released in this state during the early 1960s. However, TFP growth slowed down to 1.8 percent per annum during late the GR period.

**Table 7. Annual growth rates of output index, input index and total factor productivity of sorghum in major states of India. (% per year)**

| State | Period | Output index | Input index | TFP |
|---|---|---|---|---|
| **Maharashtra** | Early GR | 2.5 | 1.1 | 1.4 |
| | Late GR | 1.4 | 0.0 | 1.4 |
| | Overall period | 2.0 | 0.6 | 1.4 |
| **Andhra Pradesh** | Early GR | 3.0 | -0.8 | 3.8 |
| | Late GR | 4.0 | 2.1 | 1.8 |
| | Overall period | 3.5 | 0.6 | 2.8 |
| **Karnataka** | Early GR | 2.1 | -0.1 | 2.2 |
| | Late GR | -1.2 | 1.4 | -2.5 |
| | Overall period | 0.5 | 0.6 | -0.1 |
| **Madhya Pradesh** | Early GR | 2.6 | 0.7 | 1.9 |
| | Late GR | 2.8 | 1.0 | 1.8 |
| | Overall period | 2.7 | 0.9 | 1.8 |

In Maharashtra and MP where sorghum is grown largely under rainfed conditions, the TFP continued to grow at 1.4 and 1.8 percent per annum respectively during the (early or late) GR period.

TFP growth of sorghum was very impressive, and grew at 2.2 percent per annum during the early GR period in Karnataka, where considerable area of sorghum is under irrigated conditions. In sum, the estimates of TFP growth for sorghum clearly demonstrate that technological progress has made a substantial contribution to the output growth during the GR period.

*(c) Pearl Millet*

The states of Rajasthan, Gujarat and Haryana are the principal producers of pearl millet that accounts for about 70 percent of the country's production area of pearl millet. The estimated TFP growth rates for these states are given in Table 8.

**Table 8. Annual growth rates of output index, input index and total factor productivity growth of pearl millet in major states of India. (% per year)**

| State | Period | Output index | Input index | TFP |
|---|---|---|---|---|
| **Rajasthan** | Early GR | -1.6 | -0.7 | -0.8 |
| | Late GR | 5.7 | 1.9 | 3.8 |
| | Overall period | 1.6 | 0.4 | 1.2 |
| **Haryana** | Early GR | 2.9 | -1.1 | 4.0 |
| | Late GR | 4.0 | -0.3 | 4.3 |
| | Overall period | 3.4 | -0.7 | 4.1 |
| **Gujarat** | Early GR | 3.8 | 0.6 | 3.2 |
| | Late GR | 0.9 | -0.2 | 1.0 |
| | Overall period | 2.4 | 0. 2 | 2.2 |

The TFP growth was very impressive in Rajashthan during the late GR period, which was 3.8 per cent per year, while it was continuously growing at about 4 per cent per annum in Haryana throughout the entire GR period. In Gujarat, TFP growth slowed down to 1 percent per annum from 3.2 percent per annum during the early GR period. These results clearly imply that pearl millet was clearly a beneficiary of the green revolution during the green revolution period.

## 5. Conclusions

The access of MVs of cereal crops backed by the favorable public policy support and infrastructure development since the 1960s and 1970s were the principal factors for achieving GR in India. However, it is widely argued that GR has not made an adequate impact on the output growth of coarse cereals such as maize, sorghum and pearl millet. The paper addressed the important issue of whether GR missed coarse cereals or vice-versa. Specifically, it analysed the growth performance of the coarse cereals at the disaggregate level under different yield regimes (high, medium and low), and TFP growth during the early and late GR periods.

The time-series and cross section data on area, production, yield, MV coverage, and irrigated area from published sources of Ministry of Agriculture were used for the study. Available Input-output data were obtained from cost of cultivation reports for the selected states, and the TFP was computed using the Tornoqvist-Theil TFP index method.

The adoption rate of MVs, and coverage of irrigation for coarse cereals were substantially higher for high yield regimes than for low yield regimes. There has been an increasing trend in adoption rate of MVs in all yield regimes, with higher adoption rates for high yield regimes over the period. The medium and low yield regimes also picked up with increased adoption rates after the 1980s. It implies that the high productive regions, which experienced GR as early as the 1970s, have registered high yields with a marginally declining or stagnant trend in subsequent period. The medium yield regimes, however, have performed appreciably well, and their yields are reaching close to those of high yield regimes due to increased adoption of GR technologies over the period.

The TFP, an indicator of technological progress, contributed substantially to the output growth of coarse cereals over the past three decades. The TFP growth was higher in those states where coverage of irrigation was relatively high. For instance, the TFP grew at an average of 1.4 percent per annum throughout GR period for sorghum in Maharashtra state, where about half of the India's sorghum (harvesting) area is concentrated, even though sorghum area is mostly rainfed. Similarly, it grew continuously at more than 2 percent per annum for sorghum in the state of Karnataka, where it is grown under irrigated conditions. For pearl millet, TFP growth was as high as 3.8 per cent per annum in Rajashtan during the late GR period.

The overall findings suggest that although output per unit land was small, GR technologies contributed considerably to the output growth of coarse cereals over the past three decades. The contribution of technological progress was considerably higher in those regions where MVs were adopted under irrigated/semi-irrigated conditions. It suggests that the contribution of technological progress to the output growth of coarse cereals could be further realized if the provision of irrigation and other policy support were also provided to these poor man's crops of India.

## References


Barker, R. and R.W. Herdt, '*Rice Economy of Asia'*, Washington D.C: Resources for the Future, 1985.

Byerlee, D. and G. Traxler. 1995. National and international research in the post-green revolution period: evidence and impacts. *American Journal of Agricultural Economics,* 77, pp.268-78.

Evenson, R.E. and D.Jha. 1973. The contribution of agricultural research system to agricultural production in India, *Indian Journal of Agricultural Economics,* 28, pp.212-20.

Evenson, R.E. and J.W. McKinsey. 1991. Research, extension infrastructure and productivity changes in Indian agriculture. In: Evenson, R.E., and Pray, C.E. (Eds), *Research and Productivity in Asian Agriculture*, Cornell University Press, New York and London:

Evenson, R.E. and C.E. Prey. 1991. *Research and Productivity in Asian Agriculture*, Cornell University Press Ithaca, N.Y.

Evenson, R.E., C.E. Prey and M.W. Rosegrant. 1999. Agricultural Research and Productivity Growth in India*, International Food policy Research Institute Report* 109, Washington D.C.

Kumar, P and Mrithyunjaya. 1992. Measurement and analysis of total factor productivity growth in wheat. *Indian Journal of Agricultural Economics* 47, pp. 451-458

Kumar, P. and M.W. Rosegrant. 1994. Productivity and sources of growth for rice in India. *Economic and Political Weekly* **29**, A183-A188.

Murgai, R. 2001. The green revolution and the productivity paradox: Evidence from Indian Punjab. *Agricultural Economics* **25**, pp. 199-209.

Pingali, P.L. M. Hossain, and R. Gerpacio. 1997. *Asian Rice Bowls: The Returning Crisis,* Oxon: CAB International, Wallingford

Pingali, P. L. and P.W. Heisey. 1999. Cereal crop crop productivity in developing countries: past trends and future challenges. *Economics Working Paper # 99-03*, CIMMYT, Mexico.

Ramasamy, C. and K.N. Selvaraj. 2002. Pulses, Oilseeds and Coarse Cereals: Why They Are Slow Growth Crops? *Indian Journal of Agricultural Economics* **57**, pp. 316-325.

Rao, C.H.H. and A. Gulati. 1994. *Indian Agriculture:* Emerging Perspectives and Major Policy Issues, International Food Policy Research Institute, Washington, D.C., USA.

Rosegrant, M.W., and R.E. Evenson. 1992. Agricultural Productivity and Sources of Growth in South Asia, *American Journal of Agricultural Economics* **74**, pp. 757-765

Rosegrant, M.W., and R.E. Evenson. 1993. Agricultural productivity growth in Pakistan and India: A comparative analysis. *The Pakistan Development Review* **32**, pp. 433-451.

Rosegrant, M.W., and R.E. Evenson. 1995. Total factor productivity growth and sources of long-term growth in Indian agriculture. EPTD Discussion Paper # 7, IFPRI, Washington, DC.

Rosegrant, M.W and P.L. Pingali. 1994. Policy and technology for rice productivity growth in Asia. *Journal of International Development* **6**, pp. 665-688.