ECONOMIC IMPACT OF UNIVERSITY RELEASED ONION VARIETIES IN MAHARASHTRA

By

Miss. Nirpal Ratnamala Shriram
(Reg. No. Ph.D./018/42)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRICULTURAL ECONOMICS

DEPARTMENT OF AGRICULTURAL ECONOMICS

POST GRADUATE INSTITUTE
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RAHURI – 413 722, DIST. - AHMEDNAGAR
MAHARASHTRA, INDIA.
2021

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

Place : MPKV, Rahuri

Date : / /2021

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The assistance and help received during the course of this investigation have been duly acknowledged.

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Place : MPKV, Rahuri

Date : / /2021 (P.N. Rasal)

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Date : / /2021

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LIST OF ABBREVIATIONS

$	:	Dollar
%	:	Per cent
₹	:	Rupees
Acre	:	43560 sq. feet/ 0.40 hectare
AICRP	:	All India Co-ordinated Research Project
AVC	:	Average Variable Cost
C.V.	:	Coefficient of variation
CDVI	:	Cuddy Della Valle Instability Index
CPMCC	:	Scheme for Creating Permanent Machinery for Studying the Cost of Cultivation of Principal Crops in Maharashtra State., Department of Agricultural Economics, MPKV, Rahuri
et al.	:	et alli (and other)
EVMP	:	Estimated Value of Marginal Product
FAO	:	Food and Agriculture Organization
GAA	:	Growth Accounting Approach
GDP	:	Gross Domestic Product
GIA	:	Gross irrigated area
GoI	:	Government of India
ICAR	:	Indian Council of Agricultural Research
IRR	:	Internal Rate of Return
K	:	Kilogram
KI	:	Kendrick Index
kj	:	Kilo joula
MT	:	Million Tonne
N to P ratio	:	Nitrogen to Phosphorous ratio
NARS	:	National Agricultural Research System
NEPZ	:	North Eastern Plane Zone
NPV	:	Net Present Value
PFA	:	Production Function Approach
PPP	:	Purchasing Price Parity
q	:	Quintal
R&D	:	Research and Development
S.E. ±	:	Standard Error

SCH	:	Single Cross Hybrids
SI	:	Solow Index
t	:	Tonne
TFP	:	Total Factor Productivity
TFPI	:	Total Factor Productivity Index
TII	:	Total Input Index
TLI	:	Translog Index
TOI	:	Total Output Index
TSS	:	Total soluble salt
TTI	:	Tornqvist-Theil Index
U.K	:	United Kingdom
U.S.	:	United States
USA	:	United States of America
WTO	:	World Trade Organization

ABSRATCT

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A candidate for the degree of

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2021

Research Guide	:	**Dr. V.G. Pokharkar**
Department	:	**Agricultural Economics**

In this study, economic impact analysis of M.P.K.V., Rahuri released onion varieties in Maharashtra state was analyzed and quantified by using Total Factor Productivity (TFP), estimated value of marginal product, internal rate of returns and partial budgeting approach. For this purpose, varieties released by the Onion Research Scheme, Pimpalgaon Baswant and Onion storage Scheme, Central Campus, MPKV, Rahuri have been considered as they were appreciably performing with increasing adoption over time. The data regarding research, extension investment and outcome of onion was collected from official records of Onion Research Scheme, Pimpalgaon Baswant and Onion Storage Scheme, MPKV, Rahuri. The data on per hectare input use, output and their prices were collected from the official records of the state cost of cultivation scheme for the year 1990-91 to 2018-19. In the year 2018-19, area, production and productivity of onion were increased by 754.55, 919.91 and 23.97 per cent, respectively, over the base year (1980-81) for entire Maharashtra. It indicates that the production of onion was increased due to both area expansion and productivity improvement for the entire period in the state. Similar trend was observed for all regions of the state *viz.*, Western Maharashtra, Vidarbha, Marathwada and Konkan region for the entire study period. For the entire study period 1980 to 2020 it observed that the university developed high yielding varieties have significant impact on onion production.

In which, Baswant-780, N-53, N-2-4-1, Phule Samarth, Phule Safed and Phule Suvarna were tremendously demanded by the farmers in Maharashtra and other states also. At present, the area under onion varieties released by MPKV, Rahuri is 55-60 per cent to the total area under onion of Maharashtra for the year 2019-20. Among the different university released varieties Phule Samarth variety was mostly (28.11 %) preferred by the farmers followed by N-53 (16.10 %) and N-2-4-1 (14.09 %) on the sample farms.

The input, output and TFP indices of onion crop was estimated by Tornqvist index for study period 1990-91 to 2018-19. The TFP index is below one in the year 1993-94, 2001-02, 2006-07, 2009-10, 2010-11, 2013-14 and 2015-16 .The highest TFP index was observed in 2016-17 (2.29). The average TFP index for 29 years was 1.31. For most of the years TFP was more than one it indicates that as TFP increases the cost of production decreases and it helps to stabilize the prices. The output index of onion increased from 1.12 in 1992-93 to 1.85 in 2018-19. The output growth fell to 0.99 in 2011-12 and reached the lowest in 2002-03 (0.83). The average output index for twenty-nine years was 1.35. In the case of input index, there were heavy fluctuations, decreasing from 1.30 in 1990-91 to 0.90 in 2018-19 and average input index was 1.05 for twenty-nine years.

The determinants of TFP (Y) were estimated by log linear production function. The results indicated that, the research investment (0.14), road density (1.12), GIA (0.15) and Minimum humidity (0.85) have significantly contributed to TFP growth in onion. The average TFP elasticity with respect to research investment was 0.14. The estimated R^2 value was 0.76 indicating that 76 per cent of variation in TFP explained by the factors included in the model. To assess the returns to investment, Estimated Value of Marginal Return (EVMP) and Internal Rate of Return (IRR) of investment in Onion research and extension were analyzed. EVMP was 29.87 which indicated that an additional investment of one rupee in onion research generated additional income of ₹ 29.87. Internal Rate of Return (IRR) to investment in onion research estimated to be 31.75 per cent. It means that every rupee invested in onion research generates additional income of ₹ 31.75. The inverse of TFP elasticity with respect to research gives flexibility to research expenditure. The estimated value was 0.14 which mean that to achieve one per cent increase in TFP, the investments in research need to be increased by 7.14 per cent for onion in Maharashtra.

Partial budgeting analysis reveals that, the total additional cost (direct + indirect) of university released varieties over other competing varieties was observed to be ₹ 25079.75 per hectare. However, the reduced costs (or saving) and added returns due to university released varieties over other competing varieties was ₹ 71445.47. Thus, the economic worthiness of university released onion production technology over other competing varieties of onion in the region was ₹ 46365.72 per hectare and ₹ 29558.18 per hectare after upscaling for the year 2019-20. Thus, these university released varieties have gross economic impact of ₹ 44957.34 crores and net economic impact of ₹ 4658.87 crores for 18 years (2002-03 to 2019-20), respectively on farm economy of Maharashtra. An investment of one rupee in onion crop research and extension generated income of ₹ 29.87 with 31.75 per cent IRR. The study advocates that the Government may provide substantial funds for research and extension in onion crop.

Pages 1 to 112

1. INTRODUCTION

1.1 Indian Agriculture

In most non-industrial nations, agriculture is the main monetary area. Many developing countries must reckon on agriculture for economic progress as means to cope with demand of food requirement and agricultural raw materials, gain foreign exchange for overhead investment and industry expansion, meet labour need, and sustain rural people's cash income. The total share of agriculture and allied sectors, including agribusiness, domesticated animals, and ranger service and fishery sub segments as far as rate of national GDP is 16 per cent for 2020 (India stat). Agricultural exports constitute a fifth of the total exports of the country in the year 2020. The new technology has helped to increase the food grain production in the country and thus overcoming the problems of drought, famine, different calamities and some extent of hunger. Initially the new technology was adopted in regions with abundant resources and pick-out crops in particular wheat and rice, due to immense increase in yield levels, agro-product has recorded impressive growth in these regions.

1.2 Horticulture Scenario

Horticulture is fast growing sector in Indian agriculture, because a percentile has been established change in consumption pattern characterized by decline in share of food-grains and increasing share of non-food grains products in the consumption baskets particularly fruits and vegetables. The percentage involvement of horticulture products in agriculture is more than 32 per cent (Agriculture Statistics at a Glance, 2020). The area under horticulture crops of India was 25.66 (million ha) along with the production of 320.48 million tonnes in 2019-20 (Ministry of Agriculture, GOI).

Our country is blessed with diverse agro-climatic conditions with distinct seasons making it possible grow wide array of vegetables and fruits. Fruits and vegetables together contribute 90 per cent total horticulture in the country. India is the second largest producer, after China, in both the commodity groups (Horticultural Statistics At a Glance, 2020).

1.7 History of Vegetables

Vegetables are plant portions that are utilized as food by humans and other animals. Vegetables were originally harvested from the wild by hunter-gatherers and produced in a variety of locations around the globe, most likely between 10,000 and 7,000 BC, when a new agricultural way of life emerged. Vegetables, which are low in fat and carbohydrates but abundant in vitamins, minerals, and dietary fibre, can be consumed raw or cooked and serve a vital part in human nutrition. Many nutritionists advise people to eat a lot of fruits and vegetables, recommending five or more pieces each day.

1.8 Importance of Vegetable in Indian Economy

India is one of the largest producers of vegetables next only to the China. The total area under vegetable cultivation is around 1263 thousands ha with a production of 191.77 million tonnes in the country in 2019-20. In case of vegetables potato, tomato, onion, cabbage and cauliflower account for around 60 per cent of total vegetable production of country. Vegetables are typically grown in India in field conditions; the concept is indisposed to the farming of vegetables in green houses as practiced in developed countries for higher yields (Agriculture Statistics At a Glance, 2019).

India is currently the world's second-largest vegetable grower. India, China, United States and Turkey are the major vegetables producing countries in the World. India is number one position in the yield of okra together with vegetable pea. Vegetables are grown in almost all the states within nation under varied agro-climatic and soil conditions in plains as well as in hilly regions. At present, out of leafy, fruity and starchy tuber varieties of vegetables, the major vegetables grown in India are onion, potato, tomato, brinjal, cucumber etc.

India’s diverse agro-climatic condition has traditionally helped to grow a large variety of vegetables. In India production of vegetables has increased from 58532 thousand tonnes during 1991-92 to 191.77 million tonnes for 2019-20 (India stat). The overall productivity of vegetables is increasing due to the advent of hybrid varieties and general awareness of nutrition security among the people, the vegetable production of the country is gaining momentum.

1.9 Importance of Onion in the Indian Economy

The onion (*Allium cepa* L.), in any case called the bulb onion or typical onion, is a bulb type vegetable because well known most by and large created sorts of the collection Allium. Onion plant has been developed and explicitly duplicated being developed for something like 7,000 years, it is a biennial plant but usually grown as annual crop. Currently available varieties frequently produce to a stature of 15 to 45 cm (6 -18 inch). The leaves are yellowish-to light blue green and fill of course in a smoothed, fan-shaped wrap. Onion is main utilized for culinary reason, for arrangement of flavors, normally utilized for scarring. It is likewise utilized for other skin conditions and to forestall malignant growth and coronary illness, however there is nothing but bad logical proof to help these different employments. Most onion cultivars are around 89 per cent water, 9 per cent starches (counting 4 % sugar and 2 % dietary fibre), one per cent protein, and immaterial fat. Onions contain low proportions of basic enhancements and have an energy worth of 166 kJ. Onions contribute mouth-watering flavour to dishes without contributing basic caloric substance.

Allium cepa is a major commercial vegetable crop grown in India. For the year 2019, the world's onion area, production, and productivity were 5.1 Mha, 99.94 MT, and 19.4 t/ha, respectively (FAO, 2019). In the World India is the second largest onion grower, trailing only China, however India's onion productivity is poor (17.01 tonne/ha), when draw an analogy among China and other countries by its nature Egypt, the Netherlands, and Iran, among others. India ranked seventh in onion productivity, despite being a poor performer in comparison to different countries.

Diverse agro-climate coupled with abundance of natural resources provide India a comparative advantage for growing the several crops almost around the year. In India, onion is largely grown in the Western, Northern and Southern parts both in *rabi* and *kharif* seasons. Its supply is available throughout the year, albeit in varying amounts. India produces all *rabi* types cultivars of onion – red, yellow and white. While in case of Maharashtra's Southern and Western states, Andhra Pradesh, Karnataka, Tamil Nadu and Gujarat, it is grown in winter (*rabi*) besides in rainy (*kharif*) seasons. Onion production in *kharif* is currently gaining popularity in the country's northern regions.

Maharashtra is India's most important onion-producing state. Maharashtra primary onion-growing districts include Nashik, Ahmednagar, Pune, Aurangabad, Satara, Dhule, Jalgaon, and Solapur. Higher water content in onion has led to higher post-harvest losses in Maharashtra. *Rabi* arrivals start from March end and continue till May and June. Make an estimate of post-harvest losses to be 10 per cent of new arrivals and 2 per cent of stored/accumulated onion per month. There could be more losses in cold shops, such as weight loss and so forth.

The World's major producer of onion are China (24.92 %), India (22.28 %), Egypt (0.3 %), United States of America (0.32 %), Iran (0.25 %) and Turkey (0.21 %) which together accounts for half of the global output. Among the total horticultural crops vegetables contributes about 21 per cent in the production with area, production and productivity of 6506 thousand ha, 184.34 MT and 179.7 qtl/ ha, respectively for the year 2018-19 (Horticultural Statistics At a Glance, 2019).

The Netherlands, India, China, the United States, Mexico, Egypt, Argentina, Spain, Turkey, and Pakistan are all major onion exporting countries. In the onion trade, the Netherlands is initially followed by India. In 2020, the Netherlands, India, and China would account for 49 per cent of total onion exports (FAO). India is exporting out 15.04 per cent of home grown onion creation, amount about 23.74 MT and procured 45.58 Lakh in the year 2020 (APEDA). India mostly exports onion to neighbouring countries such as Sri Lanka, Malaysia, the Maldives, Bangladesh, and Nepal, as well as inlet countries such as Kuwait, Saudi A*rabi*a, Qatar, the United Arab Emirates, Dubai, and Singapore.

Import of onion is more diverse as compare to onion export. The following are the top onion-importing countries: Russia, Bangladesh, Germany, Japan, Malaysia, Saudi-A*rabi*a, UAE, Sri-Lanka, UK and USA. Russian Federation stands first in onion import followed by Bangladesh.

Onion has medicinal properties and which add taste to the food preparations. The onion has a lot of possibilities for value development when processed. Advances in processing have allowed for the production of various value-added products from onion, such as minimally processed ready-to-use or ready-to-cook fresh onion,

onion paste, dehydrated onion flakes, onion powder, onion oil, onion vinegar, onion sauce, pickled onion, onion wine and beverages, and so on.

1.10 Economic Impact Assessment

The goal of an economic impact assessment is to predict how a proposed project or programme will affect employment, income, and levels of business activity (usually measured in gross receipts or value added). The general approach, as with the assessment of other types of impacts, entails projecting the levels of economic activity that would be expected to prevail in the study area with and without the project. The difference between the two projections represents the project's impact. A project's or program's economic effects can be divided into direct (initial expenditures, people directly employed, etc.) and secondary effects. Most analysts use input-output models to estimate a project's secondary effects, which quantify the linkages between sectors of the local economy. Others rely on employment or income multipliers calculated using a variety of statistical techniques.

1.11 Why impact Assessment

The current state of the business sectors and large arrangements, as well as the improvement of science and correspondences, is propelling further events and the propagation of farming breakthroughs, which has an impact on various agrarian spaces. Agricultural inventions are aside from just new or improved goods; they are also models and systems having capability to benefit society. The most frequently indicated goal of impact assessments is to figure out how efficient the economy is for investments in technologies**.** The productivity evaluation (ex-post) and its overflow approach are still the most often used techniques for judging the effect of farming innovations. Impact assessments should aid in prioritizing competing interventions and making policy decisions about how to best allocate scarce resources. To assess the research's outcome and impact interventions with the aim of determining interposition impacts, this is especially difficult in resource management. Policymakers, and researchers all require data to track progress toward output and results.

Strategy creators look for answers from beneficiaries of examination finances like the SAUs/ICAR establishments for an impression of financial effect of their advancements/developments. Financial analysts are regularly approached to search out the monetary effect of most recent advances in SAU/ICAR setting. Researchers try in creating new advancements and upon age, discharge them following the authority codes of exploration techniques through their individual Zonal Research and Extension Councils. Examination store suppliers look for criticism from reserve beneficiaries on monetary effect of advancements. Augmented hole was found in the exchange of innovation from lab to field, might be the reason of difference in the financial practicality and financial effect of new innovations. It is a necessary condition inside the feeling that it empowers horticulture to stay away from a entrap in to Ricardo's theory of unavoidable losses to which the world is more inclined.

1.12 Concept of Total Factor Productivity (TFP)

The proportion of total output to the whole number of resources/factors is used to measure total-factor productivity (TFP), also known as multi-factor productivity. Growth in TFP explained the contribution of yield growth not explained by growth in normally measured employed manpower and investment in inputs in the production when specific assumptions about production technology are made. Total factor productivity is a count of economic efficiency that explains some of the discrepancies in per-capita income among countries. From the growth rate of output, subtract the growth rates of labour and capital inputs which yields the rate of TFP growth. Technology growth and efficiency are two of the most important sub-divisions of Total Factor Productivity, with the former having "unique" inherent properties such as positive externalities and non-rivals that strengthen its position as a growth driver. Productivity is separated into two categories: partial and total factor productivity. Partial productivity make mention of how much one factor (such as labour or capital) contributes to the expansion of output while the remaining variables are still constant. As a result, we have notions like labour productivity and capital productivity, which evaluate resource utilisation efficiency. However, partial productivity does not accurately indicate whether productivity gain is due to increased input consumption, increased input efficiency, or improved technology. Changes in technology, or more broadly Total Factor Productivity, are credited to any growth in output isn't explained by resources. As a result, TFP growth encompasses all measurements that reflect changes in efficiency as well as pure technological change in the sense of production function alterations.

The frontier and non-frontier ways to measuring TFP increase are the two options. Parametric and non-parametric mechanisms are in each of these approaches. The goal of the frontier technique is to calculate the best possible positions using a bounding function estimates, given inputs, and price levels. A cost frontier, for example, follows the lowest possible cost given input prices and output, whereas a "production frontier" traces the maximum possible output for a given combination of inputs and technologies. This differs from parametric non-frontier techniques, in which an average function is frequently computed as the line of best fit via the sample data using conventional least square regression. Furthermore, while non-frontier techniques presume that companies are technically efficient, frontier approaches identify the importance of technical efficiency in whole firm performance. As a result of this discrepancy, the TFP growth estimates from both methodologies are interpreted differently.

TFP expansion established on frontier method has two components : (i) outward changes in the production function as a result of technological advancement, and (ii) technical efficiency connected to production frontier movements. The non-frontier method, on the other hand, uses technological advancement as a measure of TFP increase.

Parametric and non-parametric methods can be helped to estimate both frontier and non-frontier perspectives. The specification of a practicable form of the frontier is required for parametric estimations, and parameters are determined using econometric approaches employing sample data and outputs. The precision of the outcome estimates is sensitive to the supplied functional form, that is a significant implication of this problem. The strength of non-parametric methods (such as data envelopment analysis DEA or other mathematical programming methods), any other way, is that they are parameter-free and do not assume any functional forms. The latter non parametric approaches, have, in different circumstances, the drawback of being unable to conduct direct statistical tests to validate the estimates.

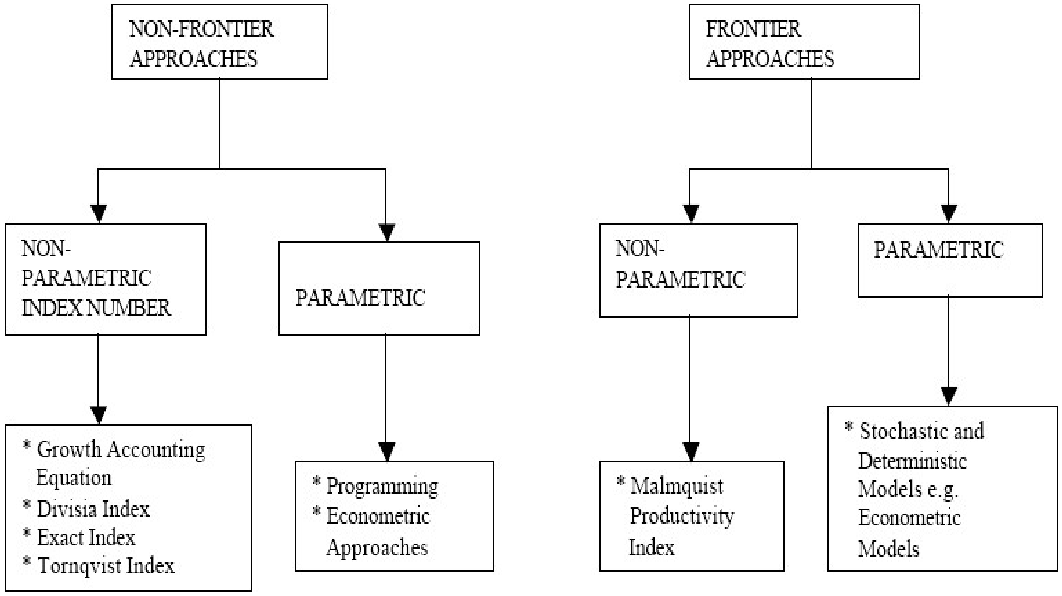


Fig. 1. Different approaches to Total Factor Productivity measurements

1.13 Determinants of TFP in Agriculture

Domestic agricultural research is not the only driver of agricultural TFP, but also international technology transfer, domestic investments in extension and infrastructure, weather and disease shocks, and international commodity prices, according to an error correction model analysis of TFP determinants. In agriculture, new inputs such as irrigation, HYV seeds, sophisticated agriculture machinery and equipment, fertilisers, and so on are invariably embodied in technical advancement. The marginal productivity of land, labour, and capital is imposed by the usage of modern inputs. They also resulted in enhanced cropping intensity due to greater usage of these fundamental inputs. It would also account for the impact of optimal timing, higher labour quality, better farm management methods, increased use of resources such as land equipment, which resulting in an increase in crop intensity, changes in cropping patterns in favour of high-value-added crops, and so on.

1.14 Need of Investigation

Maharashtra is the first place in the acreage and yield of onion in India. There is a steady growth in area and yield of onion over the last few years. However, the decline in its productivity in recent decades is of great concern. For the last few decades, Onion growing farmers have stumbled upon many threats, as price fluctuations, increasing cost of inputs, unsystematic and insufficient institutional and infrastructural facilities, and these put large force on the farmers to with the intent that they are losing the interest to continue in farming as a source of their livelihood. During the last few decades, Maharashtra has made noteworthy headway in onion production. Remarkable varieties of onion released by MPKV, Rahuri University in Maharashtra viz; Baswant -780, N-53, Phule Suvarna, N-2-4-1, Phule Safed and Phule Samarth, N-257-9-1, etc to increase the productivity. These varieties are in work of the socio, political, economic and cultural changes in the agriculture of Maharashtra. In these circumstances, it is imperative to appraise the impact of research and extension on income creation and achievement of onion over the years, especially its yield and resources in terms of quantity and prices to calculate the returns and investment in monetary terms.

1.15 Specific Objectives of Investigation

1. To estimate the growth rates of area, production and productivity of onion.
2. To study the extent of investment in research and extension activities in onion.
3. To assess the impact of research and extension on income generation.
4. To quantify the contribution of investment on research, extension.

1.16 Hypotheses of the Study

1. Ho : The area, production and productivity of onion is constant.

   H1 : Area, production and productivity of onion is fluctuating.
2. Ho : Onion research activities doesn't affect output of crop.

   H1 : Onion research activities affect output of crop.
3. Ho : Adoption of university released onion varieties doesn't changes farm income.

   H1 : The farm income changes with adoption of university released onion varieties.
4. Ho : Investment in research and extension of onion doesn't affect profitability of crop.

   H1 : Investment in research and extension of onion affect profitability of crop.

1.17 Scope and Utility of Study

The two different onion research stations i.e., Onion research station established in 1959 at Pimpalgaon (Baswant) and Scheme for Research on Onion storage in the calendar year 1981-82 were established under MPKV, Rahuri jurisdiction. Thereafter, all technologies and varieties released by these research stations have been adopted by farmers of Maharashtra. Nowadays, price fluctuations for onion is most common phenomena i.e. cobweb phenomenon occurred for onion which is most hot button topic for onion price and quantity supplied. The onion cultivars made available by these two research stations are dispersed throughout the entire Maharashtra which strengthen the monetary system of farmers in Maharashtra. That's why the impact of investment in onion research and extension on farmers economy in Maharashtra is chosen for the current research.

The first *kharif* onion variety N-53 was released by Department of Agriculture, Government of Maharashtra in the year 1987. After that Baswant-780 variety of onion released in the year 1986. This variety became very popular to farmers as a result of its wide adaptability in all types of soil and climatic conditions. This variety is suitable for two growing seasons i.e., *Kharif* and late *kharif* with yield of about 250 q/ha. Since last 40 years, it is being cultivated due to its popularity among farmers. During the year 1987 another HYV variety i.e. N-2-4-1 was released for *rabi* season, which is rust red in colour and having high TSS which is helpful for improving storage quality.

During the year 2004, another short duration onion variety *viz.,* Phule Samarth was released for the months of *kharif* and Rangada which take a header with rapid bulb development among *kharif* cultivars with unsusceptible to premature bolting. Phule Samarth has good capacity of storage for 2-3 months. The area under Baswant -780, N-2-4-1, Phule Samarth is about 35 per cent in Maharashtra under *kharif* and *rabi* season.

Even though number of improved varieties released by research station, it is essential to evaluate the economic impact of improved onion varieties on farmers field in monetary terms. It will become roadmap for future investment for State Government and university. This study will analyze varietal spread and monetary returns of the investment and evaluates technical feasibility and economic viability of research schemes for onion crop.

The goal of this research useful to the farmers for making an appropriate decision or planning regarding choice of variety to increase the production as well as net income. The finding of the study would also be useful to all onion growers, State Government, Ministry of Agriculture, GOM, university scheme/project funding agencies, ICAR and policy makers. It would also be useful to academics and researchers in carrying out further research in the onion economy as well as economic impact of investment in onion research.

1.18 Limitations of the Study

The study pertains only research achievements in selected universities released onion varieties in monetary terms. In addition, the study was mostly based on secondary data gathered from various published sources. Data from various sources may not agree with each other and some attempt to choose the better among them are inevitable. Care has been taken to avoid personal bias in such decision. However, the obstructions inherent in the secondary data are to be recognized.

1.19 Presentation of the Study

The entire study has been presented in six chapters; 1st Chapter highlights the introduction to the topic, concepts of total factor productivity, history of vegetables and onion, need of investment, specific objectives of study and hypothesis of the study. Chapter 2nd includes the review of earlier studies connected with present investigation. Chapter 3rd explains the methodology i.e., description of the study area, nature and resources of data and techniques of analysis adopted for evaluating the objectives of the study. The outcome obtained in consistent with the objectives of research are discussed and presented in detail under Chapter 4th. 5th chapter summarizes the entire study and brings about the significant policy suggestions for the improvement of onion production in addition to monetary returns to the farming community. Last literature cited include the list of citations of previous research studies related to the research topic.

2. REVIEW OF LITERATURE

2.1 General

It is requirement that the knowledge of the similar previous research work completed by other researchers is known to be concerned. It gives an insight into the way in which issue has been resolved, the nature of outcomes obtained and the end of line reached. It's possible that the earlier study work it could have be carried out in various regions, under different set of conditions. Nevertheless, the knowledge of such research is helpful in designing the research problem under study, adopting suitable methodology and interpretation of the result properly. The examination of the past literature relevant to the subject under research, therefore, forms an integral part of any scientific research work. Therefore, the literature is closely connected with the present research is reviewed in this chapter.

The literature is grouped into following categories

2.1 Growth and Instability Analysis

2.2 Total Factor Productivity (TFP) and its Factors.

2.3 Contribution of Agricultural Research and Extension and Rate of Returns to Investment

2.4 Partial Budgeting and Upscaling the Technology

2.1 Growth and Instability Analysis

Barman (2004) studied analysis linear and compound growth rates of onion and garlic production in Bangladesh for 33-year period. He discovered an inconsistency in growth rate in relation to acreage, yield, and production components. However, decomposition analysis revealed that yield and interaction consequences are positively combined with total production, whereas area effect is negatively associated with it over this period for both onion and garlic. Due to less stress in the previous for these crops and left marginal land in contrast to cereal crops throughout the growing time, lower total production and a deficit in local requirements results into variation in both nominal and real prices of products in the markets, apart from seasonal movement. Apart from seasonal movement, lower total production and a deficit in local requirements resulted in a higher degree of difference in both nominal and real prices of the products in the markets due to less stress in the previous for these crops and left marginal land in comparison to cereal crops during the growing season.

Thippaiah (2005) identified direction in production, yield and area of flowers in Karnataka. Karnataka paramount in the country in production of traditional and modern flowers. The goal of the research is to analyse the trends, production, and yields of flowers, additionally the infrastructural facilities available in Karnataka, as well as to study the socioeconomic condition of flower grower and the problems they face in Karnataka. The research relied on both primary and secondary data (1978-79 to 2001-02). The area under traditional flowers increased from 0.65 lakh hectares in ternary ending 1982-83 to 0.22 lakh hectares in trinity ending 1999-00, according to the study. Production increased from 0.30 lakh tones in 1978-79 to 1.51 lakh tones in 1999-00. In terms of crop proportion area, marigold came in first with 20.30 per cent, followed by chrysanthemum with 13.19 per cent.

Singh (2009) studied tendency in production, productivity and area of onion and potato. The research discovered that the increase in area under potato was reported approximately three times followed by onion (2.6 times) during the Period 1970-2004. The area under onion and potato entered the positive and considerable growth of 3.19 and 2.99 per cent per year, respectively. The production of potato and onion were increased approximately five and three times, respectively. The production of potato and onion registered positive and meaningful growth rate of 4.98 and 3.42 per cent each year, respectively. The yield of potato increased 1.8 times followed by onion (1.13 times) only with a positive compound growth rate of 1.99 and 0.23 per cent annually, respectively. The growth of productivity of onion was extremely low as compared to potato.

Al-Gahaifi and Svetlik (2011) studied production and consumption of vegetables in Republic of Yemen. They noticed that the trend was positive in cultivated area, production, and consumption, and negative for productivity. Production of main vegetables crops viz; onion, potatoes and tomatoes enlarged, but the annual increase rate of onion production was highest amongst the mentioned crops on account of the increasing in its cultivated area. The production functions of the groups under work explained that productivity was more important for increasing the production of potatoes and tomatoes; however cultivated area was more influential in increasing the production of onion.

Kulkarni *et al.* (2012) explained growth trends of onion export, area and production in India. The information gathered for the years 1978-1979 to 2010-11. The percentages were calculated using tabular analysis for easy comparison. The area, production, productivity, and export of onions were studied using the growth and lack of stability analysis. The share of export in the output has enlarged from 7.27 per cent (343.26 thousand tonnes) during 2000 to 12.45 per cent (1664.92 thousand tonnes) in 2010. When contrasted to the pre-WTO and overall Periods, growth in area, production, and yield was found highest in the post-WTO Period, with 3.31 per cent, 10.19 per cent, and 5.68 per cent, respectively. The annual growth rates in area, production, and productivity during the pre-WTO and overall Periods were 2.93, 6.24, and 4.37 per cent, and 0.37, 3.72, and 1.26 per cent, respectively. In terms of the instability analysis, for overall Period had the inflated level of instability in production and area with 70.18 per cent and 48.13 per cent, respectively, when compared to the pre-WTO and post-WTO Periods.

Deokate (2013) attempted trends in sugarcane area, production, and productivity in Maharashtra during the pre-green revolution, post-green revolution, and post-liberation periods She concluded that sugarcane area (2.69 % per year) and production (3.29 % per year) increased significantly during the pre-green Period. Sugarcane area (3.60 % per year) and productivity (1.15 % per year) increased significantly during Period II, indicating a positive conclusion of the green revolution. During Period III, there was a noticeable increase in sugarcane area (3.76 % per year) and production (3.54 % per year) in Maharashtra.

Dhakre and Bhattacharya (2013) investigated growth and inconsistency of vegetables area, production and yield reached from secondary data from 1997-1998 to 2010-11in West Bengal. It done for the growth of area, production, and productivity of all vegetables registered were all positive and significant instability index for all vegetables is also positive, indicating that cultivation in the state is less risky. Compound growth rates of cabbage and cauliflower productivity have been observed to be negative but significant. As indicated by the negative values, the growth of area and productivity in cabbage, cauliflower, pea, brinjal, onion, cucurbit, ladyfinger, and radish were decreasing. Regardless of the fact growth rate of area and productivity in tomato and other vegetables finished to be increasing. The growth in output was due to an increase in area in addition to the vegetable productivity in the state.

Ardeshna and Shiynai (2014) studied spatio-temporal growth of garlic and onion crops in Gujarat. The area, yield and production of onion and garlic in various districts of Gujarat were studied. Secondary data was mined and examined for the period 1990-91 to 2007-08. The annual area, production, and productivity of onions have increased significantly at rates of 6.50, 9.96 and 0.68 per cent, respectively. In the case of garlic, annual growth rates in area, production, and productivity were 2.98, 4.61 and 1.522 per cent, respectively.

Gurikar (2014) explained that there was a positive and meaningful growth in onion area and production of 4.06 and 4.18 per cent per year, respectively. In relation to productivity, it has shown a downward trend over time. The growth in production was primarily caused by an expansion in area of onion.

Immanuel Raj *et al.* (2014) focused on the onion growth and instability in Maharashtra. The study classified periods as follows: Period I : 1980-81 to 1989-90, Period II : 1990-91 to 1999-00, and Period III : 2000-01 to 2010-11 and discovered that acreage allocation is the primary driver of onion production in Maharashtra. However, increasing the area under onion may not be possible in the long period without curtailing the area under other important crops. From 1980 to 2000 (Periods I and II), yield variance was around 68 per cent, with area variance ranging from 13.6 to 19.6 per cent. However, in the subsequent Period, area variance increased to 62 per cent, while yield variance decreased to 26 per cent. The major part of production instability (68 %).

Kappa (2014) studied growth rate of area, production, and yield of onion crop in Andhra Pradesh. The current study relied on time series data on onion crop area, production, and productivity from 1992-1993 to 2011-12 in Andhra Pradesh. Simple statistical tools were used in this study. The annual compound growth rate of onion with regard to productivity was found to be negative (-1.84 %) from 2007-08 to 2011-12, regardless of the fact area under cultivation of onion and its output was positive. Onion's overall growth rate of area was 6 per cent. In terms of production, the overall compound annual growth rate of onions was 10.42 per cent. The overall compound annual growth rate of onion in relation to yield was 4.18 per cent.

Agarwal *et al.* (2016) studied horticultural crops in India – growth, instability and decomposition approach. The results revealed that, growth in production of flower was particularly due to the growth in productivity instead area, this means stress on land in coming years. The instability analysis demonstrates that there was high riskiness in flower production as compared to vegetables and fruits production. The contribution of area in productivity was high in all the three crops. The results show that available technologies were not adequate to push up the yield of these crops. Therefore, generation and dissemination of technologies was a matter of great challenge for researchers and extension agencies.

Stephan and Naik (2016) estimated growth rate in area, output and productivity of tomato, cabbage, green chilli and brinjal crops in Karnataka of Haveri district and considered data from 2005-06 to 2015-16. It was mentioned that vegetables in Haveri district had shown growth in area ranges from 6.46 to 10.78 per cent. The highest growth in acreage was observed in green chilli and the smallest in tomato. Similarly, production of selected crops in the locality was grown within the limit of 5.22 per cent to 13.07 per cent and highest growth was recorded in production of green chilli. Significant productivity was observed in tomato and cabbage. Overall, production increased caused by increase in area, not by reason of productivity augmentation in the selected vegetables. Projected demand for all selected vegetables in Haveri district revealed that increasing the demand of vegetables schedule being five years and growth rate of demand will be from 1.68 to 5.59 per cent each year. Highest growth in demand is predicted for green chilli in the district.

Sharma *et al.* (2017) used a component analysis model and researchers examined trends in onion area, production, and yield in Rajasthan, India. The study data collection period has been categorized inside three periods: period one, 1984-1995, period two, 1996-2005, and period three, 2006-2015. The decomposition analysis and growth indicate that the onion productivity effect is the root source of growth in production for the Periods 1984-1995 and 1996-2005, with the exception of Period 2006-2015, for this area effect was the major source in output growth of onion in Rajasthan.

Throughout this period 1986-1995, the growth rate of onion production increased significantly by 9.09 per cent per year, owing largely to significant growth in area of 4.13 per cent per year and 4.76 per cent non-significant growth in productivity. The growth in production of onions decreased during the period 1996-2005, which was recorded at 7.13 per cent, mainly due to low productivity growth of 0.32 per cent per annum, while the area recorded growth of 6.79 per cent each year, area only showed significant impact during 1996-2005.During the period 1996-2005, growth in onion production was 7.13 per cent, owing to low productivity growth of 0.32 per cent per year and area growth of 6.79 per cent per year. Only one area has shown a significant impact between 1996 - 2005. Throughout this period 2006-2015, the rate of production growth was 9.19 per cent, whichever largely ascribed to area expansion of 9.03 per cent per year, while productivity growth was 0.57 per cent. The production growth rate was 9.25 per cent over the entire period. It was attributed to both non-significant growth in area of 6.66 per cent per year and productivity growth of 2.433 per cent by the year.

Shreeram and Leelavathi (2017) estimated trends in floriculture area, production and yield in India and Karnataka. The study findings highlight that an increasing trend have been discovered in area, production and yields in India but in Karnataka, production and area are increasing but productivity per hectare is decreasing. Better returns from floriculture have been identified as the primary cause for expansion in area, production, and yield per hectare. The reason for decrease in yield per hectare is in view of lack of adoption of technology, inadequate knowledge about floriculture, unseasonal rainfall, unfavourable climatic condition and low-quality planting materials. In 2011-12, a large annual growth rate of area is 32.98 per cent, production is 60.23 and yield per hectare is 20.48 per cent under floriculture in India. The CGR of area, output and yield regarding the floriculture in India was 7.27, 10.56 and 1.75 per cent, respectively for Period 2006-2016. The CGR of area is 2.81 per cent and production is 4.39 per cent and productivity per hectare is decreased by 1.04 per cent in Karnataka.

Tawheed and Bagalkoti (2017) used growth rate analysis in economic studies to determine the trend of a specific variable in the long run. The area of fruits in Karnataka gradually increased 1.53 lakh hectares in TE (triennium ending) 1980-81 to 2.08 lakh in TE 1990-91, and then to 3.87 lakh hectares in 2013-14. In line with the increase in area, fruit production in the state increased from 24 lakh tonnes in TE 1980-81 to 32 lakh tonnes in the TE 1990-91 and then to 47 lakh tonnes in the TE 2000-01. Fruit production fluctuated throughout the 2000s, with total fruit production reached 66 lakh tonnes in TE 2013-14. Tumkur ranks first with 11 per cent of total area under horticulture crops in Karnataka, followed by Chikmangalore (6.6 %), Chitardurga, Hassan, D Kannada, Kolar, Davengree, and Mandiya, respectively. Growth rates in the current decade of the 2000s have shown some reversal in terms of area and yield. Fruit crops that experienced impressive growth rates in area during the 1980s and 1990s experienced negative but insignificant increase in area whereas experiencing considerable1.7 per cent growth in yield during the 2000s.Vegetables continued to expand their area at a rapid pace in the 2000s, with area under vegetables expanding at a rate of 7 per cent each year. Their output increased at a rapid pace similar rate of around 2.7 per cent, though it was still significant at 10 per cent.

Gowri *et al.* (2017) discussed growth rate and trend in major horticulture crops for area, production and productivity in Tamil Nadu. The necessary data was gathered from 2000-01 to 2011-12 was purely based on secondary sources. The growth rate of major fruits such as banana, mango and grapes revealed that, fairly large number of districts had positive growth in area, output and productivity of banana and mango. Yet, few districts had negative growth. The research explained the expansion in yield, production and area of horticulture crops was discovered to be statistically significant. Within the greater horticulture sector, the value of output for fruits and vegetables was found to be at the highest, accounted for 26 per cent of comprehensive agricultural value of output. However, despite impressive output growth of horticulture, the trend in yield of fruit crops was discovered to be statistically insignificant.

Kulkarni *et al.* (2018) estimated district wise growth rates of production, area and productivity of pearl millet for WM (Western Maharashtra) as an aggregate for 53 years of study Period viz., 1960-61 to 2012-13 were worked out. The production and productivity of paddy has been increased in Nasik, Pune, Kolhapur, Satara, Sangli and Nandurbar districts while, it is declined in Dhule, Jalgaon, Ahmednagar and Solapur districts. They revealed that the area has continuously declined for all districts of Western Maharashtra except Ahmednagar districts. The production of pearl millet was increased primarily because of the productivity improvement. For the entire Period (1960-61 to 2012-13) productivity was highly increased in Nandurbar district with 6.66 per cent per annum.

Kulkarni *et al.* (2018) studied growth and lack of consistency in production, acreage of major *rabi* crops *viz*., sorghum and wheat in western Maharashtra. They noticed that the area under *rabi* sorghum in the entire district was quite fluctuating over time. It was primarily due to the rainfall and competing crops viz., *rabi* onion and wheat in irrigated region and chickpea in un-irrigated region for *rabi* sorghum. They discovered that there is a wide difference in the behaviour of the *rabi* sorghum for complete period in terms of area, production, and productivity across districts and the region as a whole. In case of wheat for overall Period (1960-61 to 2012-13) in Western Maharashtra, area, production and productivity discovered both positive and significant, with 0.63, 3.31 and 2.66 per cent by the year, respectively. The production of wheat was increased mainly due to the productivity improvement for Nasik, Dhule, Jalgaon, Pune and Ahmednagar districts of Western Maharashtra region.

Niranjan *et al.* (2018) estimated compound growth rate of gram by using data from various sources. These data have been classified as follows: Period-I (1982-1991), Period-II (1992-2001), and Period-II (2002-2011), as well as an overall Period (1982-2011). A positive and non-considerable growth (CGR) of area (1.02 percent/year) for overall period was observed. The growth in production of gram was commemorate positive and considerable at 1.7, 2.02 and 2.96 per cent per year in all periods, while the CGR was established positive and non-significant at 2.37 per cent per year in gram of entire period.

Pandeswari and Vanitha (2018) studied the growth rate of area, productivity and production of banana cultivation in Theni District, Tamil Nadu and computed the relative importance of area and yield in alteration of banana production. The results of this research disclosed that the productivity impact (25 %) had significant contribution in Tamil Nadu and area effect (59.46 %) had significant contribution in the entire state for increasing the production of banana cultivation. In Theni district, it reveals that the yield effect (26.08 %) had significant contribution and area effect (39.20 %) had significant contribution in the district as whole in increasing the production of banana cultivation. Therefore, keeping the area as constant the productivity of horticultural crops can be further increased by taking appropriate production technologies.

Sekhara (2019) studied direction in area, productivity and production of paddy crop for 45 Period from 1950-51 to 2015-16 and data gathered from secondary sources. The CGR of area under paddy for area during the period 1991-92 to 1999-2000 was 0.77 per cent. The CGR of area under paddy during 2000-01 to 2009-10 decreased to 0.51 per cent and which is not significant during 1991-92 to 2015-16 and value was 0.39 per cent. CGR of production of paddy for the period 1991-92 to 1999-2000 was 1.91 per cent. But CGR of area under paddy during 2010-11 to 2015-16 declined to 0.94 per cent. In the Period1991-92 to 2015-16, the compound growth in the production of paddy is 1.33 per cent. The compound growth rate of the yield of the paddy through the period 1991-92 to 1999-2000 is 1.22 per cent. However, it fell to 1.08 per cent from 2000-01 to 2009-10. The growth of paddy productivity was 0.94 per cent over the entire study period.

Adhale *et al*. 0(2019) studied the growth rate of production, area and productivity of sugarcane for entire Maharashtra. He observed that area and production of sugarcane was positive and significant. It implies that the production of sugarcane was increased by only area expansion and productivity improvement.

Divya Lakshmi and Venkatraman (2020) studied growth and instability of area, production and productivity of paddy in Kerala, in connection with the Kerala Conservation of Paddy Land and Wetland Act, 2008.In this study, Bai-Perron test identified a structural break in area, production and productivity during 2007-08 and 2009-10, which could be associated to the conservation act. The annual growth rate of production and area was noticed negative. The growth in area reduced prior to and after the break, but the decreasing rate was less after the break (-2.52 %) than the Period before the break date (-4.40 %). So, as is the case with production. Productivity showed a positive growth rate for the complete Period. Inconsistency in production was high after the break date, whereas, instability in area remained almost same for both previous and next the break dates.

Gade *et al* (2020). estimated growth andlack of stability in acerage, production and yield compound growth rate and Cuddy-Della Valle Index was used.

Area, production and productivity data of chilli were obtained for 23 years from the year 1995-96 to 2017- 18. Analysis showed compound growth rate of area (-0.77 %) of chilli in India was negative and significant, whereas production (3.64 %) and yield (4.262 %) were positive and significant. Also observed that, area consist lower instability rate, were production as well as yield shows higher instability rate.

Mahmadajaruddin and Mamani (2020) conducted study on growth performance of onion in India. Data on onion area, production, and productivity in India's major onion-growing states, as well as onion export from India over the years, were gathered for this purpose. The growth rate approach and instability index were employed to analyse. The data collected from 2006-07 to 2017-18. The results revealed that Gujarat recorded negative and significant growth rates of -6.11, -6.28 and -0.18 per cent per year in area, production and productivity of onion respectively. Rajasthan exhibited high variability in area (43.30), production (46.70) and productivity (36.76). Quantity of onion production in India exhibited higher growth rate of 6.34 per cent each year and was statistically non-significant at five per cent chances of error. The growth in quantity of onion exports increased by 3.14 per cent per year, and the value increased by 9.09 per cent per year, which is insignificant. When it comes to the variability of onion exports, the value of onion exports had the highest variation (35.11 %), followed by quantity (25.22 %). The positive growth rate in onion production is caused by an increase in onion cultivation area combined with the use of improved cultivars, as well as an increase in demand for India's onions in the international market.

Nalegaonkar *et al.* (2020) studied inconsistency and growth rate of onion in acreage, production and yield were studied for a whole country. The data related to acreage, productivity and production of onion were gathered for the Period 1995-96 to 2018-19. To estimate the growth in area, production and yield compound growth rate were used. Cuddy-Della Valle Index was used to calculate the inconsistency in area, production and yield. CGR for area was 6.15 per cent and 8.58 per cent for production and 2.92 per cent for yield which recorded statistically significant and positive. The results revels that, compound growth rate for area, yield and production of onion were statistically significant and positive. The highest instability was observed in production of onion followed by area and yield.

Salunkhe *et al.* (2020) studied instability and growth rate of chickpea in Maharashtra. For estimating the expansion and lack of stability in area, production, and yield of chickpea in Maharashtra, the annual compound growth rate, coefficient of variation, and Cuddy Della Vella index were used. The study implies that the production of gram was increased due to both area expansion and productivity enhancement for complete Period in the State. Similar thing was occurred for all regions viz; Western - Maharashtra, Vidarbha, Marathwada and Konkan region for the entire study Period. The acreage, production and yield of chickpea growth occurred at the rate of 4.01, 6.59 and 2.48 per cent each year, respectively during the entire Period for Maharashtra. It was obtained from the work that area, productivity and production of chickpea were inconsistent or instable for the whole Period in four regions of the state except in Konkan region.

Shivalika *et al.* (2020) investigated the growth performance of pulses in Rajasthan. For research purpose secondary data gathered from different publications of government. Compound growth rate, instability index and decomposition analysis help to find out the growth and inconsistency in production, area and yield of major pulses in Rajasthan for eighteen years i.e., 2000-01 to 2017-18, which was again categorized into two sub-Period i.e., Period-I (2000-01 to 2008-09) and Period-II (2009-10 to 2017-18). Results implies that, pulse area in state has significant growth. When compared to other pulse crops, area of green gram increases at the fastest rate of 6.66 per cent. Chickpea growth rates for area, production, and productivity were raised significantly positive. Chickpea and pigeon pea pulses in the state were more stable than other pulse crops. The increase in production of chickpea, moong bean, and black gram in the state was primarily because of land expansion. Chickpea production increased more due to the area effect, while pigeon pea production increased due to yield improvement and its interaction with area.

Yadav *et al.* (2020) estimated compound growth rate of pomegranate for India and Maharashtra. The data separated into two sub periods Period I (2000-01 to 2009–10), Period II (2010–11 to 2016-17) on area (A), production (P) and productivity (Y) of pomegranate. For the entire period of 16 years, the expansion rates of output and area of pomegranate for the state were discovered to be positive and highly significant at the 1 per cent accepted as error. During the entire Period, pomegranate area and production increased at rates of 2.91 per cent and 6.24 per cent each year, respectively. Although, pomegranate productivity has increased by 2.35 per cent per year at a 5 per cent level of significance. From above result production of pomegranate influenced by expansion of the work area and an increase in productivity for the entire Period of Maharashtra. Pomegranate area and production increased at rates of 4.71 and 7.76 per cent, respectively, and were highly significant at the 1 per cent level of significance for the complete period in India. Pomegranate production has also increased at a rate of 2.91 per cent per year in the country, with a 5 per cent level of significance. It implies that output/production of pomegranate in India depend upon area and productivity.

In growth analysis authors like Sharma (2017) and Gurikar (2014) studied and revealed that growth rates of production and area of onion were significant and production of onion increased mainly caused by area expansion. Kappa (2014), Ardeshna and Singh (2009) revealed that the main cause of the increase in onion production is the expansion of the growing area and slightly improvement in productivity. Barman (2005), Kulkarni (2012), Immanuel raj et al.

(2014), Mahmadajauraddin (2020) and Nalegaonkar (2020) found that high variation and more instability in area and output of onion as compared to productivity. While Thaippaih (2005), Al-Gahaif (2011), Deokate (2013), Dhakare (2013), Agarwal (2016), Stephen (2016), Shreerm (2017), Taweed (2017), Gowri (2017), Kulkarni (2018), Niranjan (2018), Pandeswari (2018), Sekhara (2019), Adhale (2019), Divya lekshmi (2020), Gade (2020), Salunkhe (2020), Shivalika (2020) and Yadav (2020) studied the growth rates of different crops.

2.2 Total Factor Productivity and its Factor

Mittal and Kumar (2000) used TFP as a measure of quality inputs and technology. Using cross-section and time series data for1973-95 for wheat and rice Tornquist – Theil index was worked out. The Period was sub-divided into 1973-90: pre-trade liberalization; 1990-95: short -term liberalized economic development; 1973-95: long term perspective. In order to examine the impact of literacy on TFP simultaneous equation model was utilised. According to the study, literacy was positively related to crop productivity and strongly linked to farm modernisation.

Mukherjee and Kuroda (2001) constructed the TFP index for Indian agriculture in fourteen states from 1973 to 1993 using Törnqvist-Theil methodology. They calculated the TFP index as 1.73 for 1973-1979, 2.51 for 1980-1989, 1.34 for 1990-1993 and 2.19 for the entire period 1973-2003.

Pillai (2001) estimated productivity growth of paddy in Orissa and West Bengal. TFP was computed using Tornqvist Theil Divisia index while technical efficiency was computed using stochastic frontier model considering a translog specification of production technology. In Orissa, average annual growth of inputs, outputs and TFP indices show a steady increase at the rate of 1.11, 2.7 and 1.5 per cent by the year, respectively during 1971-72 to 1992-93, while in West Bengal annual growth rates on average were 2.42, 4.27 and 1.75 per cent per annum. Research work concluded that input productivity has indeed played a significant role in the growth of inputs and TFP. They contributed significantly to the output growth in both the states.

Pandya and Shiyani (2002) examined the multi-factor productivity (TFP) growth in eight food crops of Gujarat utilising the input-output data from 1981-82 to 1998-99. Torn-qvist Theil was used for computing total output index, total input index and total factor productivity index. A continuous improvement in the productivity of all crops under research work was reported 1960-61 to 1999-2000.However, an increase in acreage during the same Period was noticed only in the case of wheat, paddy, maize, tur and gram. Bajara crop registered a exorbitant growth rate of TFP indicating technological change. Moderate technological change was found in case of wheat, maize and pulse crops

Bhushan (2005) estimated the Malmquist TFP index using DEA technique for the major wheat producing states of India: Punjab, Haryana, Madhya Pradesh, Uttar Pradesh, and Rajasthan. He discovered that TFP growth in Punjab and Haryana is the highest, which he attributes to technical progress in these two states. Rajasthan (no change in efficiency) and Uttar Pradesh have increase in TFP growth rates, whereas Madhya Pradesh (no change in efficiency and negative growth in technological progress) has a negative TFP growth rate. In the 1990s, mean TFP growth was found to be greater than in the 1980s, and the primary source of TFP growth was technical progress rather than efficiency improvements.

Rao (2005) investigated fluctuations in multi- factor productivity indices in the crop sector, food grain crops, and non-food grain crops in Andhra Pradesh, as well as the state's contribution to total factor productivity from 1980-1981 to 1999-2000. The total factor productivity index was calculated using the Tornquist-Theil Index. TFP index for crop zone in its entirety in the state throughout the post-reform Period was found to be 5 per cent lower than throughout the pre-reform Period. In case of non-food grains, it was discovered to be 9 per cent less than that during the pre-reform Period, whereas in the case of food grains, it was found to be below 100 during both Periods. Total factor productivity was found to 31 per cent and contribute a healthy growth in yield growth in pre-reform Period. Throughout the post-reform Period, the state's crop sector experienced an absolute decline (–37). In the time of the post-reform Period, the absolute decline in the contribution of technical change has been dramatic in the case of non-food grain crops in the state. This absolute decrease in total factor productivity appears to be a part of it primary causes of the state's farmers' distress, which has manifested itself in the form of suicides since the late 1990s.

Kumar and Mittal (2006) examined crop-by-crop agricultural productivity growth from 1971 to 2000. The authors used the Divisia-Tornqvist Index to measure TFP and discovered that the benefits of technological development had not accrued to all crops and there was a difference in technology use. It was discovered that paddy and wheat outperformed other crops in terms of productivity gains. He also discovered that several crops, including coarse cereals, pulses, oilseeds, fibres, sugarcane, and others, had no technological gains, particularly in the 1990s. The research explained the need of decompose the total output growth not into area and yield portions, instead of input-driven and TFP-driven components, owing to the likely decline in the importance of variation in area under cultivation and soil quality compared to other inputs since the 1960s, and the increased importance of technology in shaping the behaviour of agricultural output. In Indian agriculture, they discovered diminishing returns to scale.

Thorat *et al.* (2006) estimate TFP and growth rates of input, output, and TFP indices for 20 years from 1981-82 to 2000-01 and for two Periods, namely Period I (1981-82 to 1990-91) and Period II (1991-92 to 2000-2001), to determine whether a significant swing in the TFP occurred as a result of horticultural research and development. The study period lasted from 1981 to 2000. TFP grew at a 5.4 per cent annual rate. During the same period, the input index increased by 8.7 per cent per year and the output index increased by 14.6 per cent each year. The higher increase in the output index than the input index was because of the certainty the rate of increase in output prices was more than the increase in input prices. Sub-period results, on the contrary, were more revealing. During Period I, the input index fell at a rate of 4.5 per cent each year, while the output index rose at a rate of 2.0 per cent per year. During Period I, the TFP index grew by an impressive 6.8 per cent. During Period II, the input and output indices increased significantly; however, the TFP indices increased only marginally. During Period II, the input and output indices grew at rapid pace of 15.67 and 17.49 per cent each year, respectively. During the 1990s, the TFP grew at a rate of 1.30 per cent by the year. The higher growth rates of the input and output indices were caused by price increases in inputs and outputs in 1990.

Nadeem *et al.* (2011) examined TFP, input and output growth indices for Punjab's (Pakistan) agriculture for the Period from 1970 to 2005. The indices were measured using the most commonly employed index number method specifically Tornqvist -Theil approximation to divisia index. The findings disclosed that the average annual growth rate of input, output and TFP indices remained at 1.46,3.49 and 2.0 per cent for the study Period. According to the study, TFP made up 57 per cent of the increase in output in Punjab agriculture, and productivity growth has been a significant factor in the performance of the agriculture territory in Punjab over the last 36 years.

Ghose and Bhattacharya (2011) estimated TFP growth (TFPG) using non-parametric approach for seven major crops viz., aus, aman, boro these are type of rice on the basis of time of sowing, jute, wheat, rapeseed -mustard and potato in West Bengal, from 1980 to 2003. TFPG was decomposed into the components of technical change, scale change and efficiency change. All selected crops except for aus and jute experienced positive growth. Boro registered the highest yield growth of about 6.6 per cent, while aman obtained the lowest positive productivity growth of about 0.02 per cent. Except for jute and aus, all crops demonstrated technical progress and an increase in technical efficiency. For aus and jute, there exists technical regress accompanied by a high level of efficiency. However, the downward extend of the frontier in the case of these two crops interpreted the high level of efficiency. A second stage regression analysis highlighted the favourable role of factors i.e. public expenditure, credit, irrigation, regulated markets and disproportion depletion in the reduction in the distribution of operational land holdings in fostering TFPG.

Kannan (2011) find out TFP for ten major crops using a crop output growth model with a Cobb-Douglas production function from 1967-68 to 2007-08 in Karnataka. The study discovered that expansion in agricultural income and employment shares for the state were similar to those noticed at the national level. It was further noted that because of the higher level of reliance on the state agro- sector for employment, productivity gains for the major crops under consideration were hampered. The scope of the research was limited to a single state, and regional analysis provide more information about productivity differentials across the Southern region, of which the chosen state is a part. The study also ignored the various alternatives for constructing a TFP index, which could have taken into consideration for more complexity of Productivity behaviour at a disaggregated level. An in-depth empirical analysis of the sources of TFP in the chosen state could have provided richer insights into the possibilities for increasing productivity in the state.

Sehgal and Sharma (2011) compiled data for various categories of Haryana's organised manufacturing industries from 1981-82 to 2007-08. The inter-temporal and inter-industry in comparison to total factor productivity (TFP) as measured by the Malmquist productivity index (MPI), which is a DEA application to panel data that calculates indices of TFP change, technology change, and efficiency change. Haryana's general development pattern is unquestionably not a healthy sign of structural change in the economy. While the tertiary sector has maintained its lion's share of GDP in India and Haryana, the analysis of the discussion revealed a downward trend in the proportion of the fundamental sector and a more or less stable endowment of the secondary sector. According to the study, during the pre-reforms period, technical efficiency change was the primary driver of TFPG in Haryana's manufacturing sector; however, the picture has shifted during the post-reforms time. The privatization / liberalisation policy has had a positive impact on the state's manufacturing sectors and technological advancement. However, during the post-reform period, the state located in competency in the utilisation of available resources, which is a warning sign specifying the in aptitude of the state's manufacturing sector to keep up with technological advancement.

Reddy (2012) examined Odisha's production and other related issues from 1991 to 2008, and while this study is not directly relevant to productivity analysis, some aspects of productivity and related issues were covered. It was discovered that Orissa was not using fertilisers, HYV, and a sufficient number of technological inputs in comparison to other states, and the author concluded that the use of all such factors would almost certainly result in increased TFP, which would reduce regional disparities across various regions and districts in Odisha. Estimated technical inefficiencies provided insights into the various dynamics at work in productivity issues. Income growth is possible if crop diversification and the use of HYV are accompanied by technological know-how.

Suresh (2013) investigated the way in which total factor productivity (TFP) grow of / paddy /rice in India from 1980-81 to 2009-10 and decomposed TFP growth into its constituent components, namely changes in technological forward movement and efficiency. The TFP was estimated by employing Malmquist Productivity Index method and data envelopment analysis in the research. The examination was also carried out for two sub-periods, namely 1980-1981 to 1994-1995 (Period I) and 1995-1996 to 2009-10 (Period II). TFP has changed at a moderate rate of 0.2% per year over the period, with large interstate variations. Positive TFP growth has been associated with a 0.3 per cent mean technical progress and a 0.1 per cent mean physical efficiency deterioration per year. Andhra Pradesh, Punjab, Tamil Nadu, and Uttar Pradesh all experienced positive TFP growth throughout the Period. The revival of the mean TFP to 1.8 per cent annually for Period II was primarily influenced by positive technical change during this period. However, the decline in technical efficiency is reason for concern. According to the study, the share of current / present-day and capital inputs in total cultivation cost has decreased during Period II, and input intensification has slowed. According to the findings, the recent yield stagnation in rice is not on account of technology fatigue, but rather to slow input intensification.

Karunakaran (2014) reported that TFP growth had declined over the years in many parts of India even with the application of increased inorganic fertilizers. The cropping system was sustainable if it could maintain total factor productivity over time. The TFP growth rate showed stagnation in the crop sector in Kerala and a similar pattern was recorded in all districts. A perspective of the TFP change over the districts and the state the percentage share of total factor productivity in product growth in Kerala showed clear signs of unsustainability of the crop sector. According to the findings of the research all the districts (except Kollam, Idukki, Wayanad and Palakkad) and entire State, the part of TFP in production/output growth was negative during the time span from 1980-81 to 2009-10. The Period wise analysis also indicated deceleration in the TFP growth.

Saha (2014) estimated the aggregate TFP for the Indian economy using the conventional growth accounting method. TFP increased by 1.49 per cent on average during the study period, but this expansion was erratic. Even though average TFP growth in India was positive during the 1960s, it was extremely small and close to zero. In similar fashion, the economy experienced technological regress instead of technical regress during 1970s due to the average negative growth. External shocks like war, drought, oil price-hike along with rigid conditions and rules during these Periods may be the probable reasons for low productivity has increased considerably after the initiation of internal economic reforms measures during 1980s. The economy had been experience of continuous rise in TFP growth since the introduction of external economic reforms. The research also disclosed that the TFP estimates in India were not sensitive to factor shares.

Praveena *et al.* (2015) evaluated the performance and efficiency of Indian sugar mills. On the output and resources data from 2009 to 2014, Data Envelopment Analysis (DEA) was performed using the constant returns to scale method. The Malmquist DEA was used to calculate the TFP. According to the study, the average physical efficiency of sugar mills in India was 59.50 per cent. Based on the average physical efficiency change, the majority of the mills were performing optimally, while the remainder of the mills were under utilizing their labour input. In comparison to the rest of the part, the mills in the southern regions were performing well. TFP changes may be increased or decreased as a result of technical and technological advancements. The TFP values of a few examples of firms were greater than one, indicating that the mills had increased their productivity.

Gami *et al.* (2016) analysed the growth in TFP of arhar crop and its sources in Gujarat state from 1990-91 to 2011-12. The Tornquist Theil Index had been employed to compute the total output index, total input index and TFP index. To create output and input indices, two outputs and ten factors were considered. The examination displayed that the arhar crop which registered negative TFP growth in 1990, vitally revived during 2000 with significantly positive growth of total input, total output and TFP indices at the rate of 2.16, 5.06 and 2.84 per cent per year, respectively, along with contribution of 67 per cent to output growth. During 2001-02 to 2011-12 though, the acreage has declined by 2.43 per cent, the production and productivity increased significantly at remarkable rate of 2.19 and 4.73 per cent per year, respectively.

Sharma and Dupare (2016) estimated TFP growth of soybeans and returns on soybean research spending / investment in India. The study discovered that TFP in soybean grew at a moderate rate (1.2 % each year), accounting for 10.5 per cent of total output growth. TFP growth and the portion of TFP in production growth have both increased in the last decade, according to a decade-by-decade examination. The research investment and irrigation were discovered being significant variables positively affecting TFP. Regardless of the fact that marginal value of research output is less than one, the IRR on research investment has expanded in recent decades, implying that research allocation and irrigation infrastructure should be improved for improved productivity and edible oil security in the country.

Mukherjee *et al.* (2017) estimated the performance of TFP growth of cotton crop and its determinants in Telangana state. TFP indices of cotton in Telangana were calculated to reveal the long-term performance of the sector. TFP of cotton in Telangana increased by 6 per cent per year from 2000-01 to 2012-13, owing primarily to rapid growth in the output index (12 % annually). Government spending on agricultural research, education, and extension, as well as average annual rainfall, were identified as the major determinants of cotton TFP growth in Telangana.

Niranjan *et al.* (2018) investigated growth in TFP of wheat, as well as growth in wheat area, productivity, and production in Madhya Pradesh. Secondary time series have been gathered for the study. These data have been categorized into three Periods: Period-I (1982-1991), Period-II (1992-2001), and Period-II (2002-2011), as well as an overall Period (1982-2011). The overall compound growth rate in area, output (production), and productivity of wheat (0.49, 2.35, and 1.86 %) was recorded to be statistically significant. As reported by the data, the output index was positive and extremely significant at 4.029 per cent overall period. During 1992-2001, seed was the primary cause of growth (0.698). In the case of fertilizer, the source of growth was positive throughout the period, but it was at its peak between 1982 and 1991. Fertilizers received the overall best response as a reason of growth. Manure is a source of growth, which was positive from 1982 to 1991, became negative and less responsive from 1992 to 2011 due to its insignificant use. TFP growth was more responsive to labour resources during 1982-1991 and 1992-2001. Similarly, in the case of animal labour, the negative impact as a source of growth is depicted throughout the Period. Input as a source of growth has a tendency to fall regarding to all input, indicating that the proportion of output /production to input has declined over time, but fertilizer and seed remain the major sources of growth for wheat crop in Madhya Pradesh.

Divya *et al.* (2018) investigated crop productivity growth in Andhra Pradesh. Time-series data on the expenditure of cultivation of selected crops were gathered for the study purpose from reports of the Commission on Agricultural Costs and Prices from 1996-97 to 2014-15. Malmquist productivity indices were calculated using a non-parametric data envelopment analysis (DEA) programming method. The research described the role of efficiency change in increasing crop productivity in Andhra Pradesh. The results explained that decomposing TFPch for the corresponding years into EFFch and TECHch revealed that a 72.6 per cent increase in TFPch is due to a 68 per cent improvement in efficiency.

Rana and Anwer (2018) analysed nature of yield /productivity growth in Indian potato sector and the measurement of Total Factor Productivity (TFP) was completed with the assistance of Malmquist Productivity Index (MPI). Year 2005 being the inflection point in the growth in Indian agriculture was employed as Period break year for the study and two Periods, viz. pre-Period (1997 to 2004) and post Period (2005 to 2013) were considered for all analysis and descriptions. Bihar, Uttar Pradesh and West Bengal constitute about 74 per cent of Indian potato production hence, these states were assumed to represent Indian potato scenario. Except mild decline in potato productivity growth in Uttar Pradesh, area, production and productivity growth of potato showed acceleration in post-Period compared to the pre-Period in all the states. TFP improved in all the three states in post Period however, in West Bengal the growth was negative (-2.3) even in the post Period. Except Bihar where efficiency change was positive (1%) in pre-Period, and further improved in post-Period (2.1%), the efficiency change stagnated in all other cases. The TFP enhancements in all cases were either solely or primarily led by the technical change. Invariably the TFP has showed improvement during post Period in all the states under consideration. For three states TFP improved by 4.81 per cent during post-Period and it was mostly affected by the technological adoption rather than the efficiency improvement.

Dinesh *et al.* (2019) calculated total factor productivity of millets in Karnataka and returns to investment in research in Karnataka. The Tornqvist Theil index of TFP is used for measuring TFP growth. For identification of sources of TFP growth regression analysis is used. Total output index (TOI), total input index (TII) and total factor productivity index (TFP) of jowar in Karnataka were measured for a Period of 45 years from 1971 to 2015-16 and sub-Periods considered were Period I (1971-1984), Period II (1985- 1994), Period III (1995-2004), Period IV (2005-2015) and pooled samples have been presented for comparison (1971-2015). The values of TOI for jowar started to increase from 1971- 1984 to 1985-1994 Period and decreased in 1995 -2004 Period i.e., after the liberalization of the economy, it could be because of the liberalization of the economy did not bring much investment into the coarse cereals and much importance has been laid to the commercial crops. The average value of TOI was 1.227 and growing annually at a rate of 0.352. Growth of TII started from 1971-84 to 1995-2004 and decreased in the 2005-2015 and registered higher in period 1995-2004. The average value of TII was 1.037 and growing annually which was about 0.281 per cent and which was significant at 5 per cent level. Similar to the TOI, TFP growth of jowar increased in 1994 and decreased during 1995-2004 Period, later during the Period IV the same has been picked because of the realization of importance by government spending on research and acceptance of HYV and hybrids might be contributed due to increased growth of TOI over TII and recorded more than one(1.272). The average value was 1.188 and growing annually at a rate of 0.07 and non-significant. TFP growth of jowar were government spending on agricultural innovation and education (per ha) (0.16), cropping intensity and percentage canal irrigated area. Value of R^2 was 0.57which suggests that variables present in the model causes 57 per cent changes in TFP.

Mishra (2019) Computed TFP growth for two sub-Periods, namely, 2001-2008 and 2009-2015, the study finds a deterioration in TFP growth for India in addition to other 10 and 19 states under study in the post global financial crisis Period. TFP is positively impacted by irrigation, health and road infrastructure. While financial depth and education had statistically insignificant effects on state level TFP, installed capacity of electricity had a negative impact.

Yadav *et al.* (2020) used the Tornqvist Theil index to work out the output, input, and TFP indices of the pomegranate fruit crop from 2000-01 to 2015-16. The TFP for pomegranate has increased from 1.36 in 2002–03 to 1.92 in 2015–16. In 2009–10, the TFP index was at its highest (3.71). For the previous 15 years, the average TFP index was 1.75. Pomegranate output index increased from 1.20 in 2002–03 to 1.38 in 2015–16. In 2010–11, output growth slowed and reached its lowest point (0.97). It's possible that it's due to severe drought conditions and the prevalence of Telya (oily spot) disease on pomegranate in Maharashtra. In 2014–15, the output index was at its peak (1.76). For fourteen years, the average output index was 1.28. In case of the input index, there was significant fluctuations, with the value falling from 0.98 in 2004–05 to 0.42 in 2009–10. For the previous fifteen years, pomegranate average input index was 0.78. TFP is growing at a 4.86 per cent annual rate. The average share of input in output was estimated about 63.70 per cent, with TFP accounting for 36.30 per cent of total production.

TFP growth was examined in order to quantify the contributions of various factors to TFP growth, such as research expenditure, rural literacy, rainfall, road density, N to P ratio, net irrigated area, and so on. It shows that research investment (0.08), N to P ratio (0.66), and area under drip (0.99) have all significantly contributed to pomegranate TFP growth. The nitrogen-to-phosphorous nutrient ratio (0.66) was used as a proxy for fertilizer balance. This coefficient was highly significant, indicating that farmers' output would increase if they used the correct N to P ratio. The density of roads (1.05) was used as a proxy for rural infrastructure. It is also non-significant but significant. The estimated R2 value was 0.64, indicating that the variables included in the model explained 64 per cent variation in TFP.

To sum up authors like Mittal and Kumar (2000), Mukherjee and Kuroda (2001), Pillai (2001), Pandya and Shiyani (2002), Bhushan (2005), Rao (2005), Kumar and Mittal (2006), Thorat (2006), Srinivas (2007), Nadeem (2010), Ghose and Bhattacharya (2011), Kannan (2011), Sehgal and Sharma (2011), Reddy (2012), Suresh (2013), Karunakaran (2014), Saikia (2014), Saha (2014), Das (2015), Praveena (2015), Gami (2016), Sharma and Dupare (2016) , Mukherjee (2017), Niranjan (2017),Divya (2018), Rana and Anwer (2018), Dinesh (2019), Mishra (2019), Yadav (2020), appraised Tornqvist Theil index to study the productivity performance of various crops and revealed that increase in TFP growth was contribution of technology for most of the crops.

2.3 Contribution of Investment in Agricultural Research and Extension

Kumar *et al.* (2004) evaluated the TFP growth in the Indian fisheries sector, examines the effect /impact of aquaculture /fisheries sector on various stakeholders and estimates the return to investment on fisheries research work and development. Time series-cum-cross-section data by state for inland and marine fish productions pertaining to fisheries resources, production, input use, prices and investment on fish research and development have been compiled from various published sources. TFP for inland and marine fisheries has been computed using the Divisia-Tornqvist index. The aquaculture sector is expected to grow at the rate of 4 per cent each year, while the marine sector is expected to grow at a rate of 2 per cent per year. Multi-market fish sector model developed at the World Fish Centre (Malaysia) has been used for India. For a given time horizon (2005–2015), projections for price, supply, demand, and export have been obtained under different fish technological growth scenarios. The contribution of technological change to the development of fisheries sector has been substantial on producers as well as consumers. Further technological advancements would improve the situation of the availability of fish to the costumers at cheaper rates and improve their nutritional security. The producers' income will also be enhanced. The internal rate of return of investment in fish research and development has been projected to exist in the range of 42 to 55 per cent under different TFP scenarios.

Kumar and Jha (2005) estimated the growth of TFP and return to rice research in India. Rice TFP growth was estimated across states and revealed that the largest growth was noticed in Uttar Pradesh and Punjab. The return from research investment for rice in Karnataka ranges from 32 to 74 per cent in Uttar Pradesh.

Nadeem and Mushtaq (2012) discussed long run relationship between agricultural research and TFP (total factor productivity) were estimated by using co-integration technique for 1970-2005. The consequences of the long run relationship between TFP and agricultural research indicated that agricultural research had a considerable and positive impact on TFP. The estimated coefficient of research was 0.571 and which was considerable at one per cent. Granger-causality tests showed a bidirectional relationship between research and productivity. The MIRR on research was calculated to be 73 per cent, indicating that the Punjab agricultural research system remained productive.

Joshi *et al.* (2015) illustrated the significant role of public investment in agricultural research and extension (R&E) plays in enhancing productivity, accelerating agricultural growth and reducing poverty in India. The study reveals that significant structural changes have occurred in the pattern of agricultural R & E investments across sectors and states over the past five decades. R&E investments on the crop and fishery sectors improved over time at the expense of the livestock sector. Similarly, the states 'share in aggregate R&E investments declined over the years, while the centre's improved proportionately. Returns to investments differed significantly according to geography, with the states that had a higher portion of TFP growth in their output growth performing better than the rest in relative terms. The investment in R & E for crop sub-sector in India has been especially rewarding, generating returns which were close to 50 per cent. In general, the study's findings suggests that the deliberate change in focus from alternative types of investment to agricultural R & E to meet the subsequent growth challenges in India's agriculture sector.

Gautam and Yu (2015), studied the comparative study of India and China regarding the total productivity growth. Research implies that, China's TFP growth rate was around 2 per cent, while growth rate of India was 1 per cent. But the agriculture of India is more susceptible to the weather conditions compared to China. It is figured out that there may be changes in certain policies in India to increase productivity and increase investment in R&D to use advanced technology and increase diversification. But certain measures are to be taken in modifying the policies considering the negative effects such as greenhouse emissions, over pumping of ground water without decreasing the efficiency of production.

Suresh and Chandrakant (2015) analyzed Total factor productivity and IRR in Ragi (finger millet) crop research in Karnataka state. Research is considered as an important factor responsible for productivity enhancement. The return to investment for ragi crop during the Period 1990-91 to 2009-10 was 42.50 per cent. This means that every rupee spent on ragi research yielded a 42.50 per cent annual return.

Tan and Rajan (2015) reviewed TFP growth across the country. According to the research, the TFP is highest in western regions, with Gujarat ranking first, and lowest in eastern regions such as Bihar. TFP growth can be mainly attributed to technological development. The states with good technology investments have good TFP. Though agriculture contribution to Indian GDP has been decreasing the largest work force is still in agriculture so in order to develop TFP investments in public research is crucial. They proposed that states use the best of what they have for agriculture.

Williama *et al.* (2015) estimated the effects on net benefit of switching from conventional Tanzanian growing practices (spraying of chemical pesticides and non-pest control) to the use of African weaver ants (*Oecophylla longinoda*) to control pests in cashew and mango. Yield data from one cashew and one mango plantation covering two cropping seasons was used in an economic analysis. The use of chemical pesticides and weaver ants resulted in higher yields as comparison to the non-control treatment. Lower input costs in weaver ant treatments, though, resulted in higher economic returns than the use of chemical insecticides in both seasons and crops. In all cases weaver ant treatments also produced higher returns than non-control treatments, despite their higher costs. Switching to African weaver ants without feeding was feasible due to a net increase in benefits in both crops. In cashew, average net gain for the both seasons was 94 per cent higher when ants were used and 112 per cent higher when chemicals were used. The corresponding values in mango were 117Per cent and 63Per cent, respectively. Return to investment was highest for African weaver ants without feeding in cashew at 235 per cent in 2012-13 and 405 per cent in 2013-14 seasons. Similarly, MRR was highest for weaver ant without feeding in mango at 509 per cent in 2012-13 and 743 per cent in 2013-14 seasons. In conclusion, the use of African weaver ants without feeding was consistently the most economically feasible management strategy to be used in Tanzanian cashew and mango pest management.

Gami *et al.* (2016) analysed the growth in TFP of arhar crop and sources of TFP in Gujarat state from 1990-91 to 2011-12.To calculate the total input index, total output index and TFP index, Torn-qvist Theil Index was used. The analysis reveals that arhar crop which registered negative TFP growth in 1990s, vitally revived during 2000s with significantly positive growth of total input, total output and TFP indices at the assessment of 2.16, 5.06 and 2.84 per cent per annum, respectively, with a contribution of 67 per cent to output growth. Further, the analysis of determinants of growth in TFP demonstrates the government expenditure on research, extension education, development of canal irrigation, rural infrastructure in the state and *kharif* rainfall is the important drivers of arhar crop productivity in Gujarat. Returns on investment in arhar crop research turned out to be a highly profitable proposition, generating a 55.50 per cent Internal Rate of Return.

Dhandhalya *et al.* (2017) analysed the growth in TFP of wheat crop and its sources in Gujarat state from 1990-91 to 2011-12. The Tornqvist Theil Index was helped to estimate the total output, total input, and TFP indexes. Two outputs and ten inputs have been used to construct output and input indices. The findings display that during 2000s the area, output /production and yield of wheat were increased at remarkable rate of 11.62, 14.68 and 2.74 per cent per year in Gujarat after that Madhya Pradesh and Rajasthan. It has also registered moderate growth rates of output indices and TFP indices about 1.53 and 1.05 per cent per year, respectively in 2000s. This was contributed by the release of viz., GW-496 and GW-503 in 1989, GW-273 in 1997, GW-322 in 2002, GW-366 in 2006, including proper agronomical practices as well plant protection measures by the then GAU and SAUs in the state, remarkably increased the productivity of wheat in first decade of 21st century. The Investment on wheat research generated 29 per cent IRR discovered to be as a lucrative proposition in study Period. The sources of output growth implies that government money spent on agricultural research and education, balance use of fertilizers and advancement of earth /ground water furthermore to canal irrigation in the state, and good monsoon has positive and notable impact on TFP.

Singh *et al.* (2017) estimated TFP growth for paddy, wheat, tur, cotton, banana, and sugarcane from 1986-87 to 2009-10 in South Gujarat. TFP growth in crops has created a strong consciousness/perception that technological movement occurred in rice, wheat, arhar, cotton, sugarcane, and banana, but cotton has benefited the most from technological innovations over the last twenty-four years, with TFP expansion /growth of more than 3 per cent. During the period 1986-2009, returns on research investments of an additional one rupee were ₹ 4,24 in paddy, ₹ 5.73 in cotton, ₹ 7.18 in tur and ₹ 3.16 in banana. The marginal rates of return (MIRR) on agricultural research were found to be between 35 and 54 per cent, indicating that spent in agricultural research over the last 24 years has delivered appealing returns. During the period 1986-2009, the overall international rates of return were 38 per cent for rice, 51 per cent for wheat, 47 per cent for tur, 43 per cent for cotton, 54 per cent for sugarcane, and 35 per cent for banana.

Sonawane *et al.* (2017) analysed the economic impact of sorghum improvement project in Maharashtra. On average of input index of sorghum over twenty-one years was 0.79, indicating that technology is contributing to TFP growth even though input indices are decreasing. The TFP index growth a 3.28 per cent annual rate. TFP growth for *rabi* sorghum in Maharashtra was significantly influenced by research and rainfall. An additional rupee invested in sorghum research resulted in supplementary earnings of ₹ 6.20. IRR for sorghum research investment is predicted to be 34.61 per cent.

Pokharkar *et al.* (2018) concluded that research Performed an important role in pomegranate TFP growth in Maharashtra. An additional rupee spent on pomegranate research yielded an additional income of 20.87, indicating that expenditure /investment in pomegranate research yielded significant returns to farmers. As a result, the government should allocate significant funds to public research on pomegranate for yield improvement of the pomegranate crop, thereby providing food security for the masses.

Kulkarni (2018) investigated the average share of input in output, which was estimated to be on the higher side up until 2004. Following that, the input share decreased while the TFP share increased beginning in 2005. Except for pearl millet, it appears that the contribution of technology has expanded since 2005 for *rabi* sorghum and wheat crops. An additional rupee invested in pearl millet research resulted in an additional income of ₹ 16.03. The research expenditure flexibility was 3.85. This means that in order to achieve a 1 per cent growth/increase in TFP, research investments in Pearl millet in Western Maharashtra must be increased by 3.85 per cent. During the period 1993-1994 to 2013-14, the return to investment of pearl millet crop was 34.76 per cent. It was clear that investing in pearl millet research would be profitable. According to the marginal product of research investment, an extra investment of every rupee in *rabi* sorghum research generated an additional income of ₹ 7.38. The estimated value of *rabi* sorghum research expenditure flexibility was 5.26, suggesting that investments in *rabi* sorghum research are required to achieve a one per cent increase in TFP.

Adhale (2019) calculated the return to investment and the estimated value of marginal product (EVMP) and concluded that research investment has significantly contributed to TFP growth in sugarcane, with an extra investment of every rupee in sugarcane research generating an additional income of ₹ 30.65 and the internal rate of return for the sugarcane was ₹ 40.56 per cent.

Kulkarni *et al.* (2019) studied that public research investment has a meaningful impact on TFP growth in paddy. The addition of one rupee in paddy research resulted in an additional income of ₹ 3.04, indicating a significant rate of return on investment accompanied by internal rate of return of 39.10 on paddy research in Maharashtra.

From foregoing discussion it is concluded that a number of researchers have estimated the returns on funding to agricultural research and development in India and developed countries. Kumar (2004), Kumar and Jha (2005), Chatterjee (2007), Nadeem and Mustaq (2012), Joshi (2015), Gautam and Yu (2015), Suresh and Chandrakant (2015), Tai and Rajan (2015), Willima (2015), Gami (2016), Dhandhalya (2017), Singh (2017), Sonwane (2017), Pokharkar (2018), Kulkarni (2018), Adhale (2019), Kulkarni (2019), studied the contribution of agricultural research and extension and returns to investment on different crops.

2.4 Partial Budgeting and Upscaling the Technology

Chinnappa (2005) estimated economic feasibility of land reclamation technologies of Tungabhadra Command Area in Karnataka for amelioration of irrigation-induced soil degradation has been discussed. The data have been analyzed using tabular method and partial budgeting method. It was discovered that the available technologies are not being spread effectively among the affected farm households. Amongst different technologies accepted by the farmers, adoption of leaching has been found least costly and could result in an incremental output of 14 quintals per hectare on saline soils of both head- and mid-regions. Green manuring was another effective technology and could enhance crop yields on saline as well as waterlogged soils. Partial budgeting analysis has proposed that the technologies are viable irrespective of farm size. Biological methods such as adoption of salt-resistant crop varieties can be profitable for small and marginal farmers. Instead of leaving their lands fallow due to their inability to adopt capital-intensive technologies, they should adopt them for land reclamation and higher returns.

Basavaraja *et al.* (2008) examined the technological change in paddy yield in Andhra Pradesh by comparing profitability of SRI method of rice cultivation with the traditional methods. The yield realized in traditional method was 6.07 tonnes per hectare, while it was 8.51 tonnes under SRI methods. The production functions for SRI and conventional techniques were also estimated separately. Using the decomposition model, the gap in productivity between SRI and traditional method was decomposed into its sources. It was inferred that between technological and input use differentials, which together contributed to the total productivity difference of the order of 33.72 per cent, the former alone accounted for 31.61 per cent. This implied that paddy yield/productivity as it may be larged by about 31.61 per cent if farmers could switch over to from traditional method to SRI method with the evenly matched resources. Productivity differences between these two methods was 2.10 per cent

Basavaraj *et al.* (2013) evaluated the potential of using paddy harvesters and its effect on timeliness, harvesting cost, crop yield, farm income and employment. The results indicated that mechanical harvester ensured rapid harvesting, reduced harvesting costs, minimized post-harvest losses, raised income of farmers and assisted farmers in overcoming labour shortages during peak harvesting Period. The machine replaced labour by about 90 per cent, reduced harvesting costs by ₹ 5500 /ha and increased net return by around ₹ 35000/ha. Field conditions such as crop density, crop maturity, soil moisture condition, weed population, plot size, lodging and operators' skills determines the efficiency of harvesting. Mechanical harvester harvested 10 acres per day. The mechanical harvester is impressive equipment, which reduced the cost of paddy production by 25-30 per cent and reduced losses incurred after harvest to a considerable extent. Negative effects are noticed on employment opportunities and also on the income of harvesting labourers. Although the mechanical harvester has gained greater acceptance among farmers, the price of the machine is around 15 lakhs; which tend to discourage them to invest on this technology. However, it is possible to popularize these machines in major rice producing areas by providing financial incentives to farmers and companies and by way of conducting appropriate training programmes.

Christy and Vijayalakshmi (2014) conducted a partial budget analysis of mastitis control measures in the Tamil Nadu districts of Villupuram and Namakkal. The farmers who produce milk and dairy animals were chosen using a multistage random sampling process. The Villupuram district was divided into 22 blocks, three of which were chosen at random: Kallakurichi, Thiyagadurgam and Thirukoilur. The Namakkal district was divided into 15 blocks, three of which were chosen at random: Kabilarmalai, Mohanur, and Namakkal. Personal interviews were used to collect relevant data from the sampled respondents, with a pre-tested interview schedule. The statistics covered the years 2011-12 and 2012-13. Performing the initial set of control measures, which included cleaning the udder prior to and after milking, teat dipping, cleaning the stalls twice a day, standing cows for at least 30 minutes after milking, fore stripping, and milking clinical cases, causes a mastitis incidence of only 1.36 per cent. Dry cow therapy (Measure II) single resulted in a 33.33 per cent mastitis incidence. None of the farmers in the study area used culling of chronically affected animals (Measure III) as their sole mastitis control strategy. The combination of control measures I and II was found to be highly effective, with no incidence of mastitis. Adoption of all three measures (measures I, II, and III combined) resulted in zero mastitis incidence. Because all of the animals were infected with mastitis, implementing dry cow therapy along with culling of chronic clinical cases (combining measures II and III) had no effect on mastitis control.

Partial budget analysis explained that the first set of control measures (Measure I) resulted by highest net income of ₹ 1666.96, while the implementation of dry cow therapy which results into lower positive return of ₹ 1115.83, owing to higher drug costs and veterinarian's fees when compared to the first set of control measures. Furthermore, culling of severe mastitis animals would provide in a net negative return of ₹ 2632.97. Although culling was thought to be an effective mastitis control measure, the analysis concluded that it was economically unfeasible. Furthermore, a partial budget examination described that combining control measure I with dry cow therapy (measures I and II) resulted in a net return of ₹ 1210.39. All other combinations of control measures (Measures III, II, and III, as well as I, II, and III) produced only negative results.

Awan *et al.* (2015) studied profitability analysis of sustainable cotton production it is a case study of cotton – wheat farming system in Bahawalpur district of Punjab using partial budget technique. According to the study farmers data obtained from World Wide Fund (WWF) for Nature. Survey data of 1000 farmers for year 2013 was used from Bahawalpur district with 50 per cent respondents purposively selected from sustainable cotton farmers working with and licensed from WWF-P and other 50 per cent followers were the farmers using conventional practices and not involved with WWF-P’s project. Data were evaluated using partial budgeting and Cobb-Douglas Production Function methods. The data explains the degree of acceptance of SAPs (Sustainable Agricultural Practices) was higher among licensed farmers who have strong contract and better understanding and awareness about sustainable cotton program as comparison to those of non-licensed. The results further reveal that, education level and land holding size of respondents have positive impact on adoption of SAPs, while the age and farming experience of farmers were found to have a negative influence on SAP’s rate of adoption. From years of farmer’s education, amount of fertilizer used, amount of water used and make a use of practices like water scouting, natural pesticide, farmyard manure and Bt variety can increase the cotton yield as opposed to years of farmer's age and amount of pesticide may decrease it based on the regression analysis. It is obvious from the results that extension services have a significant role to disseminate information about sustainable use of resources and introduction of market based and control policy instruments to promote BMPs (Better Management Practices) and resource conservation.

Ponnusamy and Kausalya (2017) studied the role and factors associated with integrated farming system as a potential option to improve farmers income and ensure their sustainable livelihood in Tamilnadu and Haryana. The contribution of various enterprises combination *viz.*, poultry, fishery, sheep and goat and horticulture: with crop and dairy as, base enterprises have been analysed through partial budgeting approach. Farmers got incremental net benefit of adopting different enterprise combinations with improved management practices increased by ₹ 7880 for crop + dairy, ₹ 12680 for crop + dairy + poultry, 57530 for crop + dairy + poultry + Fishery and ₹ 35840 for crop + dairy +poultry sheep/goat occurred per hectare. A demand and profit-oriented shift in preferences of farmers towards keeping farm forestry, mushroom, fishery, goat and poultry rearing from 1994-2014 in Haryana was noticed by trend analysis

Pokharkar *et al.* (2018) reveals that even input indices decreased technology played important role in TFP growth. The total extra cost (variable + fixed) of university developed /released varieties relative to other competing varieties was found to be ₹ 29230.31 per hectare. However, the difference in costs (or savings) and returns due to university-released varieties as compared to competing varieties was ₹ 89267.07.In Maharashtra, the total economic worthiness of the university-released pomegranate production technology over other competing varieties of pomegranate was 98616.07 per hectare. Pomegranate growers in Maharashtra earned a total and net economic impact of 2883 crores and 1465 crores, respectively, because of improved pomegranate varieties released by MPKV, Rahuri.

Kulkarni (2018) concluded that private-sector pearl millet varieties compete fiercely with university-released varieties. The added expenditure and reduced cost of private and university released pearl millet varieties in comparison to competitors varieties was found to be ₹ 4022.81 per hectare. Reduced returns because of university released variety in comparison to competing varieties were 1.04 quintal and ₹ 1781.38 in monetary terms. Maldandi and related races of Maldandi existed in the study area and served as the control variety of *rabi* sorghum in this study. It was discovered that the total extra cost (variable + fixed) of university-released varieties over other competing varieties was ₹ 15346.00 per hectare. However, the difference in costs and returns due to university-released varieties in excess of competing varieties was ₹ 26325.35. As a result, the total economic worthiness of the university-released *rabi* sorghum production technology over competing *rabi* sorghum varieties in the region was ₹ 10979.35 per hectare. For the fiscal year 2014-15, the net economic impact for the agricultural community in Maharashtra was ₹ 19,81,36,916.20. For this study, there were no additional returns from university-released wheat varieties. As a result, the economic worthiness of the university-released wheat production technology over competing wheat varieties in the region was ₹ 4567.07 (12516.26-7949.18) per hectare.

Pande *et al* (2018) used partial budgeting approach to evaluate drumstick-based cropping system against tobacco crop. The research was drawing on data generated at research farm during 2003–2009. The drumstick-based cropping system was not only found to be remunerative than tobacco but also provided environmental services in terms of soil carbon built up and nutrient saving in the soil. This holds promise for agro-ecosystem of central Gujarat, which has predominant tobacco mono cropping system that is averse to soil conservation. Besides saving in irrigation water, the cropping systems enhanced returns over variable cost, saving in soil nutrients valued at ₹ 657 /ha and sustained soil carbon built up valued at ₹ 3696 /ha. This environmental benefit provided by drumstick-based production system has implications for resource conservation and environmental security, thus, making it legitimate in view of the national action framework to find alternative crop after signing the Framework Convention on Tobacco Control of World Health Organization.

Roy (2018) reported impact of an intervention brackish water aquaculture technology implemented at farmer's field under NAIP project at different villages of south 24-Pargans district of West Bengal aiming for rainwater harvesting for irrigating crops. Farm data was gathered from selected farmers of both Intervened and control groups. Partial budgeting analysis done to assess the comparative performances in relation to resources of income and livelihoods, diversification of input cost, labour cost, employment generation, production etc. Partial budgeting parameters like estimated costs, returns, net income and profit are found favourable for most Intervened Technologies in comparison to the existing farming practices. The outcome of 'Brackish Water Aquaculture Technology' assessed because of the fact that the landscape and cropping pattern has been changed from single crop to multi crop round the year resulting in enhanced productivity, employment generation, income and related activities arresting migration of people to cities in search of jobs for livelihood in intervened farmer's plots compared to those in control plots. Livelihood opportunities have increased considerably in the area without affecting the environment. Beneficiaries and family members are observed fully engaged in farming, marketing and associated activities. Many people have been affected directly and indirectly in agriculture related activities like farming, input supply, trading, marketing and transport operations as a result of intervention of the proven technology of ICAR-CIBA adopted by NAIP for field extension. The 'Brackish Water Aquaculture Technology' having potential of manifold increase productivity in the low-lying saline belt of Sundarbans which depends on tide water inflow, may be continued to a wider section of non-beneficiaries for long term social, economic, benefit and social equity resulting in a balanced society frame work.

Adhale (2019) estimated that the total and net economic impact of the Co-86032 sugarcane variety on the agricultural society in Maharashtra state over the next 22 years was 100787.28 crores and 11059.40 crores, respectively. For the nine years, the total and net economic impact of the CoM-265 sugarcane variety on the farming sector in Maharashtra state was 31681.32 crores and 2215.03 crores, respectively. Co 86032 and Co 265 have a net economic impact of 13274.43 crores and a gross economic impact of 132468.60 crores on Maharashtra's farm economy, respectively.

Nagaraj (2020) used a partial budgeting approach to explore and measure the impact of micro-irrigation. Primary data was collected from a farmer in Hulidenahalli village, Kolar District, Karnataka, for this purpose. The debit side reflects the extra costs associated with drip irrigation as well as any decrease in return, whereas the credit side reflects the cost savings associated with drip irrigation as well as any incremental returns associated with drip. The total extra cost (direct + indirect) incurred as a result of drip irrigation was calculated to be ₹ 19664 per acre. However, the lower costs (or savings) and increased returns due to drip irrigation total ₹ 60000. Drip irrigation provides an additional benefit of ₹ 42,000/acre/crop. The incremental cost benefit ratio indicates that for every rupee invested in drip irrigation, an incremental return of ₹ 3 was generated.

Salunkhe *et al.* (2020) used a partial budgeting approach to assess and quantify the impact of university-released chickpea varieties. Varieties released by the AICRP, Pulses Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri were examined for this purpose because they performed admirably with a gradual increase in adoption. The total extra cost (variable + fixed) of university-released varieties over competing varieties was found to be ₹ 8231.00 per hectare. Although, the difference in costs (or savings) and returns due to university-released varieties over competing varieties was ₹ 25916.11. Thus, the economic worthiness of the university-released chickpea production innovation /technology over other competing varieties of gram in the region for the year 2017-18 was ₹ 17685.11 per hectare. The gross and net economic impact of chickpea varieties on the agricultural community in Maharashtra state was ₹ 29120.37 crores and ₹ 6189.27 crores, respectively, from 1990-91 to 2017-18. As a consequences, it is recommended that the government allocate significant funds for chickpea crop research and extension.

To sum up Chinappa (2005), Basavaraja (2008), Basavraj (2013), Christy and Vijayalakshmi (2014), Awan (2015), Robert (2016), Ponnusamy and Kaushalya (2017), Pokharkar (2018), Pande (2018), Roy (2018), Adhale (2019), Nagaraj (2020), Salunkhe (2020), used partial budgeting analysis to asses the impact of research technology, on income generation.

3. METHODOLOGY

For any scientific investigation, it is must for an investigator to get well acquainted with method of conducting research. He should also follow appropriate steps in carrying out research to get desired results. In the area of research in agricultural economics, the steps involved are planning of objectives for research, nature of information to be collected, methods of acquiring the data, selection of sample and analysis of data. In this study the analytical tools *viz*., Total Factor Productivity (TFP), factors affecting TFP, Estimated Value of Marginal Product (EVMP), Internal Rate of Return (IRR) and incomplete budgeting technique in addition to varietal impact using up-scaling technique were used. This chapter explains the research methodology used for the current research work.

The various statistical tools and techniques are organized under the headings that follow.

3.1 Selection of research station

3.2 Nature and sources of data

3.3 Analytical tools and techniques

3.1 Selection of Research Station and Study Area

The varieties developed by onion research scheme, Pimpalgaon Baswant and Scheme for Research on Onion Storage under Mahatma Phule Krishi Vidyapeeth, Rahuri have dominated the onion area in Maharashtra. So, these two research stations were purposively selected for research study. The study based on both primary and secondary data. The information related to research and extension expenditure and seed sale of onion crop were assembled from the financial records of research station. Total number of samples to know varietal spread of university released onion varieties in Maharashtra are 63 for 2019-2020 year.

3.2 Nature and Sources of Data

Onion Research Station, Pimpalgaon Baswant, and Scheme for Research on Onion Storage, MPKV, Rahuri provided the primary data on investment in research, extension costs, and seed cell ,it is also considered as secondary data. The year-by-year data on (i) research expenditures, ii) pay and contingency expenditures, and iii) agriculture district-by-district development and extension, among other things, was accumulated and employed in the current study's analysis. Data on area, production, and productivity of onion over time was collected from secondary sources i.e., different published records of the state government, cooperative institutions *viz.,*(i) Season and crop reports, Departments of Agriculture, Government of Maharashtra, Pune, (ii) Statistical Abstract of Maharashtra State, Directorate of Economics and Statistics, Government of Maharashtra, Mumbai, (iii) Epitomes of Agriculture in Maharashtra, Part–II (iv) Socio-economic Review and District Statistical Abstracts of all districts in Maharashtra, Directorate of Economics and Statistics, Government of Maharashtra, Mumbai and (v) Census report *viz.,* agricultural census. The data regarding non inputs *viz*; rainfall, temperature, GIA, road density, N to P ratio etc. were collected from several publications of government for estimating the sources of output. The data related to per hectare input use, output and their values/prices were collected from the official documents of the state's cost of cultivation scheme for the year 1990 -91 to 2018-19 to estimate input, output and TFP index.

3.2.1 Crop Covered

Onion crop was selected to study impact analysis.

3.2.2 Period of Study

To judge the effect of onion varieties on the farm economy of Maharashtra, the period was considered from 1990-91 to 2019-20 (29 years).

3.3 Analytical Techniques

3.3.1 Compound Growth Rates

The compound growth rates for each district were calculated using time series data on onion area, production, and productivity, region in addition to entire Maharashtra for 45 years of study period *viz*., 1975-76 to 2019-20 using log-linear production function. The compound growth rates of 29 years i.e. from 1990-91 to 2019-20 were also estimated for input index, output index and total factor productivity index for onion. The overall and sub-periods were divided as below

Period		Year
Period I	:	1975-76 to1985-86
Period II	:	1986-87 to1996-97
Period III	:	1997-98 to 2007-08
Period IV	:	2008-09 to 2019-20
Overall Period	:	1975-76 to 2019-20

Exponential function was used for estimation of compound growth rate.

$$Y = ab^t e$$

Where,

Y = Growth was estimated for the explained variable. (i.e. area, production, productivity, input index, output index and TFP index)

a = Intercept or constant

b = Regression/trend coefficient

t = Periods in years (1, 2, 3…n)

e = Error terms with a constant variance and a zero mean

Compound growth rates were estimated to investigate the percentage change in the parameter of interest.

3.3.2 Instability Analysis

Lack of stability in the area, production, productivity of onion was studied using two measures of instability such as Coefficient of Variation and Cuddy-Della Valle index.

Coefficient of Variation (C.V) = (Standard Deviation / Mean) * 100

Even though the most basic measure of instability and stability is the coefficient of variation (C.V.), it overestimates the level of instability in time series data with long-term trends.

Cuddy Della Valle is a character in the film Cuddy Della Valle the instability index is a modification of the coefficient of variation that accounts for data trends, which are common in economic time series data. This method outperforms standard deviation and other scale-dependent measures.

The Cuddy Della Valle Index de-trends shows the exact direction of the lack of stability. Therefore, it is a superior measure to apprehend instability in agricultural production. A low value of this index indicates low instability in different variables and vice-versa. The Cuddy-Della Valle index corrects the CV as:

$$\text{Cuddy - Della Valle Instability Index (\%)} = CV \sqrt{(1-R^2)}$$

Where,

C.V is the Coefficient of Variation in per cent, and R^2 is the coefficient of determination from a time trend regression adjusted for its degrees of freedom.

The ranges of CDVI are given as follows:

- Low instability = 0 to 15
- Medium instability = greater than 15 and less than 30
- High instability = 30 and above

3.3.3 Extent of investment in research and extension

For the present study two approaches were used *viz.,*

1. Total factor productivity
2. Sources of TFP growth

1. Total Factor Productivity

Three different approaches for estimation of TFP, namely the Production Function Approach (PFA), Growth Accounting Approach (GAA) and the most recent one being the Non-parametric Approach. Growth Accounting Approach (GAA) was helped to calculate the TFPG.

a. Growth accounting approach (GAA)

Solow (1957) was the first to propose a framework for growth accounting. TFP is measured as a leftover factor in this approach, which refers to the segment of output growth that is not considered by growth in the rudimentary inputs. This method calculates factor productivity indices, primarily the rate of change of total factor productivity indices, to approximate technological change (Christensen, 1975). The ratio of the index of net output to the index of total factor inputs is used to compute the TFP index.The total factor inputs index is calculated as a weighted average of the indices of labour, capital, and land inputs, with the respective income proportions of three variables as weights. The separation of change in yield due to the quantities of factors of production from residual influences, such as technological progress, learning by doing, etc., is a key feature of the GAA. The GAA uses three main indices : (i) the Kendrick Index (KI), (ii) the Solow Index (SI), and (iii) the Translog Index (TI) (TLI).

The Solow Residual is defined as [gy-a x gk-(1-a) x gl], where gy is the output growth rate, gki is the capital growth rate, gli is the labour growth rate, and a and (1-a) are the capital and labour share, respectively. If I the production function is neoclassical, (ii) perfect competition exists in factor markets, and (iii) the growth rates of inputs are accurately measured, the Solow residual accurately measures TFP growth.

The Divisia-Tornqvist Theil index ofTFP is widely utilized.for estimation of total output, input, and TFP indices can be specified as:-

Total Output index: $TOI_t / TOI_{t\_1} = \boldsymbol{U}_{\boldsymbol{j}}(Q_{jt} / Q_{jt-1})^{(R_{jt}+\boldsymbol{R}_{jt-1})1/2}$ .... (1)

Total Input index: $TII_t / TII_{t\_1} = \boldsymbol{U}_i(X_u / X_{it-1})^{(S+S*1)1/2}$ .... (2)

Where,

R_{jt} = Share of j^{th} output in total output,

Q_{jt} = Output of the j^{th} commodity,

S_{jt} = Share of the i^{th} input in total input cost, and

X_u = Quantity of the i^{th} input

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

TOI(t) = TOT(1).TOI(2) .... TOI (t-1) ....(3)

TII(t) =TII(1).TII(2) .... TII (t-1) ....(4)

Finally, the TFP index is expressed as

$TFP_t = TO/TH,$ ....(5)

The Kendrick index and the Solow index, on the other hand, have some drawbacks. The Translog index, on the other hand, outperforms both the Kendrick and the Solow indices because its numbers are symmetric in data from different time periods and approximate the factor reversal test. It's based on the Translog Production Function, which is characterized by constant scale returns.

Total Factor Productivity (TFP) has become the choice measure of productivity. TFP captures the effects of changes in technology, institutions, and other productivity shocks, but it gives little insights as to what takes place interior to the black box of technology. TFP can be interpreted in four different ways: (1) it is the change in output made possible by the passage of time, keeping input quantities constant (2) it is the average of the instantaneous rates of technological change of times t-1 and t; (3) it is the average rate of technological change between times t-1 and t; (4) it is the part of output growth that cannot be explained by input growth. The expression “total factor productivity” refers to an index that measures Total production per unit of total input. TFP growth refers to the increase in output that is not offset by an increase in total inputs.

For the onion crop, the output index, input index, and TFP index are created. To create the output index, time series data from 1990 to 2018 were used the main product, by product, and prices, whereas to create the input index, time series data from human labour, bullock labour, machine labour, seeds, manure, fertilizer (NPK), irrigation, and input prices were used. Finally, by dividing the output index to the input index, the TFP index is calculated. We specified that the index is equal to 1.00 in a specific year, i.e., we used 1990-91 as the base year and constructed the TFP chain index because it gives annual changes in the productivity of onion over time.

Throughout the study period, the Chain-linking index consider the changes in relative values/costs. This technique has the advantage of reducing biases by ensuring that there is no single year has a prominent role in deciding the share weights. For the years 1990-91 to 2018-19, time series data on onion costs and returns were amassed and assembled from the cost of cultivation scheme, Department of Agricultural Economics, MPKV, Rahuri.

The following are the TFP indices:

Total output index:

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

Total input index

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

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

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

Input price index is given by,

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

Where,

R_{jt} = Share of j^{th} output in total revenue

Q_{jt} = Output 'j'

S_{jt} = Share of i^{th}input in total input cost

X_{it} = input 'i'

P_{it} = Price of i^{th} in period 't'

The preceding equation yields the total output, total input, total factor productivity, and input price indices for the specified period 't' by setting TOI t-1, TIIt-1, and IPIt-1 equal to 100 in the first year.

The chain-linking index accounts for changes in relative values/costs over the study period. This method has the advantage of reducing biases by ensuring that no single period has a dominant role in determining share weights.

2. Sources of TFP growth

To quantify the contribution of different factors in TFP growth and examine the determinants of TFP, the Cobb-Douglas type of production function was carried out.The TFP index was regressed against the following variables as a means to access the determinants of TFP:

. $$\mathbf{Y = a x_1^{b1} X_2^{b2} x_3^{b3} x_4^{b4} x_5^{b5} x_6^{b6} x_7^{b7} x_8^{b8} x_9^{b9} x_{10}^{b10} e^{u}}$$

Where,

Y = Total factor productivity index (TFP)

A = Constant term

X_1 = Research investment (₹ /ha)

X_2 = Rural Literacy (%)

X_3 = Rainfall(mm)

X_4 = Road Density (km.)

X_5 = N to P ratio

X_6 = GIA (%)

X_7 = Cropping intensity (%)

X_8 = Electricity (Agril. Consumption GWh)

X_9 = Max. Humidity

X_{10} = Min. Humidity

T = Time variable (years 1, 2, 3…. n)

U = Error term

(b_1 to b_{10}) are regression coefficients of respective variables

3.3.4 Impact of research and extension on income generation

A. Estimated value of marginal return

The data was compiled from time series data from various years. The value of the marginal product of research was estimated utilizing the flexibility of TFP in research as shown below.

EVMP(R) = b*(V*TFP share/R)

Where,

R	:	Research investment (Per ha)
b	:	TFP Elasticity of research investment
V	:	TFP is associated with a high value of production.
EVMP	:	Estimated Value of Marginal Product

3.3.5 Contribution of investment on research and extension

a. Internal rate of return

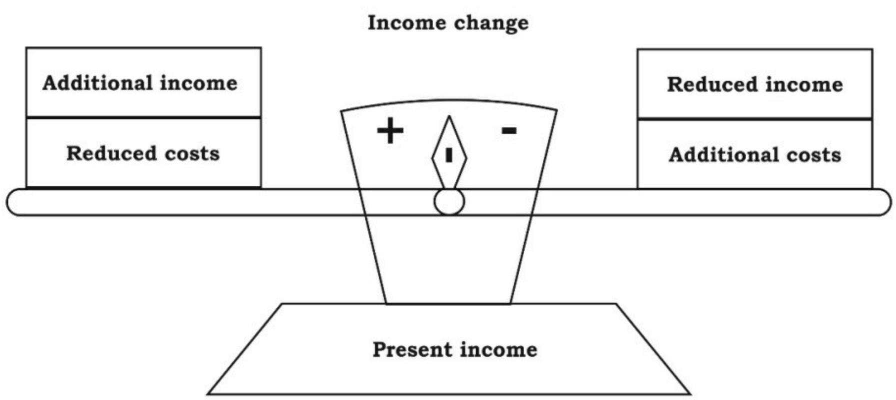
Internal rate of return, also designated as Marginal efficiency of capital or Yield on Investment, is a measure of how profitable is an investment . IRR is the interest rate which was earned on the unrecoverable balance over the life of an investment in this manner irrecoverable balance is zero at the end of that time. The discount rate at which an investment's NPV (Net present value) becomes zero is known as the "IRR." Alternatively stated, a discount rate is a figure that compares the present value of an investment's future cash flows to the primary outlay. It is one of them several methods for evaluating investments. The IRR must be greater than the minimum attractive rate of return for a firm to accept an investment decision, and it must be less than the MIRR for a firm to accept a borrowing decision. The IRR is popular in determining project adaptability in economic meaning. After examining the lower and higher discount rates at which Net Present Value (NPV) equals zero, IRR can be calculated. For estimation of IRR, the cash inflow (Research cost/ha) and cash out flow (gross return/ha) were taken in to consideration. The IRR can then be calculated as.

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

b. Partial Budget Approach

A partial budget helps farm owners/managers to evaluate the financial effect of incremental substitutes. An incomplete budget only includes resources that will be changed. It does not consider the factors/resources in the business that are left unchanged. It analyses net financial return from small changes or refinements to your farm operation. It focuses only on those income and expenses that change with the proposed new alternative. Limited budgeting is used to determine whether a partial change in the farm, for instance the application of a new variety, new technology, new innovation, new practise, new equipment, or new service, is economically viable.

The effect /impact of the research end result on income creation were estimated using a partial budget approach. Incomplete budgeting is an instrument of storing and organizing experimental data and information about the expenditures and profits of a change in the farm's technologies. Partial budgets do not estimate the total income and expenses for each of the alternative plan but list only those items of receipts and expenses that change. They measure changes in proceeds and returns to limited resources, provide a limited assessment of risk and, through sensitivity analysis, suggest a range of prices or costs at which a technology becomes profitable.



Debit side / Expenditure side

A. Expense incurred because of the cultivation of improved varieties

List of all increased costs because of the change being considered. Most of these will be costs of manufacturing for the new enterprise. This list may also include non-cash costs such as manpower and depreciation. This includes additional cost on account of human labour, machine labour, seed, manure, irrigation, management, risk premium, research and extension etc.

B. Reduced profits as a result of cultivation of improved varieties

Another consideration here may be reductions in yields due to new variety. This can reduce quality and yields that reduce farm income. It includes reduced returns in main produce and by produce in quantity terms as well as in monetary terms if any.

Credit side/return side

A. Reduced costs as a result of university-released variety cultivation

These costs could be reductions or total elimination of certain expenses. It includes saving on cost of man power, machine power, seed, manure and irrigation etc.

B. Added returns from university released variety

It includes added returns in main produce and by produce in quantity terms as well as in monetary terms. Partial budgeting technique, helps to find out the remunerative worthiness of different university released varieties, which shows the economic impact of university released varieties in Maharashtra when compared to other competing varieties.

c. Upscaling the Economic Impact

Innovations and knowledge are key drivers of economic growth. Globally, there is a growing interest in enhancing innovation, which is the method through which new knowledge is generated, disseminated, adapted and, finally, deployed on a large scale so that its socio-economic benefits can be maximized for this upscaling of technology is become essential. Due to the functioning of law of diminishing marginal returns in its early stages in agriculture, upscaling technique is appropriate for a larger area of onion varieties. However, linear extrapolation of the benefit per ha is not justifiable. Three parameters are used in linear extrapolation to consider the functioning of Law of Diminishing Marginal Returns (LDMR): I) Probability performance of the technology, II) Rate of adoption of onion varieties, and III) Depreciation in the technology.

Because conditions of field are not the same as the lab conditions, and the farmer who done actual work is not synonymous with the researcher, these perfectly express the functioning of the LDMR. The term "upscaling" refers to a method in which data from a lower spatial scale is translated into data from a higher spatial scale. The economic worth of university released varieties was multiplied by depreciation, rate of adoption, and probability of actual yield of variety in the upscaling technique, resulting net return from the concern variety.

3.3.7 Area Under University Released Onion Varieties

The onion seed sale historical data from Scheme for Research on Onion Storage, MPKV, Rahuri was collected to estimate the area under university released onion varieties. The area under the onion in Maharashtra is estimated by dividing the entire seed sales by the onion seed rate. For estimating the area under university-released onion varieties, farmers-to-farmers seed diffusion, particularly for improved varieties, was also taken into account.

3.4 Salient Features of the Study Area

The two onion research stations Onion Research Station Pimpalgaon Baswant and Scheme for Research on Onion storage, Central campus, MPKV, Rahuri were considered for the research. The salient features of the study area are as below,

3.4.1 Onion Research Scheme, Pimpalgaon Baswant

a. **Year of Start**: 1959

b. **Mandates**

1. To develop varieties for *kharif*, *rabi* and summer seasons.
2. To standardize packages of practices for onion cultivation.
3. To discover suitable control measures for different pests and diseases.
4. To standardize the storage structure of onion.

c. **Varieties released by research stations**

Sr. No.	Variety	***Kharif*/Late *kharif*/*Rabi***	Year of release
1	Baswant-780	*Kharif*/late *kharif*	1986
2	N-2-4-1	*Rabi*	1987
3	N-53	*Kharif*	1987

d. **Infrastructure:**

Land : 15.09 ha

Irrigation facilities : Well, Bore well

Laboratories : Basic facilities

e. **Ongoing research**

1. Impact of seasonal variation of *rabi* onion in context of late rains
2. Effect of silicon on growth, yield and quality of *rabi* onion.
3. Effect of silicon on growth, yield and quality of *kharif* onion
4. Effect of silicon on disease incidence, growth and yield of *kharif* onion
5. Seasonal incidence of purple blotch of *kharif* onion.
6. Seasonal incidence of Stemphylium blight of *rabi* onion.

3.4.2 Onion storage and research scheme

a. **Year of Start :** 1981-1982

b. **Mandates**

1. Collection and maintenance of onion germplasm for both *kharif*, late *kharif* and *rabi* season.
2. Development of cultivars with a high yield.
3. Standardization of package of practices for *kharif*, late *kharif* and *rabi* onion.

4. Supply of quality breeder seed for multiplication.
5. Education and training to the farmers for adopting newly developed varieties with modern techniques for maximization of production in onion.

c. Varieties released

Sr. No.	**Variety**	***Kharif*/Late *kharif*/*Rabi***	**Year of release**
1	Phule Safed	*Kharif*/*rabi*	1994
2	Phule Suvarna	*Kharif*/*rabi*	1996
3	Phule Samarth	*Kharif*/late *kharif*	2004

d. Infrastructure:

Land : 2.10 ha.

Irrigation facilities : Open well and bore well

e. Ongoing research

1. Assembling, evaluation and maintenance of onion germplasm for three seasons.
2. Improvement in onion through composite breeding.
3. Population improvement in *kharif* onion.
4. Evaluation of different storage structures for onion storage.

Seed Production

1. Nucleus seed production of Phule Samarth.
2. Breeder seed production of Phule Samarth, Phule Safed and Phule Suvarna.
3. Truthful seed production of Phule Samarth.

3.5 Onion Economy of India and Maharashtra

Onion is a cash crop that is used not only for internal consumption but as the fruit and vegetable with the highest foreign exchange earnings. For the year 2018-19, the world's onion area, production, and productivity were 5.1 Mha, 99.94 MT, and 19.4 t/ha, respectively (FAO Website). World's second largest producer of onion is India, after China, but its productivity is very low, at 17.01 tonne/ha, as comparison with China and other countries such as Egypt, the Netherlands, and Iran. However, when compared to other countries, India's onion productivity is very low; India ranks 7th in onion productivity.

Maharashtra is the leading onion producing state in India. Maharashtra ranks first in area (35.19 %) and production (34.26 %) of onion in India. Nashik, Ahmednagar, Pune, Aurangabad, Satara, Dhule, Jalgaon and Solapur are the major onion growing districts of Maharashtra. Higher water content in onion has led to higher post-harvest losses in Maharashtra. *rabi* arrivals start from March end and continue till May and June.

3.5.1 Arrival pattern of onion in Market

The request /demand for onion is almost constant throughout the year, and fresh onion accessibility is limited to 7 or 8 months, with price spikes during lean periods due to poor storage conditions in the country. The main seasons, concentrated pockets, round year availability and onion harvesting seasons in the country is presented in Table 3.1 to 3.3. Different onion production seasons are namely (i) *Kharif* (ii) Rangada (iii) *Rabi* was observed in the country.

Table 3.1 Harvesting season of crop in leading states

	Lean Period		**Peak Period**

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maharashtra												
Gujarat												
Bihar												
Karnataka												
Andhra Pradesh												
Madhya Pradesh												
Rajasthan												
Haryana												
Uttar Pradesh												

Source: Indian Horticulture Database, 2020

It is obvious that from the facts that the Table 3.1 and 3.2 that, the fresh onions are available in almost every month in the country. However, major producing states of India are Maharashtra, Gujarat and Andhra Pradesh.

Table 3.2 Details of arrival pattern of onion in leading states

Sr. No.	States	Cropping season	Availability
1	Maharashtra and Gujarat	*Kharif* Late *Kharif* *Rabi*	October – December January – March April – June
2	Tamil Nadu, Karnataka and Andhra Pradesh	Early *Kharif* *Kharif* *Rabi*	August October – November March – April
3	Rajasthan, Bihar, Uttar Pradesh, Haryana, Punjab, West Bengal and Orissa	*Kharif* *Rabi*	November – December May - June

Source : Indian Horticulture Database, 2020

Table 3.3 Concentrated pockets of onion growing states

State	Districts
Maharashtra	Nasik, Ahmednagar, Pune, Solapur,Satara and Aurangabad
Karnataka	Dharwad, Chitradurg, Gadag, Haveri, Bagalkot and Davengere
Andhra Pradesh	Kurnool, Medak, Rangareddy, Cuddapah and Mehboobnagar.
Uttar Pradesh	Varanasi, Patan, Kanpur, Lucknow, Allahabad and Faizabad
Tamil Nadu	Coimbatore, Perambadur, Namakkal, Dindigul Anna and Thirichirapalli, Periyar
Gujarat	Bhavnagar and Surendranagar
Punjab	Ropar and Ludhiana

Source: Indian Horticulture Database,2020

3.5.2. Export performance of onion

India exported fresh and chilled onions quantity was about 11.48 MT and its worth was $3239.13 million in 2018-19. which is a record quantity after the export was canalized through (NAFED). Bangladesh, Sri Lanka and the UAE are the three different destinations for Indian onions. Maharashtra exported 6.41 MT fresh onion and its worth was $1642.5 million.

Big onions produced in Maharashtra, Gujarat, Tamil Naduand Karnatakaare exported from Mumbai, Chennai, Tuticorin, Kandla and Kolkata ports to Dubai, Kuwait, Saudi A*rabi*a, Middle East, Malaysia, Singapore, Seychelles and Bangladesh. Onions grown in India are very much in demand in Gulf Countries and Singapore, Malaysia, Sri Lanka and Bangladesh because of strong pungency.

Small onions produced in Andhra Pradesh and Karnataka is exported from Chennai port to Singapore and Malaysia, and multiplier onions to Singapore, Malaysia, and Sri Lanka, etc. Maharashtra has maximum share in onion export.

All three types of onions, Agrifound Dark Red and Agrifound Light Red (big onion), Agrifound Rose (small onion), and Agrifound Red (multiplier onion), have been developed for export by the NHRDF. The NHRDF have also tested yellow varieties where Arad (H) of Hazera Seed Co., Israel has performed best.

4. RESULT AND DISCUSSIONS

This chapter deals with the analysis and interpretation of the results. The analysis regarding CAGR, instability index, TFP and its index, determinants of TFP, EVMP, IRR, partial budgeting, up-scaling the technology etc., are presented as below.

4.1 Varietal Status of Onion

Various universities and institutes in India have generated a significant variety of onion cultivars suitable for growing in various areas and seasons. The cultivars created by NHRDF, Nasik, Maharashtra, including other significant onion varieties published by MPKV, Rahuri, are generally available to farmers for onion growing. However, two research schemes have released onion varieties i.e., Onion Research Station, Pimpalgaon, Baswant and Scheme for Research on Onion Storage, MPKV, Rahuri, the details of onion released varieties are presented in Table 4.1.

Table 4.1. Onion varieties released MPKV, Rahuri

Sr. No.	Varieties	*Kharif*/Late *kharif*/*Rabi*	Released year	Research Station
1.	Baswant -780	*Kharif*/late *kharif*	1986	Onion Research Station, Pimpalgaon Baswant, Nashik
2.	N-53	*Kharif*	1987	Onion Research Station, Pimpalgaon Baswant Nashik
3.	N-2-4-1	*Rabi*	1987	Onion Research Station, Pimpalgaon Baswant Nashik
4.	Phule Safed	*Kharif*/*rabi*	1994	Onion Storage Scheme MPKV, Rahuri
5.	Phule Suvarna	*Kharif*/*rabi*	1997	Onion Storage Scheme MPKV, Rahuri
6.	Phule Samarth	*Kharif*/late *kharif*	2004	Onion Storage Scheme MPKV, Rahuri

N-2-4-1 and Baswant-780 are two very old cultivars that were released in 1986 and 1987, respectively. These types, on the other hand, were popular among farmers in the past and are still popular today. Farmer's favour Baswant -780 because of its high yield potential, suitability for two seasons *kharif* and late *kharif* (Rangada), globose bulbs with maroon red colour, 13 per cent TSS, low bolting percentage, and suitability for wet and humid climates.

Table 4.2 Varietal spread of onion on sample farms in Maharashtra

Sr. No	Variety	Season	Area (ha)		Total area under university released onion varieties (%)	
			2018-19	2019-20	2018-19	2019-20
			N=243	N=63		
1	Baswant 780	*Kharif*/late *kharif*	6.44 (4.06)	0.38 (1.32)	**35.05**	**59.72**
2	Phule Samarth	*Kharif*/late *kharif*	14.83 (9.34)	8.11 (28.21)		
3	N-53	*Kharif*	28.81 (18.14)	4.63 (16.10)		
4	N-2-4-1	*Rabi*	5.57 (3.51)	4.05 (14.09)		
5	Pune Phursungi	*Rabi*	57.94 (36.49)	10.28 (35.76)		
6	Panchganga	*Kharif*/Late *kharif*/*Rabi*	16.75 (10.55)	--		
7	Local	*Kharif*/*Rabi*	19.67 (12.39)	0.4 (1.39)		
8	AFDR	*Kharif*	3.18 (2.00)	0.9 (3.13)		
9	China	*Kharif*/*Rabi*	2.37 (1.49)	--		
10	Ellora	*Kharif*/*Rabi*	1.68 (1.06)	--		
11	V-5	--	1.56 (0.98)	--		
	Total		158.80 (100.00)	28.75 (100.00)		

(Figure in parenthesis indicate that percentage of total area under onion)

Between 1994 and 1997, the university released two different promising onion cultivars, Phule Safed and Phule Suvarna, which occupied a large portion of the onion market. Phule Samarth, a promising onion variety, was released by the university in 2004. Farmers like this Phule Samarth variety because of its excellent storage qualities (2-3 months), shorter duration (80-90 days), dark red and globular bulbs, have premature bolting resistance, suitability for *kharif* and late *kharif* i.e. Rangda seasons, rapid bulb development, and higher market price. Currently, the area planted with MPKV's Rahuri onion varieties accounts for 35-40 per cent of Maharashtra’s total onion acreage.

Table 4.2 shows information on varietal spread of onion on sample farms in Maharashtra for the years 2018-19 and 2019-2020. The data on the area planted with different onion varieties in different districts of Maharashtra came from the State Cost of Cultivation Scheme. The total number of samples collected was 243 in 2018-19 and 63 in 2019-20. According to Table 4.2, the university released onion varieties that together account for nearly 60 per cent of the total acreage of onion on sample farms in Maharashtra for the 2019-20 season. Farmers preferred Phule Samarth (28.11 %) over N-53 (16.10 %) and N-2-4-1 (14.09 %) among the university-released onion varieties. Pune Phursungi is a competitor for university-released onion varieties, accounting for 35.76 per cent of total area on test farms.

4.2 Area, Production and Productivity of Major Onion Producing Countries

Around 170 countries cultivate onions for internal use, with others growing onions for export. On a global basis, about 12.97 million acres of onions are harvested each year, with 8 per cent of this crop being exported. Table 4.3 shows the area, production, and productivity of the top ten onion-producing countries in the world.

Table 4.3. Countrywise area, production and productivity of onion in World (2018-19)

(Area –Lakh ha, Production – MT and Productivity- t/ha)

Sr. No.	Country	Area	% Share	Production	% Share	Yield	Rank in yield
1	China	11.27	21.72	24.9	24.92	22.1	6
2	India	12.20	23.49	22.8	22.8	18.7	7
3	USA	0.055	1.01	31.7	3.17	60.53	1
4	Egypt	0.087	1.69	30.8	3.08	35.03	3
5	Pakistan	1.48	2.86	20.7	6.02	14.02	11
6	Turkey	0.068	1.32	22.0	2.20	32.01	4
7	Sudan	1.044	2.01	19.1	1.92	18.37	8
8	Bangladesh	1.72	3.32	18.0	1.8	10.45	10
9	Iran	0.045	0.87	17.8	1.78	39.18	2
10	Russia	0.058	1.12	16.7	1.67	28.68	5
11	Others	21.07	40.59	34.53	34.5	16.39	9
	World	51.92	100	99.96	100	19.25	

Source : Food and Agriculture Organization, 2019.

Table 4.3 shows that India ranks first in onion area (23.49 %) and second in onion production (22.8 %) in the World. China, any other way, is first in production and second in area of the world. India and China together accounted for nearly half of all onion production and area in the world. However, in comparison to other countries, India's onion productivity was very low. India ranks 7th in onion productivity, with about 18.7 tons/ha, while the United States ranks first with about 60.53 tons/ha. However, in comparison to the total world area and production of onion, the United States had a very small area and production of onion.

4.3 Statewise Area, Production and Productivity of Onion in India

Onion is a popular commercial vegetable in India and it is cultivated in various parts of India. Maharashtra, Uttar Pradesh, Karnataka, Madhya Pradesh, Gujarat, Andhra Pradesh, and Odisha are the different states have contribution in production of onion in India. Table 4.4 shows information on onion area, production, and productivity by state for the 2018-19 season.

According to Table 4.4, Maharashtra produces the most onions (8047.14 thousand tonnes), followed by Madhya Pradesh (3714.79 thousand tonnes), Karnataka (2645.61 thousand tonnes), Gujarat (1111.09 thousand tonnes), Bihar (1403.16 thousand tonnes), and Andhra Pradesh (970.55 thousand tonne). In India, the states of Maharashtra, Madhya Pradesh, and Karnataka accounted for roughly 60 per cent of onion output and area in 2018-19. Maharashtra has the highest onion acreage and output in the country, accounting for approximately one-third of the total.

However, when compared to other Indian states, Maharashtra lags behind in onion yield. Gujarat has the highest productivity (25.06 t/ha), followed by Madhya Pradesh (24.98 t/ha) and Bihar (22.29 t/ha).

Farmers in Maharashtra plant onion throughout the year, despite the fact that onion prices fluctuate a lot. In the *kharif* season, onion productivity is lower than in the *rabi* season. Apart from natural disasters, this might be the source of the problem for low onion yield in Maharashtra.

Table 4.4 Area, Production and Productivity of onion in India (2018-19)

(Area –000 ha, Production – 000 tons and Productivity- q/ha)

Sr. No	State	Area	Production	Productivity
1	Maharashtra	444.37 (35.19)	8047.14 (34.26)	181.90
2	Madhya Pradesh	148.71 (11.78)	3714.79 (15.82)	249.80
3	Karnataka	190.52 (15.09)	2645.61 (11.27)	138.86
4	Bihar	61.03 (4.83)	1403.03 (5.97)	229.88
5	Rajasthan	70.48 (5.58)	1388.42 (5.91)	196.99
6	Gujarat	44.33 3 (3.51)	1111.09 (4.73)	250.64
7	Andhra Pradesh	45.32 (3.59)	970.55 (4.13)	214.16
9	Haryana	32.01 (2.53)	696.92 (2.97)	217.72
10	West Bengal	35.28 (2.79)	638.38 (2.72)	180.95
11	Uttar Pradesh	26.90 (2.13)	440.38 (1.88)	163.71
12	Others	163.88 (12.98)	2428.77 (10.34)	148.20
13	India	1262.83 100	23485.07 100	185.97

(Figures in the parentheses indicates percentage to the total India)
Source: Ministry of Agriculture and Farmers welfare, Govt. of India, 2018-19.

4.4 Decadal Area, Production and Productivity of onion in India and Maharashtra

Table 4.5 shows that the area, production, and yield /productivity of onion in India and Maharashtra fluctuated over a decadal year. Over the 1980-81 period, onion production, area, and productivity increased by 403.90,786.92 and 77.04 per cent at country level and 754.55, 919.91 and 23.97 per cent at the state level, respectively.

Since the decadal base year of 1980-81, onion production and area in India and Maharashtra have steadily increased over the decades. However, onion productivity has fluctuated in India, particularly in Maharashtra, where onion productivity has been steadily declining over the decades with the exception of the most recent decadal year 2018-19.

Table 4.5 Decadal Area, Production and Productivity of onion in India and Maharashtra

Year	India			Maharashtra		
	A (000 ha.)	P (000 tonnes)	Y (T/ ha)	A ('000 ha)	P (000 tonnes)	Y (T/ha)
1980-81	251.00 (100)	2648.0 (100)	10.50 (100)	52.00 (100)	789.00 (100)	14.60 (100)
1990-91	301.00 (19.92)	3226.0 (21.82)	10.70 (20)	66.50 (27.88)	804.00 (1.90)	12.10 (-17.12)
2000-01	448.9 (78.84)	4721.1 (78.28)	10.5 (0)	118.1 (127.11)	1687.4 (113.86)	14.30 (-0.31)
2010-11	1063.80 (233.82)	15117.20 (470.89)	14.20 (35.23)	415.00 (726)	4905.00 (521.67)	11.00 (-24.65)
2018-19	1262.83 (403.11)	23485.7 (786.92)	18.59 (77.04)	444.37 (754.55)	8047.14 (919.91)	18.10 (23.97)

(Figures in parentheses represents the percentage change over the base year 1980-81)
(Source: Directorate of Economics & Statistics, DAC & FW)

4.5 Annual Compound Growth Rates in Area, Production and Productivity of Onion

An attempt in this section has been made to examine the changes in area, production and productivity of onion in Maharashtra. The growth rates were estimated through the medium of exponential function. The expansion in acreage, yield and productivity of onion were studied by estimating compound growth rates for period-I (1975-76 to 1985-86), period-II ((1986-87 to 1996-97), period-III 1997-98 to 2007-08) and period-IV (2008-09 to 2019-20) and entire period 1975-76 to 2019-2020. Tables 4.6, 4.7, 4.8, and 4.9, represent the compound growth rates of variables like area, production, and productivity of onion for different periods have been calculated and displayed in district-by-district, region-by-region, and for the entire state.

The growth of area, production and productivity was positive and significant for the overall period (1975-2020) in most Maharashtra districts, as shown in Tables 4.6 to 4.8. Except for Sangali and Kolhapur districts in Western Maharashtra, Latur, Jalna, Nanded, and Hingoli districts in Marathwada, and Amaravati, Gadchiroli, Gondia, and Washim districts in Vidarbha, all districts' area growth rates were positive and significant for the total period (1975-76 to 2019-2020). The production of onion was quite satisfactory in Nasik, Dhule, Jalgaon, Pune, Ahmednagar, Solapur, Satara, and Nandurbar districts of western Maharashtra region, Aurangabad, Osmanabad, Beed, and Latur districts of Marathwada region and Buldhana, Akola and Wardha districts of Vidarbha region for the complete period of study. However, the productivity was not satisfactory in Nasik, Sangali and Kolhapur districts in western Maharashtra region and Osmanabad, Jalna, Latur and Parbhani districts of Marathwada region. The productivity of onion was positive and significant in few districts of Vidarbha region for the entire period.

For overall period the performance of onion crop in respect of area expansion, production and productivity improvement was quite satisfactory in all the regions. The proportion of expansion in area, production, and productivity varied greatly between regions and over time. In different periods across different regions, no definite trend in onion area, production, or productivity was observed. Except for the Vidarbha region, the area expansion, production, and productivity improvement of onion were all quite satisfactory in period IV.

During the time frame being considered, the area, production, and productivity of the onion crop fluctuated greatly across all districts, regions, and the entire state. For the entire period of 45 years, the growth rates of onion area and production in Maharashtra (Table 4.9) were observed to be positive and highly significant at the 1% level. During that time, onion area, production, and productivity increased at rates of 5.77, 6.27 and 0.42 per cent per year, respectively. In different periods, the area and production of onions enlarged at a faster rate in periods III and IV, while onion productivity increased.

According to findings the performance of the onion crop varied greatly over time in terms of changes in area, production, and productivity among districts, regions, and the entire State. For the entire period, onion production increased in three regions and throughout Maharashtra, both in terms of area expansion and productivity improvement (1975-2020). Onion prices fluctuate due to variations in onion area, production, and productivity. The alternative hypothesis, namely that onion area, production, and productivity vary over time, has been proven. Similar observations were made by Dhakre and Bhattacharya (2013), Immanuelraj *et al.* (2014).

Table 4.6 District wise annual compound growth rates in area, production and productivity of onion in western Maharashtra

Sr. No.	District	CGR (%)														
		Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Nashik	0.61	-3.55**	-4.14***	2.35	2.02	-0.32	11.6**	16.29**	4.2**	6.57***	10.54***	3.72**	6.16***	6.42***	0.25
2	Dhule	3.09	6.32	3.13	-2.32	-4.28	-2*	13.75**	21.12***	6.5**	10.01*	10.58*	052	5.15***	6.63***	1.4***
3	Jalgaon	2.34*	-4.39**	-6.57**	-3.2	-2.71	0.5	10.4*	10.32**	0.07	12.87**	17.62***	4.21***	5.11***	5.71***	0.57**
4	Pune	0.21	0.82	0.6	23.4***	37.04***	11.05***	21.44***	12.55***	-7.32**	13.83***	17.04***	2.82	11.8***	12.64***	0.75*
5	A'Nagar	1.62	5.86*	4.17*	10.61***	10.58***	-0.03	2.43	3.7*	1.25	7.93***	9.4***	1.36	4.77***	5.29***	0.5*
6	Solapur	0.62	6.12***	5.46*	3.16	4.72	1.52	-4.11	-3.84	0.28	5.53	11.17***	5.35**	2.77***	3.69***	0.89***
7	Satara	2.19*	2.95	0.75	13.69***	14.57***	0.77	0.46	-1.69	-2.41	2.96	7.05***	3.97*	3.47***	4.82***	1.03***
8	Sangli	-	-	-	-	-	-	-2.15	-4.47	-2.37	-3.91	-5.92	-1.86	-2.13	-1.88	0.32
9	Kolhapur	-	-	-	-	-	-	20.8	19.52	-1.06	5.83	9.61	3.61	-4.14	-3.13	1.06
10	Nandurbar	-	-	-	-	-	-	-	-	-	3.96	6.34	2.29*	7.02*	10.01**	2.88***
	W.M.	1.19	0.02	-1.16	6.94 ***	9.36 ***	4.1 ***	10.17 ***	11.04 ***	0.34	8.63 ***	11.8 ***	2.54 ***	6.46 ***	6.85 ***	1.66 ***

*, ** and *** indicates significance level at 10, 5 and 1per cent level, respectively

Table 4.7. District wise annual compound growth rates in area, production and productivity of onion in Marathwada

Sr. No.	District	CGR (%)														
		Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Aurangabad	1.12	5.5*	4.34	15.74***	20.51***	4.12	3.92***	12.49**	8.25*	19.74*	23.3*	2.98	7.44***	9.11***	1.55***
2	Osmanabad	-1.9	-3.66	-1.79	3.77**	3.5*	-0.12	-2.04	-3.14	-1.13	8.16*	12.62***	4.12*	4.97***	5.47***	0.48
3	Parbhani	-	-	-	-	-	-	-0.11	6.15	6.26 **	14.05	16.8	2.42	0.26	-1.73	-1.98
4	Beed	-	-	-	-	-	-	-2.08	-2.47	-0.39	11.93 *	11.71	-0.19	3.71	4.88 **	1.14
5	Nanded	-	-	-	-	-	-	18.41***	16.95***	-1.24	-12.29***	-11.72 ***	0.64	-2.77	0.2	3.05 ***
6	Jalna	-	-	-	-	-	-	-	-	-	2.6	11.83	8.99 **	-3.2	2.57	5.96 **
7	Latur	-	-	-	-	-	-	2.92	10.63	7.49 *	27.39 ***	23.49 **	-3.06	8.33 ***	11.01 ***	2.47 **
8	Hingoli	-	-	-	-	-	-	6.2 *	3.92	-2.15	-2.49	4.77	7.44	-2.11	-1.32	0.8
9	Marathwada	-0.35	-0.03	0.32	18.92***	21.04***	1.78	3.51	7.85 *	4.19	15.86***	18.43***	2.22 **	8.35 ***	9.38 ***	0.95 ***

*, ** and *** indicates significance level at 10, 5 and 1per cent level, respectively

Table 4.8 District wise annual compound growth rates in area, production and productivity of onion in Vidarbha

Sr. No.	District	CGR (%)														
		Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Buldhana	1.28	9.08	7.7	0.23	-1.56	-1.78	6.09	6.97	0.83	11.64	12.3	0.59	3***	4.23***	1.2**
2	Amravati	2.54	8.55*	5.86**	8.2***	7.3**	-0.83	-4.6	-4.72	-0.12	-1.86	-1.25	0.63	-0.28	0.63	0.92***
3	Akola	-	-	-	-	-	-	14.09**	23.36**	8.13	2.17	4.74	2.52	7.29***	12.32***	4.69***
4	Yavatmal	-	-	-	-	-	-	4.51	6.18	1.6	-3.68	-0.36	3.45	-4.89**	-2.41	2.62***
5	Wardha	-	-	-	-	-	-	-8**	-8.61*	-0.67	-8.8	-7.48	1.44	-8.11***	-5.13**	3.24***
6	Nagpur	-	-	-	-	-	-	2.76	1.79	-0.94	-42.89***	-47.63***	-7.72	-21.76***	-22.94***	-1.36
7	Bhandara	-	-	-	-	-	-	4.58	2.97	-1.54	-33.46***	-35.63***	-3.27	-9.82***	-13.82***	-3.65
8	Chandrapur	-	-	-	-	-	-	5.14	8.36	3.06	-27.34**	-26.7*	0.87	-12.46***	-10.87**	1.81
9	Gadchiroli	-	-	-	--	-	--	-7.59	-6.28	1.42	29.25**	26.31**	-2.28	-6.38	-5.78	0.64
10	Washim	-	-	-	-	-	-	-	-	-	-0.47	3.79	4.28	-0.47	3.79	4.28
11	Gondia	-	-	-	-	-	-	-	-	-	-1.38	-2.16	-0.79	-1.38	-2.16	-0.79
	Vidarbha	1.82	8.25	6.14*	11.01***	20.4*	-6.73	4.03	7.84	2.83	4.36	5.59	0.49	4.72***	9.82***	6.46***

*, ** and *** indicates significance level at 10, 5 and 1per cent level, respectively

Table 4.9. Region wise annual compound growth rates in area, production and productivity of onion in Maharashtra

Sr. No.	Region	CGR (%)														
		Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	West Maharashtra	1.19	0.02	-1.16	6.94***	9.36***	4.1***	10.17***	11.04***	0.34	8.63***	11.8***	2.54***	6.46***	6.85***	1.66***
2	Marathwada	-0.35	-0.03	0.32	18.92 ***	21.04 ***	1.78	3.51	7.85 *	4.19	15.86 ***	18.43 ***	2.22 **	8.35 ***	9.38 ***	0.95 ***
3	Vidarbha	1.82	8.25	6.14 *	11.01 ***	20.4 *	-6.73	4.03	7.84	2.83	4.36	5.59	0.49	4.72 ***	9.82 ***	6.46 ***
	Maharashtra	1.42	1.03	-0.38	6.86 ***	7.61 ***	0.7	9.11 ***	11.13 ***	1.85 *	11.07 **	13.99 **	2.64 *	5.77 ***	6.21 ***	0.42 **

*, ** and *** indicates significance level at 10, 5 and 1per cent level, respectively

4.6 Instability in Area, Production and Productivity of Onion

The coefficient of variation and Cuddy Della and Vella instability index were used in the instability analysis to measure the consistency and instability in onion area, production, and productivity. Table 10 shows the onion coefficient of variation, Cuddy Della, and Vella instability indexes for the years 1975-76 to 2019-2020 for districts, regions, and Maharashtra as a whole. Period I (from 1975-76 to 1985-86), period II (from 1986-87 to 1996-97), period III (from 1997-98 to 2007-08) and period IV (from 2008-09 to 2019-20) were used to divide the time series data on area (A), production (P), and productivity (Y).

During the research period, value of Coefficient of Variation of onion for area was found to be high i.e., High variability and high value Cuddy-Della Valle instability Index (CDI) i.e., high instability for all districts in Maharashtra except Kolhapur and Solapur. For entire period it is indicated that area under onion was highly instable and inconsistent for most of the districts. For entire period (1975-2020) yield of onion is highly fluctuating and unstable for all of the districts of Maharashtra. The area, as well as the production, were found to be more unstable but productivity showed lower instability and consistent for most of the districts in Maharashtra. The high instability in production and area was mainly due to unfavourable climatic conditions, pest and disease attack, poor crop protection measures, high price fluctuations etc.

The Table 4.10. reveals that except in Vidarbha, the production and area of onion were inconsistent or unstable, but productivity was consistent and stable throughout the period in all of the state's regions. The area, production, and productivity of onions were found to be inconsistent or unstable. Because of erratic weather conditions, excessive rainfall, and extreme hot and cold conditions, production in Maharashtra showed more fluctuations. Productivity of onion was consistent and more stable. It’s possible due to the improved variety of onion released by MPKV, Rahuri and other private agencies. The area under onion was fluctuating in all the region and state. It's possible as a consequence of the farmers perception that he will get good prices of onion at once in 3-4 years. Another reason for onion acreage was unfavourable to climatic conditions in *Kharif* and *rabi* season.

Table 4.10. District wise instability in area, production and productivity of onion in Maharashtra

Sr. No.	District		Instability Index															
			Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
			A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Nashik	CV(%)	8.59	19.74	18.07	15.54	20.83	18.05	54.8	75.34	23.42	54.8	75.34	23.42	93.67	115.5	23.78
		CDVI	8.38	15.18	10.99	13.46	19.38	18.02	40.94	54.16	19.09	40.94	54.16	19.09	61.65	72.92	18.01
2	Dhule	CV(%)	21.18	38.78	28.45	21.06	28.66	11.99	8.59	19.74	18.07	55.84	52.08	13.81	34.54	42.77	28.04
		CDVI	18.56	33.93	26.35	19.7	25.14	9.98	8.38	15.18	10.99	47.24	42.36	13.72	32.56	31.34	14.82
3	Jalgaon	CV(%)	14.09	24.9	36.27	28.5	24.42	10.15	51.39	52.49	21.6	56.66	66.67	21.6	117.4	140.7	28.12
		CDVI	11.73	19.8	25.96	26.62	22.82	10.02	40.28	41.57	21.6	45.11	46.07	15.18	76.23	94.06	26.86
4	Pune	CV(%)	14.32	27.46	20.74	40.61	38.76	10.18	15.96	20.23	13	18.91	30.7	17.19	67.93	81.96	24.45
		CDVI	13.33	22.96	17.5	18.94	16.79	10.18	13.75	16.49	12.33	19.15	30.7	17.19	22.42	30.9	23.4
5	A'Nagar	CV(%)	10.64	27.24	27.21	72.8	101.99	47.87	65	51.96	49.06	33.9	38.04	29.58	127.6	139.31	40.12
		CDVI	10.62	27.13	27.34	29.28	34.07	26.44	24.51	36.56	37.51	19.56	24.57	29.17	31.6	41.27	38.4
6	Solapur	CV(%)	11.86	22.42	23.83	26.38	33.17	14.71	33.82	44.13	21.01	49.62	53.08	26.55	54.83	69.42	26.85
		CDVI	11.69	16.04	19.47	24.84	29.89	14.03	32.66	43.41	20.99	46.16	42.66	18.75	41.84	48.3	23.75
7	Satara	CV(%)	12.71	23.06	21.69	48.46	48.63	9.07	35.47	50.96	22.55	25.83	31.65	23.97	53.17	68.28	27.27
		CDVI	10.53	21.46	21.56	23.87	19.99	8.7	35.45	50.73	21.31	24.06	22.1	20.73	30.3	36.5	23.49
8	Sangli	CV(%)	--	--	--	222.4	222.8	222.83	41.7	61.7	24.97	44.5	45.6	27.87	42.5	52.8	26.79
		CDVI	--	--	--	--	--	--	41.4	60.5	23.54	42.8	39.7	27.02	40.6	51.3	26.68
9	Kolhapur	CV(%)	--	--	--	222.49	224.95	224.95	282.6	277.	24.17	51.8	66.89	29.42	411.1	400.3	27.16
		CDVI	--	--	--	--	--	--	261.1	259.8	23.87	48.4	59.34	26.6	400.1	395.0	25.92
10	Nandurbar	CV(%)	--	--	--	--	--	--	171.7	175.7	173.1	57.72	69.78	14.31	64.65	79.78	17.64
		CDVI	--	--	--	--	--	--	--	--	--	56.25	66.14	11.81	56.83	65.56	12.55
11	Aurangabad	CV(%)	11.9	32.86	27.78	62.13	77.46	27.81	16.35	69.62	52.5	122.98	122.12	20.9	225.45	245.49	38.75
		CDVI	11.24	27.41	23.86	39.13	41.1	24.92	9.94	48.94	43.12	106.1	103.83	18.29	137.99	151.13	33.26
12	Osmanabad	CV(%)	34.9	51.14	26.15	20.31	24.48	11.9	69.64	92.29	28.33	35.09	43.91	27.29	101.2	118.3	28.24
		CDVI	34.51	49.55	25.22	15.92	20.82	11.89	69.1	91.34	28.13	29.12	30.74	23.44	68.14	84.74	27.46
13	Jalna	CV(%)	--	--	--	222.49	227.38	227.38	45.67	66.07	33.35	102.02	118.13	52.14	94.48	116.85	41.24
		CDVI	--	--	--	--	--	--	45.67	63.6	26.08	98.19	115.4	52.05	94.47	116.57	40.81
14	Latur	CV(%)	--	--	--	--	--	--	126.48	75.04	33.66	52.45	65.33	54.58	82.5	79.17	47.99
		CDVI	--	--	--	--	--	--	126.03	74.44	33.64	44.13	59.35	54.57	77.78	72.44	46.94
15	Nanded	CV(%)	--	--	--	225.24	225.26	222.49	91.53	67.22	28.38	64.09	53.76	15.44	81.99	56.22	30.87
		CDVI	--	--	--	--	--	--	57.81	28.9	28.07	37.33	30.1	15.32	77.8	56.2	23.05

Table 4.10 contd…..

Sr. No.	District		Instability Index														
			Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
			A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
16	Hingoli	CV(%)	--	--	--	--	--	--	--	--	--	52.03	58.57	47.66	49.09	54.57	46.85
		CDVI	--	--	--	--	--	--	--	--	--	51.84	52.57	37.69	48.57	54.09	38.95
17	Beed	CV(%)	--	--	--	--	--	--	--	--	--	89.19	99.39	31.25	116.75	135.09	39.46
		CDVI	--	--	--	--	--	--	--	--	--	58.47	72.85	30.17	92.83	97.84	35.79
18	Parbhani	CV(%)	--	--	--	--	--	--	35.35	37.66	23.83	52.14	71.05	50.02	44.12	53.3	39.61
		CDVI	--	--	--	--	--	--	30.02	36.21	22.81	51.53	69.72	44.44	42.04	52.76	39.21
19	Amravati	CV(%)	34.25	45.92	24.07	26.06	31.2	18.47	43.49	55.6	26.18	84.71	84.19	12.87	55.68	67.26	23.51
		CDVI	33	38.2	17.92	13.92	21.88	18.27	42.15	54.36	26.18	84.59	84.13	12.64	55.62	66.9	20.83
20	Buldana	CV(%)	23.09	43.48	35.38	52.96	68.66	35.74	46.22	63.41	41.17	85.86	80	29.8	119.59	131.17	39.52
		CDVI	22.66	39.47	31.8	52.96	68.49	35.55	42.33	57.8	41.08	81.31	76.28	29.76	105.61	112.33	37.71
21	Akola	CV(%)	--	--	--	222.49	223.11	223.11	49.23	80.77	56.55	25.73	30.52	23.71	51.26	70.28	42.82
		CDVI	--	--	--	--	--	--	34.29	58.26	52.78	24.51	27.01	22.37	29.69	39.85	35.06
22	Yavatmal	CV(%)	--	--	--	222.49	227.38	227.38	45.67	66.07	33.35	102.02	118.13	52.14	94.48	116.85	41.24
		CDVI	--	--	--	--	--	--	45.67	63.6	26.08	98.19	115.4	52.05	94.47	116.57	40.81
23	Wardha	CV(%)	--	--	--	--	--	--	126.48	75.04	33.66	52.45	65.33	54.58	82.5	79.17	47.99
		CDVI	--	--	--	--	--	--	126.03	74.44	33.64	44.13	59.35	54.57	77.78	72.44	46.94
24	Nagpur	CV(%)	--	--	--	225.24	225.26	222.49	91.53	67.22	28.38	64.09	53.76	15.44	81.99	56.22	30.87
		CDVI	--	--	--	-	-	-	57.81	28.9	28.07	37.33	30.1	15.32	77.8	56.2	23.05
25	Gondia	CV(%)	--	--	--	--	--	--	--	--	--	--	--	--	46.86	56.87	22.93
		CDVI	--	--	--	--	--	--	--	--	--	--	--	--	46.55	56.4	22.72
26	Washim	CV(%)	--	--	--	--	--	--	--	--	--	--	--	--	46.86	56.87	22.93
		CDVI	--	--	--	--	--	--	--	--	--	--	--	--	46.55	56.4	22.72

Table 4.10b. Region wise Instability index in Area, Production and Productivity of Onion in Maharashtra

Sr. No.	Region		Instability Index														
			Period-I (1975-76 to 1985-86)			Period-II (1986-87 to 1996-97)			Period-III (1997-98 to 2007-08)			Period-IV (2008-09 to 2019-20)			Overall (1975-76 to 2019-2020)		
			A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	W.M.	CV(%)	9.85	13.91	13.95	25.37	31.46	19.32	39.2	43.53	7.78	31.5	39.76	11.19	92.64	106.52	26.02
		CDVI	9.1	13.91	13.92	10.77	8.33	12.48	19.71	22.88	7.7	11.72	13.58	7.23	26.25	36.96	13.62
2	Marathwada	CV(%)	22.91	34.75	19.2	85.08	82.56	18.75	28.98	41.44	25.63	73.92	83.34	12.46	148.55	176.23	24.6
		CDVI	22.88	34.75	19.17	48.03	39.93	17.8	26.41	33.84	22.36	50.24	55.64	9.7	61.25	77.55	21.47
3	Vidarbha	CV(%)	25.91	41.71	28.03	50.68	56.97	87.63	31.01	36.13	25.04	49.08	47.11	9.13	76.35	87.95	71.7
		CDVI	25.14	36.7	23.72	34.18	45.5	73.48	28.84	34.3	23.42	46.56	43.45	8.96	38.75	45.63	34.41
4.	Maharashtra	CV(%)	9.92	13.62	10.86	25.88	25.84	7.56	32.89	36.78	10.71	44.11	49.52	16.22	94.65	111.38	16.61
		CDVI	8.83	13.23	10.79	12.12	8.87	7.19	12.65	13.09	8.98	35.34	38.33	13.5	38.69	52.43	15.59

4.7 Multi-facor/Total Factor Productivity Growth in Onion

Total factor productivity has a considerable impact on economic instability, economic growth and cross-national per capita income differences. Factor in total Productivity is a phrase that refers to the amount of change in output that is not make allowance for the account by changes in traditional inputs like land, labour, and capital. TFP is strongly correlated with output and hours worked at business cycle frequencies. TFP refers to the unexplained variation in output after accounting for changes in output due to conventional factors in the production function estimation. As a result, the efficiency and intensity with which inputs are used in production determines its level. The approach to estimation of TFP can be classified into three types: index-number method (Tornqvist Index), growth accounting method, and econometric methods. This residual nature of TFP has been ingrained in the methodological frameworks in which TFP has been studied up to now.

Table 4.11 displays the onion output, input, and TFP indices. For the study period 1990-91 to 2018-19, these indices were computed with the help of Tornqvist index method. Because current prices are considered construct the weights, the Tornqvist-Theil index has the benefit of accounting for changes in input quality. The TFP index is determined by taking the ratio of output index by the input index. The output per unit of non-input is referred to as TFP. Table 4.11 proves that the TFP for onion has increased since 1991-92, when it was 1.78. The TFP index was less than one in 1993-94, 2001-02, 2006-07, 2009-10, 2010-11, 2013-14, and 2015-16, which could be because of the drought conditions at the time. The year with the highest TFP index was 2016-17. (2.29). For the past 29 years, the average TFP index has been 1.31. TFP was greater than one for the most of the years, indicating that as TFP rises, there may be contribution of technology like improved onion variety. The onion output index grew from 1.12 in 1992-93 to 1.85 in 2018-19. In 2011-12, output growth fell to 0.99 per cent, the lowest since 2002-03. (0.83). In 2007-08, the largest /highest output index was recorded. For the past twenty-nine years, the average output index has been 1.35. There were significant fluctuations in the input index, which fell from 1.30 in 1991-92 to 0.90 in 2018-19. For twenty-nine years, the average onion input index was 1.05.

Table 4.11. Input, Output, TFP index and share of input and TFP of onion

Sr. No.	Year	Input Index	Output Index	TFP Index	Input Share	TFP Share
1	1990-91	1.00	1.00	1.00	100.00	0.00
2	1991-92	1.30	2.30	1.78	56.33	43.67
3	1992-93	1.08	1.12	1.04	96.01	3.99
4	1993-94	1.01	0.78	0.78	128.59	-28.59
5	1994-95	0.97	1.79	1.84	54.32	45.68
6	1995-96	1.39	2.10	1.51	66.08	33.92
7	1996-97	0.90	1.19	1.33	75.34	24.66
8	1997-98	1.04	1.20	1.15	86.90	13.10
9	1998-99	1.01	1.07	1.06	94.28	5.72
10	1999-2000	1.03	1.08	1.05	95.69	4.31
11	2000-01	0.91	1.21	1.34	74.72	25.28
12	2001-02	1.25	1.11	0.89	112.63	-12.63
13	2002-03	0.77	0.81	1.06	94.70	5.30
14	2003-04	1.78	2.17	1.22	81.93	18.07
15	2004-05	0.64	1.05	1.63	61.45	38.55
16	2005-06	0.97	1.98	2.04	48.91	51.09
17	2006-07	1.09	0.88	0.80	124.84	-24.84
18	2007-08	1.16	2.32	2.00	49.89	50.11
19	2008-09	0.94	1.55	1.65	60.75	39.25
20	2009-10	1.10	0.63	0.57	175.63	-75.63
21	2010-11	1.53	1.27	0.83	120.06	-20.06
22	2011-12	0.81	0.99	1.22	81.73	18.27
23	2012-13	0.99	1.18	1.19	83.89	16.11
24	2013-14	1.01	0.80	0.79	126.27	-26.27
25	2014-15	0.98	1.18	1.20	83.06	16.94
26	2015-16	1.01	0.99	0.98	101.70	-1.70
27	2016-17	0.85	1.95	2.29	43.73	56.27
28	2017-18	0.97	1.75	1.81	55.25	44.75
29	2018-19	0.90	1.85	2.06	48.45	51.55
	Total	**30.35**	**39.28**	**38.12**	**2483.14**	**416.86**
	Average	**1.05**	**1.35**	**1.31**	**85.63**	**14.37**

Share of input and TFP growth

Take the input index and divide it by the output index, the input share was calculated. TFP share is obtained by subtracting input share from 100. In Table 4.11, the input share and TFP share/proportion of onion are shown. The onion's share of output growth was calculated using these estimates (input index, output index of TFP growth).

In this table, the proportion of TFP growth in output growth is higher for onion that indicate there is contribution of technology in TFP growth of onion. The share/part of TFP growth in output has been estimated to have increased for onion over the last 7-8 years. However, due to adverse climatic conditions, low adoption of innovation technology, and low output prices, TFP share has been declining for a number of years. It results in a negative TFP share of output growth. For the entire study period, the average TFP share was 14.37 per cent, indicating that technology contributed 14.37 per cent of output.

4.8 The Compound Growth Rates of Input, Output and TFP Index

Table 4.12 shows the annual average growth rates in the total output index (TOI), total input index (TII), and total factor productivity index (TFPI) over time using an exponential function. The accessibility of data on inputs and outputs from the cost of cultivation study guides the period of analysis for onion. The compound growth rate of input, output, and TFP indices were estimated for 29 years from 1990-91 to 2018-19 and for three periods in order to evaluate growth performance of TFP of onion in Maharashtra. Period I (1990-91 to 1999-2000), Period II (2000-01 to 2009-10) and Period III (2010-11 to 2018-19), as well as the entire period (1990-91 to 2018-19).

Input growth

In Maharashtra, annual growth in input use increased (0.44%) during Period II (2000-01 to 2009-10), but output growth decreased (0.28%), indicating that more input is being used. Input use decreased by 3.09 per cent for Period III (2010-11 to 2018-19) and 0.45 per cent for the overall Period (1990-91 to 2018-19), respectively, while output increased. Due to inward movement in the production function, such changes result in positive TFP growth.

Output growth

For Period III (2010-11 to 2018-19) and the Overall Period (1990-91 to 2018-19), output growth occurred 3.68 per cent and 0.07 per cent, respectively, due to technological changes. The output growth of onion has been decreasing throughout the sub-periods, i.e., Period I and Period II.

TFP growth

The growth in TFP, which is a measure of productivity, has shown significant variation over time. For the third Period (6.77 %) and overall period, onion has reaped the greatest benefit from technological innovations (0.53 %). The study of TFP growth in Maharashtra onion resulted in a strong belief that onion has experienced technological advancement.

Table 4.12. CGR of Input, Output and TFP Index

Sr. No.	Period	Input Index	Output Index	TFP Index
1	Period I (1990-91 to 1999-2000)	-0.97	-1.75	-0.79
2	Period II (2000-01 to 2009-10)	0.44	-0.28	-0.72
3	Period III (2010-11 to 2018-19)	-3.09	3.68*	6.77 **
4	Overall (1990-91 to 2018-19)	-0.45	0.07	0.53

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

The improvement in total factor productivity especially in recent years is due to non-input factors such as rainfall, road length, markets, better management practices, investment in research and extension etc. The contribution/involvement of technological change to onion output growth was positive and respectable across sub-periods. This put forward the productivity growth rather than the input growth is the main driver of onion production in Maharashtra. The MPKV, Rahuri has released new and improved varieties *viz;* Baswant -780, N-2-4-1, Phule Samarth etc to increase the productivity which have qualities like less duration and good for storage. Agricultural universities thus take part of onion total factor productivity. The results are corroborated the findings of Pokharkar (2000), Kulkarni (2018) and Adhale (2019).

4.9 Prioritization of Research Resource Allocation

To address the issue of technological advancement and sustainability of onion in Maharashtra, the onion was categorized into five groups as reported by the value /magnitude of growth in TFP as under, as given by Chand *et al.* (2012).

Negative growth : TFP growth less than zero

Stagnant growth : TFP growth positive but less than 0.5 per cent

Low growth : TFP growth of 0.5 to 1.00 per cent.

Moderate growth : TFP growth of 1.0- 2 per cent

High growth : TFP growth of more than 2 per cent

Table 4.13 Trends in total factor productivity growths in onion of Maharashtra

Period	**Growth**				
	Negative growth (TFP growth < 0)	**Stagnant growth (TFP growth positive but < 0.5 %)**	**Low growth (TFP growth of 0.5-1%)**	**Moderate growth (TFP growth of > 1.0-2.0%)**	**High growth (TFP growth of> 2 %)**
Period I (1990-91 to 1999-2000)	Negative	--	--	--	--
Period II (2000-01 to 2009-10)	Negative	--	--	--	--
Period III (2010-11 to 2017-18)	--	--	--	--	High growth
Entire period (1990-91 to 2017-18)	--	--	Low growth	--	--

(Ref : Ramesh Chand, P. Kumar and Sant Kumar, 2012)

Table 4.13 shows that onion has experienced high TFP growth (more than 2%) for the third Period (2010-11 to 2018-19) but low growth for the overall Period (1990-91 to 2018-19). TFP growth results show that the onion crop has made significant technological advances, as evidenced by high growth during Period III (2010-11 to 2018-19). However, TFP growth has been low for the entire time frame (1990-91 to 2018-19), indicating that onion has not seen significant technological advancements. The disaggregated analysis also revealed the absence technological progress in onion during periods I and II. As a result, non-input factors must be prioritized in order to promote onion TFP growth.

4.10 Determinants/sources of Total Factor Productivity (TFP) Growth in Onion

Variation in efficiency as well as changes in best practise are all part of productivity growth. When it comes to the sources of productivity changes, the technical change component is more important. Changes in the variables that cause TFP to grow are critical for estimating how much each of these sources contributes to TFP growth. An effort was made in this section to analyse the determinants of onion total factor productivity in Maharashtra.

The TFP index was regressed against the variables of research investment, maximum humidity, minimum humidity, rural literacy, rainfall, cropping intensity, electricity consumption, road density, N/P ratio, and gross irrigated area to investigate the determinants of TFP. The contribution of various factors to TFP growth, such as research investment, rural literacy, rainfall, road density, N/P ratio, gross irrigated area, humidity (maximum and minimum), and so on, was quantified using the TFP index (Table 4.14).

Table 4.14 Estimates of TFP growth of onion

Sr. No	Variables	Coefficients	Standard error
1.	Intercept (a)	11.27	29.58
2.	Research Investment (₹/ha) (X_1)	0.14**	0.05
3.	Rural Literacy (%) (X_2)	-5.78	13.76
4.	Rainfall (mm) (X_3)	-0.56	0.93
5.	Road Density (km.) (X_4)	1.12**	0.53
6.	N to P ratio (X_5)	0.66	1.74
7.	GIA (%) (X_6)	0.15**	0.07
8.	Cropping intensity (%) (X_7)	5.28	6.65
9.	Electricity (Agril. Consumption GWh) (X_8)	-0.31	1.73
10.	Max. Humidity (X_9)	3.98	6.87
11.	Min. Humidity (X_{10})	0.85**	0.44
12.	R^2	0.76	-
13.	N (Number of observations)	18	-

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

The research investment has been a significant variable of TFP growth in onion, according to Table 4.14. TFP enhancement in onions has benefited from investments in research and technology transfer (extension). Assured irrigation water and low humidity have played an important role in TFP levels among natural resources. When it comes to infrastructure, road density has been found to be the most important determinant of TFP. The density of the roads was used as a proxy for infrastructure. Road density would create an input-output market interface and a favourable environment for technology adoption and investment induction in agriculture.

To compute the elasticity of TFP with respect to research investment and to assess the impact of research, regression coefficient estimates were used to assess the effect of various sources of TFP. TFP elasticities were 0.14, 1.12, 0.15, and 0.85, respectively, for research work, road density, gross irrigated area, and minimum humidity. They aided onion TFP growth in a positive way. It shows that a 1% increase in research investment will result in a 0.14 per cent increase in TFP. It implies that government spending on agricultural research and extension plays a bigger role in increasing agricultural productivity. The ratio of nitrogen to phosphorus nutrients was used as a proxy for fertilizer balance. The impact of rural literacy, on the other hand, was found to be negative and non-significant. The migration of rural literates to urban areas due to increased non-farm employment opportunities and distress-like situations in farming sector could explain such a result. As a result, they possibly not directly contribute to increased agricultural productivity.

The estimated R^2 value of 0.76 indicates that ten independent variables that were included in the model jointly explain 76 per cent of the alternation in TFP. The rainfall was negative (-0.56) and unimportant. It was discovered that the total factor productivity of onion was inversely affected by uneven, low, and dry rainfall spells. In addition, the analysis of TFP determinants shows that government expenditure on research, education, and extension, gross irrigated area, road density, and minimum humidity are the key drivers of onion productivity in Maharashtra.

4.11 Returns to Investment in Onion Research

Estimated Value of marginal product

The marginal product is the amount of money that is added to total income resulting from a one-rupee extra investment. The EVMP was calculated to calculate monetary returns. The first way is to decompose the growth of TFP to various factors, including research, and the second pace is to measure the marginal/ additional product for research investment using the product of research stock elasticity and average product value of research. The regression results were used to calculate the relative contribution of onion TFP growth to research investment. The estimated value of marginal product was calculated and presented below using TFP's elasticity with respect to the research investment variable. The research investment regression coefficient should be positive and statistically significant when estimating the EVMP. The per hectare value of output associated with TFP and research cost is required for estimating EVMP, and it can be found in Table 4.15.

Table 4.15 Research cost and output associated with TFP (per ha)

Sr. No	Year	Output Associated with TFP (₹/ha)	Research Cost per ha (₹/ha)
1	2002-2003	4892.63	131.99
2	2003-2004	8847.48	152.73
3	2004-2005	6675.98	116.96
4	2005-2006	8465.88	131.45
5	2006-2007	15075.63	98.50
6	2007-2008	10072.69	132.20
7	2008-2009	21771.72	107.02
8	2009-2010	14790.57	75.60
9	2010-2011	23971.73	51.65
10	2011-2012	10464.17	63.85
11	2012-2013	30652.43	60.13
12	2013-2014	25305.78	48.55
13	2014-2015	30799.86	48.27
14	2015-2016	24053.47	110.42
15	2016-2017	15486.65	74.64
16	2017-2018	36103.45	62.95
17	2018-2019	19976.79	46.08
18	2019-2020	28040.12	59.21
	Total Cost	335447.11	1572.27
	Average	18635.95	87.34

When the value of the percentage proportion of research in TFP growth is multiplied by the average value of production, the research-induced value of production (V) can be calculated (product of production and price). The ‘V' is used to compute the research's estimated value of marginal product (EVMP), which is calculated as

EVMPr = br (V/R). R is the average value of research stock/cost, and b is the elasticity of research stock.

EVMP(R) = b*(V*TFP share/R)

Where,

R : Research Investment

b : TFP Elasticity of Research Investment

V : Value of production associated with TFP

EVMP(R) = b*(V*TFP share/R)

= 0.14*(18635.95/87.35)

= 29.87

EVMP = ₹ 29.87

When the EVMP is 29.87, it means that a one-rupee investment in onion research yielded ₹ 29.87 in additional income. When a marginal product has a value greater than one, it means that research in that commodity has produced sufficient output to justify investment.

Onion Research expenditure flexibility

With respect to research, the inverse of TFP elasticity provides flexibility in research spending.

Research expenditure flexibility = 1/0.14 (Research elasticity)

= 1/ 0.14

Research expenditure flexibility = 7.14

The estimated value was 7.14, implying that in order to accomplish a 1% increase in TFP, investments in onion research must be increased by 7.14 per cent.

The hypothesis *i.e.,* onion research project has positive impact on output has been proved. Similar observations were reported by Suresh and Chandrakant (2015), Adhale (2019), Kulkarni (2018), Salunke (2020)

4.12 Internal rate of return

The internal rate of return (IRR) or economic rate of return (ERR) is a rate of return used in capital budgeting to measure and compare the profitability of investments. It is also called the “discounted cash flow rate of return” (DCFROR) or the rate of return (ROR). The internal rate of return is a metric used in financial analysis to estimate the profitability of potential investments. The internal rate of return is a discount rate that makes the Net Present Value (NPV) of all cash flows equal to zero in a discounted cash flow analysis. IRR is the annual rate of growth an investment is looked-for generate. IRR is calculated using the same concept as NPV, except it sets the NPV equal to zero. IRR is ideal for analyzing capital budgeting projects to understand and compare potential rates of annual return over time.

The marginal internal rates of returns to agricultural research were found to be between 30 and 35 per cent, indicating that agricultural research has provided attractive returns over the last 18 years. The IRR was calculated as follows:

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

IRR = 30+ (5) *(1128.11/3258.42)

= 30+5*(0.35)

= 30+1.75

= 31.75

IRR = Internal Rate of Return (IRR) to investment in onion research estimated to be 31.75 %. It means that one rupee invested in onion research generates additional income by 31.75% annually.

It implies that every rupee invested in onion research yielded a return of 31.75 per cent per year, indicating that onion research is a highly profitable investment. The return on investment in onion research has been found to be very high. Chand *et al.*, (2012), Suresh K. and M.G. Chandrakant (2015), Kulkarni (2018), and Adhale (2018) all made similar observations (2019). These findings suggest that increasing agricultural research expenditures will yield significant returns, resulting in increased agricultural productivity and development.

4.13 Economic Impact of Onion Varieties in Maharashtra

Farmers in Maharashtra were grown university released different onion varieties across various regions over time. However, the area under which the university released onion varieties increased dramatically from the year of their release. The economic impact of the university-released onion varieties Baswant-780, N-2-4-1, N-53, and Phule Samarth was 35 per cent, indicating that these varieties include a significant economic impact. In farm management economics, the partial budgeting framework provides a straight for ward, convenient, transparent and objective methodology for scientists to determine the economic impact of their innovations with the help of economists.

A basic method for evaluating the economic consequences of minor changes in a farming business is partial budgeting. This tool compares the benefits and costs of implementing the alternative to the current practise, focusing specifically on the implications of the intended change in a business operation. Partial budgeting is a planning and decision-making framework for a farm business that compares the costs and benefits of various options. It focuses solely on the changes in income and expenses that would occur if a specific alternative were implemented.

Table 4.16 Economic impact of onion varieties in Maharashtra

Debit side	**Cost (₹/ha)**	**Credit Side**	**Cost (₹/ha)**
Particulars		**Particulars**	
A. Item of added expenditure due to cultivation of university released onion varieties		B. Reduced cost (or saving) due to cultivation of university released varieties	
i. Human labour	6549.57	Seed	6785.15
ii. Bullock labour	2007.27	Irrigation	724.36
iii. Machine labour	3151.34	--	
iv. Manure	8136.05	--	
v. Chemical fertilizers	372.41	--	
vi. Biofertilizers	627.62	--	
vii. Micronutrinets	507.79	--	
viii. Plant protection	617.26	---	
ix. Weedicide	187.03	--	
x. Total additional cost	22156.34	Total saving due to cultivation of university released varieties	7509.51
xi. Opportunity cost of capital @ 6 % per annum for 6 months	664.69	--	
xii. Management cost @ 5 %	1107.82	--	
xiii. Risk premium @ 5 %	1107.82	D. Added returns from university released varieties over competing variety	
xiv. Research cost per ha.	27.42	72.82 qtls @878.00 per qtls	63935.96
xvi. Extension cost per ha.	15.67	--	
Total additional cost due to cultivation of university released onion varieties.	25079.75	--	
B. Reduced returns due to cultivation of improved onion varieties		--	71445.47
Total debit side	**25079.75**	**Total credit side**	**71445.47**

Economic impact of university released onion production technology over competing varieties of onion in the region : ₹ 71445.47 - ₹ 25079.75 = ₹ 46365.72

This budgeting approach is called partial because it does not include all production costs, but only those which change or vary between the farmer's current production practices and the proposed one(s). Partial budgeting allows assessing the impact of a change in the production system on a farmer's net income without knowing all costs of production. Partial budgeting is made up of four parts. The additional costs incurred as a consequence of new varieties were first considered. This includes a list of all additional expenses incurred as a consequence of new variety versus the alternative (or control). Pune Phursungi and a local variety of onion were used as control or check varieties in this study.

In comparison to the counterfactual, the second component is the reduced returns or income because of new variety. The third component is the cost savings from new varieties versus the counterfactual, which includes savings on things like seed and irrigation. The fourth component is the additional income generated by the new variety as comparison to counterfactual, as a result of increased yield. The third and fourth components were added to the partial budget's "returns side," or credit side. The summary, which is indicated by the difference between the credit and the debit, is the final step in a partial budget.

It was determined to estimate the economic impact of onion varieties on farmer economy from 2002-03 onwards based on the availability of data on seed sales. The Table included a list of all increased costs because of new variety over the counterfactual. According to Table 4.15, the total additional cost (direct and indirect) of university-released onion varieties over competing varieties is ₹ 25079.75 per hectare. However, the ₹ 71445.47 difference in costs (or savings) and returns due to university-released onion varieties over competing varieties was due to the university-released onion varieties.As a result, the total economic worthiness of the university-released onion production technology in comparison to other competing onion varieties in the region was ₹ 46365.72 per hectare.

4.14 Upscaling the Economic Impact

The World Bank (2003) defines the purpose of upscaling (or scaling-up) as "to efficiently increase the socio-economic impact from a small to a large scale of coverage." Upscaling is the "replication, spread, or adaptation of techniques, ideas, approaches, and concepts (the means)," and aims at achieving an "increased scale of impact (the ends)." It can occur horizontally, by replicating promising or proven practices, technologies or models in new geographic areas or target groups vertically, by catalysing institutional and policy change and diagonally, by adding project components, altering the project configuration or adapting strategy in response to changing circumstances.

The output of partial budgeting are applicable to a larger area under university-released onion varieties, but linear extrapolation of the benefits of ₹ 46365.72 per ha is not tenable due to the law of diminishing marginal returns in agriculture at an early stage. As a result, three parameters are used in linear extrapolation to reflect the operation of LDMR: I Probability performance of the technology, ii) Rate of adoption of the technology, and iii) Depreciation in the technology.

When comparing the potential yield on a farmer's field to the performance of a university-released onion variety, the probability performance of the new variety is calculated. It's assumed to be 0.85 because scientists calculated that varietal performance in the field is 0.85 instead of 1.00 in controlled conditions. According to the extension personnel who conducted the field trials, the rate of adoption of the new variety is estimated to be 0.75. Because of the product life cycle of technology, any technology will depreciate. The distinction between the year of introduction and the year of withdrawal of a variety is called depreciation of technology. The technology depreciation factor for onions is one because, on average, university-released onion varieties are substituted for their own varieties after ten years.

Table 4.17 shows the economic impact of onion research when scaled up. As a result, the total economic impact of onion varieties per hectare is calculated as 46365.72*0.85*0.75*1=₹. 29558.15. For the 2019-2020 season, the area under university-released onion varieties was 216000 ha. For the fiscal year 2019-2020, the total economic impact on Maharashtra's farming community was ₹. 638.46 crores. Suresh and Chandrakant (2015), Pokharkar (2000), Kulkarni (2018), and Adhale (2018) all made similar observations (2019).

Table 4. 17 Upscaling the economic impact of onion covering the area of adoption.

Sr. No.	Economic Impact of University Released Onion Varieties	Value
1	Probability performance of Onion variety	0.85
2	Rate of adoption of Onion variety	0.75
3	Depreciation of technology (if 1, No depreciation)	1
4	Economic worthiness of university released variety per ha	₹ 46365.72
5	Economic impact of university released variety per ha	₹ 29558.15
6	Area adopted under university released Onion in 2019-20	216000 ha
7	**Economic impact for the year 2019-20**	**₹ 638.46 Crores**

4.15 Total Economic Impact of Onion Varieties in Maharashtra

According to the consumer price index, the deflation method was used to estimate net and gross impact for onion varieties over an 18-year period (2002-03 to 2019-20). Table 4.18 shows the total economic impact that has been calculated. The gross and net gain from university-released onion varieties over check varieties for the 2019-20 season has occurred deflated using the Consumer Price Index (CPI). The table demonstrates that the net and gross economic impact of onion varieties on the farming community in Maharashtra over the last 18 years was ₹. 4685.87 crores and ₹. 44957.34 crores, respectively.

Table 4.18 Economic impact of university released onion varieties in Maharashtra

Sr. No.	Year	Gross Gain (₹/ha)	Net Gain (₹/ha)	Area (ha)	Net Economic Impact (Crores)	Gross Economic Impact (Crores)
1	2002-03	83688.46	8722.78	52800.00	46.06	441.88
2	2003-04	85834.32	8946.45	43200.00	38.65	370.80
3	2004-05	87945.00	9166.44	57600.00	52.80	506.56
4	2005-06	92866.94	9679.45	50400.00	48.78	468.05
5	2006-07	102615.41	10695.53	79200.00	84.71	812.71
6	2007-08	111417.38	11612.95	52320.00	60.76	582.94
7	2008-09	124072.81	12932.02	65760.00	85.04	815.90
8	2009-10	144103.14	15019.76	98400.00	147.79	1417.97
9	2010-11	160114.60	16688.62	140640.00	234.71	2251.85
10	2011-12	174606.98	18199.15	129600.00	235.86	2262.91
11	2012-13	194439.85	20266.32	135360.00	274.32	2631.94
12	2013-14	219954.58	22925.70	203040.00	465.48	4465.96
13	2014-15	236256.26	24624.81	206400.00	508.26	4876.33
14	2015-16	247648.07	25812.17	106080.00	273.82	2627.05
15	2016-17	258505.30	26943.81	175680.00	473.35	4541.42
16	2017-18	264590.89	27578.11	166080.00	458.02	4394.33
17	2018-19	270542.83	28198.48	198240.00	559.01	5363.24
18	2019-20	283587.87	29558.15	216000.00	638.46	6125.50
				Total	**4685.87**	**44957.34**

5. SUMMARY AND CONCLUSIONS

Increasing agricultural productivity remains a central concern of developing countries. Agricultural research has an important role to play in meeting this target, since many of the new technologies, inputs, and techniques of production that increase agricultural productivity are developed through agricultural research. A transformed agricultural research system helps to achieve sustainable food and income security for all agricultural producers and consumers, particularly for resource-poor households, whether they are in rural or urban areas.

Farmers' knowledge and innovation are basic and important components of the research/development continuum and research from the scientific community should complement and build on this knowledge. In particular, agricultural research priorities need to be identified in a participatory manner, there should be increased networking and knowledge sharing between farmers and researchers, and research and extension systems should be reoriented to support farmer-to-farmer agro-ecological innovation.

For many years, India has created significant strides in the production of both food and non-food crops, becoming a net exporter. It is widely assumed that rice and wheat growing areas with irrigation have benefited the most from the green revolution. Green revolution technologies, on the contrary, thought have reached their limits and will not be able to sustain future growth in Indian agriculture. As a result, the focus is shifted to total factor productivity. TFP growth is a capture all metric that captures changes in efficiency as well as pure technical shifts in the production function. Changes in technology, or more broadly total factor productivity, are ascribed to any increase in output that is not explained by some index of input growth.

As a result, estimating the proportion of agricultural innovations has occurred a difficult task for economists and technology creators, especially when policymakers are looking for information on macro-level effects. The discipline of economics provides the rationale and methodology for calculating the impacts of research, taking into account both tangible and intangible benefits. Intangible asset valuation remains a difficult task. On ad hoc basis, linear extrapolation of on-farm benefits is frequently used. The way law works of diminishing marginal returns to land, the common denominator, is discounted by scientists' linear extrapolation of micro level experimental results realized per plot. The linear extrapolation of benefits from new technology is thus irrational, as the impact is depending on variables such as the likelihood of success of the innovation or technology in the field, the adoption rate of the technology by farmers (as farmers may not fully adopt the new technology and may make on-farm adjustments), and the rate of technology depreciation. The extent to which project interventions affect the targeted population and the magnitude of these interventions affect the welfare of the intended beneficiaries should be better understood through impact assessment.

The study, titled "economic impact of onion research in Maharashtra's farm economy," aims to develop policies for university researchers and the state to develop research strategies that benefit farmers. The estimation of Total Factor Productivity (TFP), marginal returns, Internal Rate of Return (IRR), and economic impact of onion varieties released by the Mahatma Phule Krishi Vidyapeeth, Rahuri, is attempted as part of this endeavour, with the following specific objectives:

1. To estimate the growth rates of area, production and productivity of onion.
2. To study the extent of investment in research and extension activities in onion.
3. To assess the impact of research and extension on income generation.
4. To quantify the contribution of investment on research and extension.

Secondary data has been used for accomplishing the objectives.

5.1 Summary of Findings

1. Plan for onion research Station Pimpalgaon, Baswant, and scheme for research on onion storage, the Central Campus MPKV, Rahuri has developed remarkable onion varieties. N-2-4-1 and Baswant-780 are two very old varieties that were released in 1986 and 1987, respectively. However, these varieties were popular among farmers in the past and continue to be so today. Baswant -780 is well-known among farmers for its high yield potential, suitability for two seasons (*kharif* and late *kharif* (Rangada), globose bulbs with crimson red colour, 13 per cent TSS, and low bolting percentage. Suitable for humid and wet climates. Between 1994 and 1997, the university released two promising onion varieties,

Phule Safed and Phule Suvarna, which occupied a large portion of the onion market. Phule Samarth, a promising onion variety, was released by the university in 2004. This Phule Samarth variety is well-known among farmers for its excellent storage quality (2-3 months), short duration (80-90 days), dark red and globular bulbs, and resistance to premature bolting.

2. The university released onion varieties that account for nearly half of the total onion area in Maharashtra. Farmers preferred the Phule Samarth variety (28.11 %) over the N-53 (16.10%) and N-2-4-1 varieties released by the university (14.09 %).

3. In the year 2018-19, India ranks first in terms of area with 23.49 per cent and second in terms of onion production with 22.8 per cent. India, on the contrary, is ranked seventh in terms of productivity. For the year 2018-19, India's onion productivity was lower (187.00 q/ha) than the global average (192.50 q/ha).

4. Maharashtra leads India in onion area and production in 2018-19, accounting for 35.19 and 34.26 per cent of the country's, respectively. In India, Maharashtra, Karnataka and Madhya Pradesh accounted for nearly 60 per cent of the total area and production of onions in 2018-19. In comparison to other Indian states, Maharashtra state (181.00 q/ha) was far behind in onion productivity. Gujarat has the highest productivity (25.06 t/ha), followed by Madhya Pradesh (24.98 t/ha) and Bihar (22.29 t/ha).

5. Over a decadal year, the area, production and yield of onion in India and Maharashtra fluctuated. Over the 1980-81 period, onion production, area, and productivity increased by 403.90, 786.92 and 77.04 per cent at the federal/ country level and 754.55, 919.91 and 23.97 per cent at the state level, respectively.

6. For the entire period (1975-2020), Maharashtra state's production and productivity increased by 5.77 per cent, 6.27 per cent, and 0.42 per cent per year, respectively. For the entire period in the State area, onion production increased as a consequence of both area expansion and slightly improved productivity. For the overall period (1975-2020), the growth of area, production, and productivity was positive and significant in three regions: western Maharashtra, Marathwada, and Vidarbha.

7. Most Maharashtra districts, including Nashik, Dhule, Jalgaon, Ahmednagar, Pune, Satara, Solapur, Aurangabad, Nandurbar, Osmanabad, Latur, Buldhana, and Akola, experienced that both area expansion and productivity improvements in these districts increased onion production. However, most Maharashtra districts, such as Nagpur, saw a decrease in area, production, and productivity over the period 1975-2020. positive and significant growth in area, production, and yield over the period 1975-2020. Bhandara, Gondia, Sangali, Kolhapur, Yatvatmal, Wardha, Gadchiroli, Chandrapur and Jalna.

8. The coefficient of variation and Cuddy-Della Vella Index explain that the area under onion was highly instable and inconsistent for most districts over the entire period. Onion production has been highly fluctuating and instable in all Maharashtra districts for the entire period (1975-2020). For most of Maharashtra's districts, the area and production revealed higher rates of lack of stability, but productivity showed lower rates of instability and consistency. Except in the Vidarbha region, onion production was inconsistent or instable, but yield was consistent and stable throughout the period in all the regions in State. Onion production and productivity were inconsistent or instable across the entire state.

9. For the study period 1990-91 to 2018-19, the Tornqvist index was employed to estimate the onion input, output, and TFP indices. The lowest TFP for onion was 0.78 in 1993-94, and the highest TFP (2.29) index was recorded in 2016-17. For the past twenty-nine years, the average output index, input index, and TFP index have been 1.35, 1.05 and 1.31, respectively. For the entire study period, the average TFP share was 14.37 per cent, indicating that technology contributed 14.37 per cent of output.

10. Input use decreased by 0.45 per cent over the period 1990-1991 to 2018-19. TFP increased at a significant rate of 0.53 per cent each year over the course of the study. The output index increased by 0.07 per cent per year in this area. TFP has improved in recent years due to non-input factors such as research investment, rainfall, road length, minimum humidity, and so on. MPKV, Rahuri has released a number of new improved varieties in order to boost productivity. As a result, agricultural universities played a critical role in onion TFP growth.

11. Onion has benefited the most from technological innovations in the third period (6.77 %) (2010-11 to 2018-19) and has experienced low growth in the overall period (1990-91 to 2018-19). TFP growth results show that onion has made significant technological advances, as evidenced by high growth during III (2010-11 to 2018-19). It indicates that non-input factors such as high yielding onion varieties, temperature, rainfall, N/P ratio, and so on have a technological contribution.
12. The role of various factors in TFP growth is considered. TFP growth in onions has been aided by research investment (0.14), minimum humidity (0.85), road density (1.12) and GIA (0.15). The number of roads in a given area was used as a proxy for rural infrastructure. It's significant and positive. The rainfall is negative and non-significant (-0.56). The factors of rural literacy, maximum humidity, and cropping intensity were all not meaningful. The estimated R^2 value was 0.76, indicating that the factors in the model jointly explained 76 per cent of the variation in TFP.
13. Estimated marginal product addition to total income resulting from of a one-rupee additional investment. Marginal returns were estimated to be worth 29.82. It shows that an extra rupee spent in onion research yielded an additional ₹ 29.82 in profit. The inverse of TFP elasticity to research gives research investment flexibility. The estimated value was 7.14, implying that to achieve a 1% increase in TFP, onion research investments in Maharashtra would need to increase by 7.14 per cent.
14. For calculating the rate of return on investment, the Internal Rate of Return (IRR) is used. Between 2002-03 and 2018-19, the onion IRR was 31.75 per cent. It means that every rupee spent on onion research earned a 31.75 per cent annual return.
15. A basic method for evaluating the economic effect / impact of minor changes in a farming business is partial budgeting. The total additional cost of university developed /released variety over other control or check (local) variety was estimated to be Rs 25079 per hectare (direct + indirect). However, the difference between university released varieties and other competing varieties in terms of reduced costs (or savings) and added returns was Rs 71445.47. The total

economic worthiness of the university-released onion production technology in comparison to other competing local onion varieties in the region was Rs 46365.72 per hectare.

16. When partial budgeting is applicable to a larger area, upscaling technique was used for finding the economic impact of varieties. The economic impact of university released onion varieties was calculated as 638.46 crores after taking into account three factors: probability performance of variety, rate of adoption of variety, and depreciation of technology. For the 2019-20 season, the area under university-released onion varieties was 216000 ha.
17. For the past 28 years, the gross and net economic impact of onion varieties on Maharashtra's farming community has been Rs 44957.34 crores and Rs 4658.87 crores, respectively.

5.2 Conclusions

1. The area, production, and productivity of onions all grew at a positive and significant rate across Maharashtra. It indicates that output /production of onion was increased by both area expansion and less improvement in productivity. During the study period, the area, production, and productivity of onions varied greatly in different regions.
2. In Maharashtra, onion productivity was reckoned to be more stable and consistent than area and production.
3. TFP growth in onions has been helped significantly by research investment.
4. An additional rupee invested in onion research yields marginal/additional income of ₹ 29.87.
5. Onion had a 31.75 per cent internal rate of return. It clearly demonstrates the value of investing in onion research is highly paying.
6. For the 18-year period, the gross and net economic impact of university-released onion varieties on Maharashtra's farming community was 44957.34 crores and 4685.87 crores, respectively.

5.3 Policy Implications

1. In all of Maharashtra's regions, onion production has increased due to both increased area and improved productivity. However, the rate of expansion of area is faster than the rate of productivity improvement. As a result, the Agriculture

Department, non-governmental organizations, and universities may work together to increase the productivity of the onion crop by implementing the university-recommended onion technology package.

2. The lack of consistency in onion production and area is the cause of onion instability. In addition, there are significant regional/district differences in onion crop growth rates. Therefore, it is critical to ensure that farmers receive adequate and timely supplies of high-quality inputs. The state government may improve the systems for delivering high-quality inputs to farmers on time.
3. Onion crop research yields profitable monetary returns on investment. For that reason, future research investment in the project may be increased.
4. Over the course of 18 years, Maharashtra farmers received gross economic returns of ₹ 44957.34 crores and net economic benefits of ₹ 4685.87 crores from university-released onion crop varieties (2002-03 to 2019-20). It shows that a one-rupee investment in onion crop research and extension yielded a profit of ₹ 29.87, with a 31.85% Internal Rate of Return (IRR). As a result, it is recommended that significant funds be allocated to onion crop research and extension.
5. Total Factor Productivity was influenced by non-input factors such as onion research investment (TFP). As a result, policymakers and researchers should consider this non-input factor when formulating agricultural development policies.

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7. APPENDICES

Thesis Title : Economic Impact of University released Onion varieties in Maharashtra

1. Establishment of onion research unit

Sr. No.	Name of research Centre	Year of Establishment
1		
2		
3		
4		

2. Varieties developed since establishment of the research unit

Sr. No.	Variety	Year of release	Place
1			
2			
3			
4			

3. Area covered under university released Onion varieties since establishment of the research unit

(Area in ha.)

Sr. No.	Year	Onion varieties					
1							
2							
3							
4							

4. Varietywise sale of onion seed by University since establishment of the research unit

(No.)

Sr. No.	Year	Sale of Onion seed					
							Other
1							
2							
3							
4							

Expenditure on Research & Extension (₹)

Sr. No.	Year	Expenditure on Research				Expenditure on Extension				
		Salary	Conting-ency	Wages	Misc.	Demonstr-ations	Farmers rally	Trainings	Publications (Pamplet, folder, book lets etc.)	Other (specify)
1.										
2.										
3.										
4.										
5.										

APPENDIX-II

Year	Breeder Seed (q.)	Foundation Seed (q.)	Certified Seed (q.)	Total Seed (q.)	Grand total (kg.)	KG	Seed rate	Area	M.S. area (ha.)	% to M.S
2000-01	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001-02	0.90	2640.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002-03	1.20	2160.00	5280.00	5280.00	5280.00	528000	10.00	52800	120700	43.74
2003-04	1.05	2880.00	4320.00	4320.00	4320.00	432000	10.00	43200	133600	32.34
2004-05	1.65	2520.00	5760.00	5760.00	5760.00	576000	10.00	57600	203700	28.28
2005-06	1.09	3960.00	5040.00	5040.00	5040.00	504000	10.00	50400	107100	47.06
2006-07	1.37	2616.00	7920.00	7920.00	7920.00	792000	10.00	79200	229800	34.46
2007-08	2.05	3288.00	5232.00	5232.00	5232.00	523200	10.00	52320	204600	25.57
2008-09	2.93	4920.00	6576.00	6576.00	6576.00	657600	10.00	65760	211900	31.03
2009-10	2.70	7032.00	9840.00	9840.00	9840.00	984000	10.00	98400	251600	39.11
2010-11	2.82	6480.00	14064.00	14064.00	14064.00	1406400	10.00	140640	329600	42.67
2011-12	4.23	6768.00	12960.00	12960.00	12960.00	1296000	10.00	129600	248400	52.17
2012-13	4.30	10152.00	13536.00	13536.00	13536.00	1353600	10.00	135360	264000	51.27
2013-14	2.21	10320.00	20304.00	20304.00	20304.00	2030400	10.00	203040	398500	50.95
2014-15	3.66	5304.00	20640.00	20640.00	20640.00	2064000	10.00	206400	443200	46.57
2015-16	3.46	8784.00	10608.00	10608.00	10608.00	1060800	10.00	106080	553300	19.17
2016-17	4.13	8304.00	17568.00	17568.00	17568.00	1756800	10.00	175680	473100	37.13
2017-18	4.50	9912.00	16608.00	16608.00	16608.00	1660800	10.00	166080	472800	35.13
2018-19	0.45	10800.00	19824.00	19824.00	19824.00	1982400	10.00	198240	428400	46.27
2019-20	3.34	1080.00	21600.00	21600.00	21600.00	2160000	10.00	216000	686600	31.46

8. VITAE

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DOCTOR OF PHILOSOPHY (AGRICULTURE)

IN

AGRICULTURAL ECONOMICS

2021

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