

**IMPACT ANALYSIS OF INVESTMENT ON RESEARCH AND
EXTENSION OF UNIVERSITY RELEASED CITRUS VARIETIES**

By

Miss. Vilhekar Rohini Ashok

(Reg. No. Ph.D./2018/41)

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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DEPARTMENT OF AGRICULTURAL ECONOMICS

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MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. - AHMEDNAGAR
MAHARASHTRA, INDIA.**

2022

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 : / /2022

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CERTIFICATE

This is to certify that the thesis entitled, “**IMPACT ANALYSIS OF INVESTMENT ON RESEARCH AND EXTENSION OF UNIVERSITY RELEASED CITRUS VARIETIES**”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ECONOMICS**, embodies the results of a piece of *bona fide* research work carried out by **MISS. VILHEKAR ROHINI ASHOK**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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

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CERTIFICATE

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Place : MPKV, Rahuri

Date : / /2022

(P.N. Rasal)

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Date : / /2022

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LIST OF ABBREVIATIONS

\$: Dollar
%	: Per cent
₹	: Rupees
Acre	: 43560 sq. feet/ 0.40 hectare
AVC	: Average Variable Cost
C.V.	: Coefficient of variation
CGR	: Compound Growth Rates
CDVI	: Cuddy Della Valle Instability Index
et al.	: et alli (and other)
EVMP	: Estimated Value of Marginal Product
FAO	: Food and Agriculture Organization
GAA	: Growth Accounting Approach
GIA	: Gross Irrigated Area
GDP	: Gross Domestic Product
GoI	: Government of India
ICAR	: Indian Council of Agricultural Research
IRR	: Internal Rate of Return
K	: Kilogram
MT	: Million Tonne
N to P ratio	: Nitrogen to Phosphorous ratio
NARS	: National Agricultural Research System
NPV	: Net Present Value
PFA	: Production Function Approach
Q	: Quintal
R&D	: Research and development
S.E. ±	: Standard Error
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
TTI	: Tornqvist-Theil Index

ABSRATCT

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

The study focused on, “**Impact Analysis of Investment on Research and Extension of University Released Citrus Varieties**” was examined and quantified by using the Total Factor Productivity (TFP) and Partial Budgeting Approaches. For impact analysis, Acid Lime and Sweet Orange varieties released by All India Coordinated Research Project on Fruits, Mahatma Phule Krishi Vidyapeeth, Rahuri was considered as they were appreciably performing with increasing adoption over time. The data regarding expenditure on research and extension was collected from All India Coordinated Research Project, Mahatma Phule Krishi Vidyapeeth, Rahuri. Besides this the data on cost of cultivation of Acid Lime and Sweet Orange was collected by survey method from 60 samples (30 University released and 30 Counterfactual Variety) each from Acid Lime and Sweet Orange growers. The Statistical tools *viz*; Compound Annual Growth Rates (CAGR), Coefficient of Variation (CV), Cuddy Della Valle Index (CDVI), Total Factor Productivity Index (TFPI), Cobb Douglas Production Function, Estimated Value of Marginal Product (EVMP), Internal Rate of Return (IRR), Partial Budgeting, etc. were used for analysis purpose. The data on per hectare input used and output obtained for Acid Lime and Sweet Orange fruit crop was taken from the official records of Central and State Cost of Cultivation Scheme. The district wise, state wise and country wise data on area, production and productivity of Acid Lime and Sweet Orange was taken from various published sources; Department of Horticulture, Horticulture Statistics at a

Glance, Pocket Book of Agricultural Statistics, Government of India, Department of Agriculture and Cooperation, Horticulture Statistics Division, New Delhi, Socio Economical Statistical Information about India (India stat), *etc.* The area under university released varieties of Acid Lime and Sweet Orange in Maharashtra was estimated on the basis of seedling sell by university, KVK, private nursery, government nursery, *etc.*

Acid Lime growth rates were found to be positive and significant in terms of area, production, and productivity. It implies that the production of Acid Lime has increased as a result of both area expansion and productivity improvement. However, the production of Sweet Orange was increased by only area expansion. Among the regions of Maharashtra and for the state of Maharashtra, the production of Acid Lime in Vidarbha region was increased only due the productivity improvement. In case of Sweet Orange, the growth rate of production was noticed positive and significant in Marathwada and Vidarbha region and it was because of the area expansion. During the study period, similar results were found for the state of Maharashtra. Significant growth rate in production of Acid Lime and Sweet Orange may be because due to improved varieties developed by AICRP on Fruits, MPKV, Rahuri during the period of study. Acid Lime varieties *i.e.* Sai Sharbati, Phule Sharbati and Sweet Orange varieties *i.e.* Nucellar and Phule Mosambi were highly demanded by the farmers in Maharashtra. Acid Lime varieties published by AICRP, fruits, MPKV, Rahuri currently account for 32.42 per cent of the entire area under Acid Lime fruit cultivation in Maharashtra. Sai Sharbati and Phule Sharbati university released acid lime varieties together contributing 37.43 per cent area to the total area of acid lime varieties of Maharashtra on farmer's field during the year 2019-20. Sweet Orange varieties published by AICRP, fruits, MPKV, Rahuri currently account for 63.47 per cent of the entire area under Sweet Orange fruit cultivation in Maharashtra. While Sweet Orange university released varieties *i.e.* Nucellar and Phule Mosambi together contributing 44.40 per cent area to the total area of sweet orange varieties of Maharashtra on farmer's field during the year 2019-20.

For the study period 1994-95 to 2018-19, the Tornqvist Theil index was used to estimate the input, output, and TFP index of the Acid Lime and Sweet Orange fruit crop. During the study period 1994-95 to 2018-19, the growth rate of Total Factor

Productivity (TFP) in the Acid Lime fruit crop was stagnant, whereas the growth rate of TFP in the Sweet Orange fruit crop was moderate. Research investment (0.18), cropping intensity (1.25) and N to P ratio (1.44) have played a significant role in growth of total factor productivity of Acid Lime and the estimated R^2 value was 0.72 indicating that 72 per cent variation in TFP explained by the 8 factors included in the model and f value was significant indicating a good fit of the model. Research investment (0.09), gross irrigated area (1.92) and N to P ratio (0.97) has significantly contributed in the growth of total factor productivity of Sweet Orange and the estimated R^2 value was 0.71 indicating that 71 per cent of variation in TFP explained by the 8 factors included in the model and f value was significant indicating a good fit of the model.

To analyze the returns to investment, Estimated Value of Marginal Return (EVMP) and Internal Rate of Return (IRR) of investment in Acid Lime and Sweet Orange research and extension were analyzed. The Estimated Value of Marginal Return (EVMP) in Acid Lime research was ` 17.49. It revealed that additional investment of one rupee in acid lime research generated additional income of ` 17.49, indicating very high rates of returns to public investment in Maharashtra. Internal Rate of Return (IRR) in Acid Lime was 33.12 indicating investment made on in Acid Lime research is generating rate returns of 32.45 per cent annually. Inverse of TFP elasticity in Acid Lime research was 5.46 which mean that to achieve 1 per cent increase in TFP, the investments in acid lime research needs to be increased by 5.46 per cent. The Estimated Value Marginal Return (EVMP) in Sweet Orange research was ` 23.56, indicating additional investment of one rupee in sweet orange research generated additional income of ` 23.56. Internal Rate of Return (IRR) in Sweet Orange is 44.99 which denote the investment made in sweet orange research is generating rate returns of 44.99 per cent annually. Inverse of TFP elasticity in Sweet Orange research was 10.93 which mean that to achieve 1 per cent increase in TFP, the investments in Sweet Orange research needs to be increased by 10.93 per cent.

Findings of the partial budgeting analysis reveal that the total additional cost (direct and indirect) of university released Acid Lime varieties over counterfactual or

check variety was to be ₹ 27611.21 per hectare. Whereas, the reduced costs or savings and added returns due to university released improved variety over the counterfactual or competing variety was ₹93417.64. The total economic worthiness of university released acid lime varieties *i.e.* Sai Sharbati and Phule Sharbati over the counterfactual variety in the state of Maharashtra was ₹ 65806.42. After up scaling the university released Acid Lime varieties, the gross and net economic impact of ₹ 3822.21 crores and ₹ 387.38crores, respectively was gained by the farmer in Maharashtra during the year 1996-97 to 2019-20.

The total additional cost (direct and indirect) of university released Sweet Orange varieties over the counterfactual variety was ₹ 22807.03 per hectare. While, the reduced cost or saving and added returns due to university released varieties over the counterfactual varieties was ₹ 70474.11. Thus, the total economic worthiness of university released sweet orange varieties *i.e.* Nuceller and Phule Mosambi over the counterfactual variety in the state of Maharashtra was ₹ 47667.08. After up scaling the university released Sweet Orange varieties the gross and net economic impact of ₹ 6142.85 crores and of ₹ 467.61 crores, respectively was gained by Sweet Orange growers in Maharashtra during the year 1990-91 to 2019-20.

The study recommended that, the Government, private agencies, NGO's, *etc.* may invest in Acid Lime and Sweet Orange fruit crop research for increasing monetary benefits to farming community of the state.

1. INTRODUCTION

1.1 Indian Agriculture

Agriculture is the backbone of the Indian Economy and it plays a critical part in the countries socio-economic growth. Approximately 52 per cent of the total working force is engaged in agriculture sector and contributes 16.6 per cent of the country's overall GDP (Economic Survey of India, 2020). It assists in ensuring food security, employment generation and ultimately the country's overall economic development.

Agriculture is the mainstay of many countries' economies. Agriculture is considered as a catalyst for the overall development of any nation. It is a crucial sector that supports the developing nation's economic development and industrialization, as well as holding the key to reducing unemployment. Its development is critically important for ensuring food and nutritional security, income and employment generation, and for stimulating industrialization and the country's overall economic development.

The technological strides recorded by the world's leading economies had their roots in agriculture. Regardless of whether that the sector has increasingly shrunk in its contribution to the Gross Domestic Product (GDP) of many nations, it still provides the chunks of the GDP of many nations especially the developing ones. The agriculture sector plays an important and strategic role in the course of country's economic development. Agriculture was the foundation of national growth and prosperity and no strategy of economic development can succeed without the rapid modernization of the agriculture sector. Agriculture directly provides food, raw material, employment and income generation opportunities to a very large proportion of the population.

1.2 Agricultural Research System in India

The agriculture system in India began as early as 9000 BC. In this period the methods were created for the settled mode of production in agriculture. Wheat, barley and jujube were the popular crops that were domesticated in the subcontinent by 9000 BC. Along with the cultivation of wheat, barley and jujube, people were moved towards the domestication of cattle primarily sheep and goat was visible in Mehrgarh by 8000-6000 BCE. In such a way the growth of agriculture happened in our country.

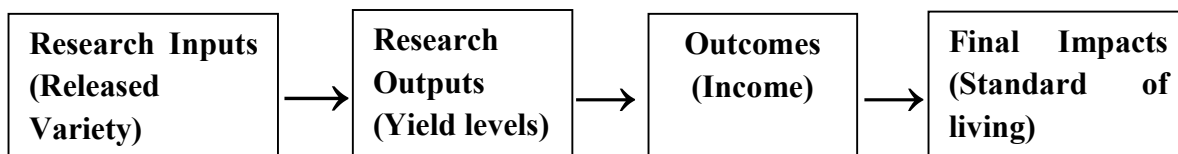
The function of the research system in the development of India's agricultural sector is critical. India boasts one of the world's most extensive and institutionally complicated agricultural research systems. The Indian agricultural research system is the culmination of a process that began in the nineteenth century and culminated in the Imperial (now Indian) Council of Agricultural Research (ICAR) being established in 1929 on the proposal of a Royal Commission on Agriculture. The Indian Council of Agricultural Research (ICAR) at the national level primarily assists, promotes, and coordinates research and education activities in the country under the current research system.

There are innumerable innovations that have been part of agricultural transformation in India. Some of the innovations occurred inadvertently that are believed to have had higher impact on food production and livelihood security. Measuring the contribution of agricultural innovations has been a difficult task for economists and technology creators, particularly when policymakers are looking for information on macro-level effects.

1.3 Impact Assessment

Impact assessment it is an effort to measure its social, economic, environmental and other benefits. An impact evaluation measures the changes in people's lives that can be traced back to a certain project, programme, or policy. Impact evaluations are known for their emphasis on attribution. The most difficult aspect of doing effective impact evaluations is determining the causal relationship between the project, programme, or policy and the desired outcomes. Impact assessment can be take place for completed project, ongoing project and planned project. The assessment takes place when the proposed project, program or policy is innovative, replicable, strategically relevant, untested and influential.

The consequences of the various stages of an innovative system or intervention are evaluated in an impact assessment.



1.4 Why Impact Assessment

There has been a lot of argument on need to increase production and sustainability in agriculture globally in medium to long terms but very less information is available on specific mean to achieve this aim. Increasing agricultural productivity is critical to meet expected rising demand and as such, it is instructive to examine recent performance in cases of modern agricultural technologies. By raising productivity, decreasing food prices, and making food more available to the poor, upgrading crop technology can help rural farmers conquer hunger and food insecurity. The utilization of high-yielding crop varieties promotes the growth of agro-processing businesses and non-farm sectors, as well as the shift from low-yielding subsistence agriculture to a high-yielding agro-industrial economy.

Technological innovation can shift agricultural productivity from lower level to an upper level. To confess this and to enhance the agricultural research investment there is need to assess the evaluation of technological innovations. Impact evaluation is not necessary to evaluate ex-post means after implementation of any program, policy, project, *etc.* it can be evaluated by ex-ante means before the implementation of any program, policy, project, *etc.* to improve the quality, efficiency and effectiveness of the proposed project, policy, program, *etc.* The goal of assessing an agricultural innovation is to see if it has had the desired impacts in the places where they are needed. The majority of the evaluations focused on determining the rate of adoption of the invention as well as the economic advantages of its investment. However, there are more reasons to evaluate innovations nowadays, such as looking for unexpected effects of innovation, providing feedback to researchers and research institutions, identifying and learning from defects in the development and diffusion of innovation, as well as deriving strategic and programmatic lessons that provide for future investment, providing information for management decisions, determining external effects of innovation, and prioritizing the best investments. The evaluation looks at the outcomes and tries to figure out how much of a difference the intervention makes. Impact assessments are a type of evaluation that focuses on finding answers to cause-and-effect issues. Unlike general assessments, which can answer a wide range of questions, impact evaluations are focused on a single question: What is a program's influence (or causal effect) on a desired

outcome? This fundamental question has a crucial causative dimension: we're only interested in the program's impact, or the effect on outcomes that the programme causes directly. The goal of an impact evaluation is to find changes in outcome that are directly related to the programme.

Impact assessment should enhance the understanding of the extent to which the project/program/ policy interventions effects on the targeted population and magnitude of these intervention effects the well-being of the intended beneficiaries. Resources are limited and the researchers in research and development are under pressure to allocate available resource efficiently and effectively. Impact assessment should help in setting priorities over competing interventions and policy decision on efficient allocation of scarce resources. To measure the outcome and impact of research interventions, aiming to discern intervention effects, which was particularly challenging in resource management. Donors, policy makers and researchers need information to monitor progress in achieving output and outcomes.

1.5 History of Citrus

Citrus is native to a large area, which expand from Himalayan foot hills of Northeast India to North Central China, the Philippines in East and Burma, Thailand, Indonesia and New Caledonia in Southeast. It's worth noting that the majority of Citrus species are native to Southeast Asia's tropical and subtropical climates, mainly India and China. The biggest citrus producing countries in the world include the United States, Spain, India, Japan, Argentina, Mexico, Brazil, Morocco, Algeria, Greece, South Africa, Australia, Israel, Egypt and Jamaica. The North Eastern region of India is thought to be one of the natural homes of citrus – at least for a few species. The main citrus varieties are sweet oranges, mandarins, grapefruits, lemons, and limes, which all play key commercial roles in the citrus sector.

The true home of the lemon has yet to be discovered, though it has been traced to Northwestern India. It is thought to have been first planted in Southern Italy in 200 A.D. and by 700 A.D., it had spread to Iraq and Egypt. The lemon was originally mentioned in a tenth-century Arabic treatise on agriculture, and it was also utilized as an aesthetic plant in early Islamic gardens. Between 1000 and 1150 A.D., Arabs widely diffused it over the Mediterranean region. It was revered for its medical properties in the

palaces of Egypt's and Syria's sultans between 1174 and 1193 A.D. In 1493, Christopher Columbus brought lemon seeds to Hispaniola. Lemons may have been among the fruits brought to St. Augustine by the Spaniards. The dissemination of lemon seeds was aided by Spanish conquests throughout the New World. It was mostly utilized as a decorative item and for medical purposes. When lemons were first employed in cooking and flavoring in the 1700s and late 1800s in Florida and California, they were in high demand.

1.6 Citrus

Citrus is the world's most widely grown tree fruit crop. The majority of Citrus species are found in Southeast Asia's tropical and subtropical climates, primarily India and China. Citrus is a genus of flowering trees and shrubs belonging to the Rutaceae family. The world's biggest citrus-growing countries are India, Japan, Argentina, United States, Brazil, Mexico, Spain, Morocco, Greece, Algeria, Australia, South Africa, Egypt, Israel, and Jamaica. A few species regard India's north-eastern region to be their natural habitat. Plants in the genus produce citrus fruits, including important crops such as sweet orange, mandarin, pumelo, acid lime, grape fruit, lemon and sweet lemon. There are various species are coming under the citrus group the details of that species is discussed in Table 1.2.

Table 1.1. Citrus species

Sr. No.	Citrus Species	Botanical Name
1.	Sweet Orange	<i>Citrus sinensis</i>
2.	Mandarin	<i>Citrus reticulata</i>
3.	Pumelo	<i>Citrus grandis</i>
4.	Acid Lime	<i>Citrus aurantifolia</i>
5.	Grape fruit	<i>Citrus paradise</i>
6.	Lemon	<i>Citrus lemon</i>
7.	Sweet lime	<i>Citrus lemetoides</i>

Commercially grown citrus crops in India are the mandarin orange (*Citrus reticulata*), sweet orange (*Citrus sinensis*) and acid lime (*Citrus aurantifolia*), overall production of 13.4, 8.9 and 7.5 lakh tones, respectively. In India, Andhra Pradesh, Maharashtra, Karnataka, and Punjab account for more than 65 per cent of the country's total citrus production.

Citrus are mostly consumed in developed countries, whereas the consumption per capita is increasing in the developing countries. According to FAO, consumption of fresh orange is decreasing in developed countries and increasing in emerging developing countries such as Mexico, Argentina, India, China and Brazil. The main characteristics of citrus fruits are acidic, exotic fruits with juicy, bitter segment fruit inside. Citrus fruits and their derivatives are consumed on a daily basis by people all over the world. Citrus fruits are a good source of dietary fibre and are thus considered crucial in maintaining human health. Citrus fruits include phyto vitamins and nutrients that have medicinal effects such as anticancer and anti-inflammatory. Citrus species are also used extensively in herbal medicine. Citrus species contain beneficial components such as vitamin C, beta-carotene, flavonoid, limonoid, folic acid, and dietary fibre.

Citrus has an enormous socio-economic and cultural impact on the whole society. The various nutritional and medicinal values make this fruit essential in different parts of the world. Citrus is mainly valued for the fruit, which can be eaten as fresh fruit, processed into juice or added to dishes and beverages.

1.7 Importance of Acid Lime and Sweet Orange in Indian Economy

In case of lemon and lime total world's production in 2016-17 was 17.3 Million Tonnes in which India contributed about 3 Million Tonnes with 17.2 per cent share. India ranks first both in area and production of lemon and lime in the world in 2016-17. During 2016-17, China noted first place both in case of area and production of citrus fruits while turkey place first position in case of productivity. Lowest area and production of citrus fruits crops observed in Argentina with 0.15 ha and 3.28 MT respectively while lowest productivity observed in Nigeria with 4.83 t/ha (Anonymous, 2018).

During the 2016-17 fiscal year, India ranked first in the world in terms of acid lime area and output. Argentina had the highest productivity, at 32.03 t/ha. Italy has the least area and production. With 11.54 t/ha, India had the lowest productivity. Horticulture production in India has increased throughout the years. Area expansion has made significant progress, resulting in increased production. The area under horticulture has expanded by 2.6 per cent per year over the last decade, while annual production has

climbed by 4.8 per cent. Horticulture crops produced 311.71 MT from a total area of 25.43 thousand hectares in 2017-18 (Anonymous, 2018).

Gujarat and Andhra Pradesh placed in first position in case area and production of Acid Lime during 2019-20 while Karnataka is in first position regarding productivity of Acid Lime during the year 2019-20. Maharashtra is in third position both in area and production of Acid Lime fruit crop during 2019-20 (Anonymous, 2020). While in case of Sweet Orange Andhra Pradesh is in first position both in area and production during the year 2019-20. Rajasthan is in first position in productivity of Sweet Orange during the year 2019-20. Maharashtra is in second placed both in area and production of Sweet Orange during the year 2019-20 (Anonymous, 2020). Highest area and production of lemon/lime was observed in Jalgaon district during 2019-20. While highest productivity was observed in Nanded district. Thane, Bhandara and Gondiya districts had the lowest area, production, and productivity, respectively. During 2019-20, the districts such as Aurangabad, Jalna, and Nanded had the highest area, production, and productivity under the sweet orange fruit crop, respectively. While Thane district was recorded smallest area, production, and productivity under sweet orange.

1.8 Practical Utility of the research problem

Following the green revolution, Maharashtra's food grain production expanded dramatically over the decades. A large number of new agricultural technologies, practices, and innovations developed and released by Agricultural Universities for the benefit of state farmers to enable them to produce sufficient quantities and quality of agricultural produce while also ensuring remunerative returns for the improvement of farmers' socioeconomic lives. Agriculture has been able to attain sustainable expansion thanks to new technologies such as enhanced varieties, improved package of methods, new implements, and machineries. Publicly supported institutions such as State Agricultural Universities, ICAR Institutes, and International Institutes have played a significant role in this direction. The Mahatma Phule Krishi Vidyapeeth, Rahuri, in Maharashtra, is a prominent institute that was founded in 1968 and has contributed significantly to current technology for the benefit of farmers.

Economists are frequently tasked with determining the economic impact of new technology in the setting of SAU/ICAR. The science of economics provides the

reasoning and methods for calculating the impacts of research, taking into account both tangible and intangible advantages. Intangible asset valuation is a difficult task. For a reflection of the economic impact of their technologies / inventions, policymakers seek answers from recipients of research grants, such as SAUs / ICAR institutes. Scientists work hard to develop new technologies and make them available through their Zonal Research and Extension Councils. Farmers' acceptance and adoption rates, on the other hand, appear to be lower than expected.

It is vital to analyze the economic impact of technologies on beneficiary's farm economy as compare to non-beneficiaries in terms of profit, cost of production and productivity, *etc.* by adopting the technologies.

Keeping in view, the current study was focused on impact assessment of investment in acid lime and sweet orange research in Maharashtra. To develop research strategies for sustainable food and livelihood security by providing policies and design programmes for university technologists and the state.

The specific objectives of the study are as below:

1.9 Objectives

1. To estimate the growth rates of area, production and productivity of citrus (acid lime and sweet orange) in India and Maharashtra.
2. To study the extent of investment in research and extension activities of citrus (acid lime and sweet orange) at the AICRP Fruits, MPKV, Rahuri.
3. To assess the impact of university released variety on income of citrus grower in Maharashtra.
4. To quantify the contribution of investment on research and extension in Maharashtra.

1.10 Hypotheses

1. H_0 : The area, production and productivity of citrus (acid lime and sweet orange) remain constant throughout the period.
 H_a : The area, production and productivity of citrus (acid lime and sweet orange) crop changing over a period of time.
2. H_0 : Research investment in citrus crop does not affect economic viability
 H_a : Research investment in citrus crop affects economic viability

1.11 Limitations of the study

The current study is focused on university released citrus varieties under AICRP on Fruits, Department of Horticulture, MPKV, Rahuri. Among citrus group acid lime and sweet orange fruit crops have been selected for the current study. Thus, the study pertains only research achievements in selected university released acid lime and sweet orange varieties in monetary terms. Similarly, the study relied heavily on secondary data gathered from a variety of published sources. Often data from various sources may not agree with each other and some efforts to choose the better among them were inevitable. Care has been taken to avoid personal bias in such decision. However, the limitations inherent in the secondary data need to be recognized.

1.12 Organization of the study

The thesis has been divided into six chapters. The first chapter highlights the introduction and objectives of the study. A brief review of the earlier work carried out by various researchers in the concerned field has been discussed in the second chapter. The third chapter devoted to the details of methodology, data and its sources and analytical techniques used to achieve the objective of the study. The results and discussion part of the study was seen in fourth chapter. The fifth chapter includes the summary and conclusion of the study. The last chapter devoted to the list of citations of previous research studies related to the study.

2. REVIEW OF LITERATURE

Methodological and technical aspects emplane for achieving the research investigation is introduced in this chapter. Literature published anywhere related to subject under study is always useful to the researcher to formulate an outline of the research, decide the objectives, choose suitable methodology and avoid useless duplication of efforts. It also provides introduction about the topic of investigation and about subject as a whole. Some of the findings of research carried out elsewhere relevant to the present study are reviewed in this chapter. The chapter has been organized under following sub heads.

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

Lathika and Kumar (2005) estimated the growth trends in area, production and productivity of coconut in India. The findings revealed that the high growth with low instability was a more common situation among the Indian states than high yield growth with low yield instability observed in Phase-II (1996 to 2002). In India area expansion is still viable option in most of the regions, it emerges that the problem of growth stability in yield had been trickier to tackle with than the problem of stability in area growth and it warrants urgent attention.

Dutta (2010) studied the growth of area, production and productivity of fruits and vegetables in West Bengal. The findings of the study revealed that the proportion of fruits and vegetable crops to the net cropped area are gradually increasing in West Bengal. Among the total fruit crops mango occupies maximum proportions of area to net cropped area even though the total area under mango gradually decreasing. It was observed that except the mandarin orange fruit crop positive change in area was notified in all the fruit crops. The growth rate of production was 6.15 per cent per annum. The stagnation over the years in production was observed in mango, mandarin orange and

other category of fruit crops. Stagnation in productivity for all the fruit crops except jackfruit was noticed during the study period. While in case of vegetable cultivation the 1.63 per cent per annum growth rate was observed.

Bairwa *et al.* (2012) studied the economics of growth and instability of fruit crops of India. It was found that productivity of fruits is almost stagnant over last decade and area and production has been almost double from 1991-92 to 2007-08. The fruit crops like citrus, grapes, papaya and sapota recorded higher growth rate in production. While higher instability in production was noted in banana, citrus, mango and papaya fruit crops. Banana, citrus, mango and papaya have shown higher change in production from 1991-92 to 2007-08. Relative share of grapes in total export was increased year by year and that of mango was decreased.

Rai (2013) examined the production and growth of horticultural crops at district level in West Bengal. Findings of the study revealed that the there was no satisfactory picture was observed in case of productivity levels was low especially for fruits. The horticulture sector development has not received the thrust it deserves. So it was needed that government to recognize and tap the enormous potential of the horticulture sector through research and development, infrastructure development and training and capacity building of farmers.

Ramachandra *et al.* (2013) studied the growth in area, production and productivity of major crops in Karnataka. Findings of the study revealed that the significant positive growth rate was observed in case of pulses, vegetables, spices, fruits and nuts while in case of cereals significant negative growth rate was observed. Jowar, bajra, ragi and minor millets were experiencing a substantial annual decrement. The area under the rice has recorded a mild annual increment. Negative and insignificant growth rate was observed in case of oilseeds and commercial crops. In case of cereals, pulses, vegetables and fruits recorded a significant and positive growth rate. Insignificant and positive growth rate was observed in case of production of oilseeds and commercial crops.

Singh and Nimmy (2013) analyzed the growth rate of area, production and productivity of fruit crops in Jharkhand. The findings of the study revealed that the positive growth rate was observed in all the selected fruits like litchi, mango, guava and

banana except citrus. It was also observed that the fourth period (2005-10) was favourable particularly for litchi, mango and guava while negative growth rate observed in case of banana and citrus. The growth rate of productivity for litchi, mango, guava and banana were 2.56, 2.56, 1.50 and 5.21 per cent, respectively. The growth trend indicated positive growth in volume of these fruits in the state.

Immanuelraj *et al.* (2014) examined the Maharashtra's onion growth and instability. The results showed that the onion production in Maharashtra was mainly driven by area expansion. But in the long run increasing area under onion production might not be feasible without reducing the area of other important crops. The reason behind the instability in onion production after period-II was mainly due to instability in area and partially due to instability in yield.

Kadli *et al.* (2014) studied the growth and instability analysis of fruit crops in India. The results showed that the growth of productivity was found positive at the rate of 1.05 per cent per annum and was associated with instability index of 10.16 per cent per annum. Similarly, the growth rate of area was found positive at the rate of 7.34 per cent per annum with the high instability index of 10.16 per cent while in case of production of fruit crops 8.48 per cent per annum growth rate was noticed with low instability index of 0.10 per cent. Due to the absence of regulated markets, fluctuations in market prices, absence of support price in the case of glut, non availability of quality testing laboratories and lack of adequate cold storage facilities were the major constraints in the growth rate of area and productivity of fruit crops in India.

Kondal (2014) estimated the growth rate of area, production and productivity of onion crop in Andhara Pradesh. It was noted that the compound annual growth rates of onion productivity was negative (-1.84 %) during the 2007-08 to 2011-12, even though the area under the cultivation of onion crop and its production were positive.

Kumar and Singh (2014) estimated the trends in growth rates of area, production and productivity of sugarcane in Haryana. They observed that the growth rate in area of sugarcane crop was found negative in both the region and most of the districts of Haryana. While in case of growth rate of production was found negative in almost all the districts except Bhiwani and Karnal. On the contrary, the growth rate of productivity

of sugarcane crop was found positive in most the district of Haryana. This indicated that the rate of change in area of sugarcane crop was higher than the rate of change in production in most of the districts of Haryana.

Lokesh and Singh (2014) examined the horticultural development in Himachal Pradesh: an empirical analysis. The results of the study revealed that in spite of multifold increase in production of horticultural crops over the years, the productivity is continuously declining and the contribution of the horticulture sector in the primary sector indicate mixed trend for the last ten years from 2000-01 to 2009-10.

Singha *et al.* (2014) examined the inter district growth and diversification of horticulture crops in Karnataka. Complete diversification towards horticultural crops in the districts of Gulbarga, Raichur, Bijapur, Bidar, Koppal, Bagalkot and Bellary while the least diversification was observed in the districts of Koalr, Udupi and Dakshina Kannada. Those districts were lesser diversified to the horticulture have got the lesser growth rate of area under horticultural crops but contributes higher share of area under the crops.

Choudhary and Kundal (2015) estimated the area, production and productivity of tomatoes in India from 2002 to 2011. Findings revealed that during time period of the study the area, production and yield of tomatoes in India was remarkable. Such a rise assures reflects a bright future of the horticulture sector in India in the coming times.

Kadam *et al.* (2015) examined the growth and performance of horticulture in India. Findings of the study revealed that the fruit production was increased five times from 5.5 million tonnes in 1952-53 to 28.63 million tonnes in 1991-92 and further nine times to 54.04 million tonnes by 2013. The growth rate in mango crop showed positive trend for area, *i.e.*, 5.32 per cent and 4.78 per cent for production. The productivity was decreasing due to market behaviour. The growth rate in onion crop showed positive trend for area and production *i.e.*, 3.86 and 5.51 per cent, respectively. The productivity was increased due to market behaviour and more technology innovation. The growth rate in spices crop showed positive trend for production and productivity *i.e.*, 4.74 and 5.72 per cent, respectively. The area was declined due to market behaviour and aggregate

deviations. India's export of fruits and vegetables was found to be 12 crores to 13,240 crores, still at the global level our share was only around 1.4 per cent.

Kaur *et al.* (2015) analyzed the trends in area, production and yield of important crops in India. The trend analysis area (India), state (Gujarat) and district (Vadodara) level; production at state Gujarat and district (Vadodara) level of Banana. Area under banana crop showed variations at all three levels. Its production showed annual instability at state level but overall decrease at district level. Its yield also showed decreasing trend at district level.

Wasim (2016) estimated the trends, growth rate scenario and instability in area, production and productivity of mango fruit in Punjab and Sindh provinces of Pakistan. It was observed that during the period-I (1970-71 to 1991-92) of Sindh, growth of production was mainly due to both area expansion and productivity improvement while, in case of Punjab it was only due to the area expansion, not due to the improvement in productivity. As compared to period-I the growth rate of production of mango was increased during period-II (1992-93 to 2013-14) in both the provinces. It was also reported that the growth rate of productivity of mango in Sindh recorded negative and significant growth, while in case of Punjab growth rate of productivity was found positive and insignificant during period-II as compared to period-I it may be due to the drought and flood from 2000 onwards and non-availability of proper roads from mango garden to markets. The instability in mango production was declined in period-II as compared to period-I.

Arti and Rai (2017) studied the growth rate of area, production and productivity of sugarcane crop in Uttar Pradesh. Results showed that the compound annual growth rates of area, production and yield of sugarcane crop showed positive sign which reflects that increasing growth rate of sugarcane production pattern. Sugarcane yield was stable in past sixty five years, whereas production and area increased at 2.25 and 1.96 per cent, respectively.

Islam and Shrivastava (2017) estimated the area, production and productivity of apples in Jammu and Kashmir from 2006-07 to 2015-16. The increasing trend was observed in case of area under apples in the state of Jammu and Kashmir during the period of study. Similar, picture was observed in case of production of apples

in the state. While in case of productivity of apples in the state rising trend was observed during the study period except in the years 2009-10, 2012-13 and 2014-15. The highest decrease in productivity was seen in the year 2014-15 and the reason behind this was the floods in the September 2014.

Kashish and Dhawan (2017) examined the production and trade performance of fruits in India. It was found that 3.18, 4.72 and 1.48 per cent per annum growth rate of area, production and productivity of fruits, respectively. The productivity of fruits in India increased from 9.96 Mt/ha to 14.2 Mt/ha during the year 1991-92 to 2014-15. Export of fruits increased over the years which was good for the growth of a country but as far as commodities (with low value addition) were concerned, India's volume of imports were growing at a much higher rate than the growth rate for exports.

Nabi and Bagalkoti (2017) estimated the growth trends of horticulture crops in India. It was found that there was significant growth of area, production and productivity of horticultural crops in the country. The value of output for fruits and vegetables was found to be at the highest, accounted for about 26 per cent of the total agricultural value of output. However, despite impressive output growth, the yield growth rate of yield of fruit crop was found to be statistically insignificant.

Saravanapandeeswari and Vanitha (2018) studied the growth of area, production and productivity of banana (*Musa paradisiaca*) cultivation in Theni district of Tamil Nadu. The results showed that the both area expansion (59.46 %) and improvement in productivity (25 %) has significantly contributed in the increased in production of banana cultivation in the state. While in case of Theni district of Tamil Nadu both area expansions (39.20 %) and improvement in productivity (26.08 %) contributed in increasing production of banana in the district. Hence, by keeping with the area constant the productivity of horticultural crops can be further increased by taking appropriate production technologies.

Singh *et al.* (2018) examined the production performance of fresh mango in India: a growth and variability. The results of the analysis revealed that the growth rate of area under mango cultivation was found positive and non significant at the rate of 3.78 per cent per annum, while the production registered a growth rate of 3.00 per cent during same period. The growth of productivity was declined at the rate of 9.6 per cent per

annum but it was highly significant at 1 per cent level of significance. The Andhra Pradesh ranks first in case of average area (19.35 %) and production (25.39 %) of mango cultivation. The growth rates of area and production were 3.36 and 1.38 per cent per annum, respectively which were highly positive and significant at 1 per cent level of significance. Uttar Pradesh was in top position in case of productivity of mango followed by Karnataka and Bihar. The total area and production under mango cultivation was increasing gradually while the productivity declined gradually. Thus there was need to pay attention to carried out some productivity enhancing measures like adoption of high density planting techniques, appropriate orchard system, infrastructure services, enhanced technical awareness level of growers regarding the cultivation of mango to tackle the natural calamity and disease attack with respect to fruit protection.

Adhale *et al.* (2019) estimated the growth and instability of area, production and productivity of sugarcane in Maharashtra. It was observed that the production of sugarcane in Maharashtra was increased mainly due to area expansion and slightly because of improvement in productivity for the districts *viz.* Kolhapur, Sangli, Satara, Pune, Solapur, Beed, Osmanabad, Dhule, Jalgaon, Aurangabad, Nagpur, Parbhani and Akola. The production was increased only due to area expansion for the districts *viz.* Ahmednagar, Latur, Nashik and Jalna. The growth rate of productivity of these districts declined over a period of time.

Bhat (2019) studied the growth rate of area, production and productivity of apples in India from 2001-02 to 2017-18. During the period of study the rising trend was observed in case of production and productivity of apples in India. Similarly, the rising trend was observed in case of area under apple cultivation in India during the study period except the year 2002-03. The production of apples has increased from 1158.4 (000" MT) in 2001-02 to 2371 (000" MT) in 2017-18. The productivity of apples has increased from 4.8 Mt/ha in the year 2001-02 to 7.7 Mt/ha in 2017-18. Similarly, in case of productivity of apples the rising trend was observed during the period of study except the years 2006-07, 2009-10, 2011-12, 2012-13 and 2014-15.

Jha *et al.* (2019) examines the trends of the horticultural sector in India and identifies the growth prospects. Out of the overall growth rate of 3.56 per cent in agriculture during 2000-2011, fruits and vegetable alone accounted for 19.2 per cent. The

share of high value crops in value of output of the agricultural sector was also increased, both in absolute terms as well as in shares. To the total exports of agricultural commodities share of horticultural sector was about 37 per cent and the exports have recorded sustained rising trend. Across the states of India there was wide variation on the growth performance. The major reason behind the sector were improving the productivity through research and development, enhancing the share of value added products, geographical diversification of exports and enhancing the infrastructure including cold storage and rural roads. The public sector research needs to be strengthened factoring in the constraints of small holders who constitute the major producers.

Mondal and Chattopadhyay (2019) studied the growth performance of fruits production in the era of globalization in West Bengal. Findings of the study showed that the growth rates of production of crop-groups were found significantly positive in West Bengal and India. While in case of all fruits combined, Burdwan experienced significantly positive growth in its production both in case of West Bengal and in India. The production growth rates of mango and litchi were significantly positive in the country as well as in the state.

Panghal *et al.* (2019) estimated the growth rates of guava (*Psidium guajava L.*) fruit in Haryana using Non linear model. The growth rate of area of guava for Hissar, Kurukshetra, Yamunanagar district of Haryana and for the whole state were found to be 8.48, 5.17, 8.19 and 6.47 per cent per annum, respectively. While the growth rate of production of guava for the same were 7.93, 7.62, 8.82 and 10.20 per cent per annum, respectively.

Raju and Kumar (2019) examined the trend analysis of area, production and productivity of sugarcane in India. The findings of the study revealed that the growth rate of area, production and productivity of sugarcane in India for the entire period were 1.65, 2.93 and 1.25 per cent, respectively.

Shah (2019) examined the trend analysis of area, production and productivity of apple fruit in Jammu and Kashmir. Growth rates of area, production and productivity of apple were observed to be 1.71, 2.83 and 1.1 per cent per annum, respectively during the study period. The growth rate of area was increased from 2.33 to 3.16 and production was increased from 3.51 to 3.83 while yield has decreased from 1.15

to 0.64. There have been various fluctuations in the area and production over the years and across the states. From the results it was suggested that there was need to analyze the trends in the area, production, yield of apple fruit in the state of Jammu and Kashmir and taking the necessary steps to improve the apple production and productivity in India as well as in the state of Jammu and Kashmir.

Bee and Rahman (2020) studied the growth rate of area, production and productivity of sugarcane crop in India. It was found that the growth rates of area, production and productivity were positive. The area under sugarcane crop was reported an increased at the rate of 5.63 per cent in duration of thirty years from 1985 to 2015 and the sugarcane production has increased by 7.40 per cent during the same period.

Mehazabeen and Srinivasan (2020) studied the area, production and productivity of banana in Y.S.R. district of Andhra Pradesh. The findings of the study revealed that the growth rate of area, production and productivity were 11.07 per cent, 19.96 per cent and 9.08 per cent per annum, respectively during 2007-2017. It was observed that the research priorities should be in accordance to achieve higher production and productivity with minimum cost of production.

2.2 Total Factor Productivity (TFP) and its factors

Hsu *et al.* (2003) analyzed total factor productivity growth in agricultural sector of China. Results of study revealed that the overall growth in total factor productivity remains sluggish in China's agricultural sector. The tax policies of the government and investments made in research and development have not yet been very effective in promoting productivity, efficiency and technical progress. On the other side, regional factor seems to be a very important determinant on efficiency improvement and technical innovation.

Rao (2005) studied the total factor productivity in Andhra Pradesh. It was observed that the average annual index of the total factor productivity during the post-reform period was 5 per cent which was less than the pre-reform period in the state in the whole crop sector. In case of non-food grain crops, the average annual of TFP index was 9 per cent observed to be less than pre-reform period. While in case of food grain crops it was less than 100 during both the periods. The share of total factor productivity to output was found to be a healthy 31 per cent in the pre-reform period. An absolute decline (-37)

has been noted during the post-reform period in the crop sector of the state. The drastically fall of contribution of technical change in non-food grain crops in the state during the post-reform period. The major reason behind the decline in total factor productivity in the crop sector of the state during the post reform period was may be due the distress among the farmers in the state, which has been manifesting in the form of suicides since the late-1990s.

Surya (2005) examined the total factor productivity growth of wheat in India by Malmquist approach. He concluded that although technological progress has contributed mainly to the total factor productivity growth of wheat production for the period under study, it has been uneven among major wheat producing states. Total factor productivity was higher in developed states, like Punjab 11.4 per cent and Haryana 4.6 per cent in comparison with relatively less developed states like Uttar Pradesh 0.4 per cent, Madhya Pradesh -3.2 per cent and Rajasthan 1.7 per cent for the period 1981-82 to 1999-2000. In Punjab the growth of TFP has more than doubled from 7.91 per cent in the pre-reform to 18.6 per cent in the post-reform period due to boost in the technological change supported by matured and/ or sustained public R and D, extension, supplies of new inputs including irrigation, power and credit, besides inputs subsidies and private investment by the farmers In the state of Madhya Pradesh it turned from -0.9 to 4.2 per cent in the post reform period which could point to a cycle of total factor productivity in Madhya Pradesh's wheat production. Growth of TFP has declined during the post-reform period in comparison to the pre-reform period in the state of Haryana, Uttar Pradesh and Rajasthan.

Ananth *et al.* (2006) estimated the impact of research investment on technology development and total factor productivity in major field crops of peninsular India. For estimating the total factor productivity Tornquist Thiel Index was used. Those crops attracted higher research investments, in turn attributed to growth in productivity due to continuous up gradation in the technologies which in turn growth in TFP was higher in such crops.

Khobarkar *et al.* (2006) examined the economic analysis of total factor productivity in agriculture in Konkan region in Maharashtra. Findings of the study revealed that total input index was 0.912 per cent higher than the total output index i.e.

0.883 per cent, which turn out to be negative total factor productivity growth i.e. 0.02 per cent.

Kumar and Mittal (2006) estimated the agricultural productivity trends in India: sustainability issues. It was observed that during post green revolution period the usage of input was increased and decelerating total factor productivity growth (TFPG). The agricultural productivity attained during the 1980s has not sustained until the 1990s and had a challenge for the researchers to upward shift of the production by improving technology index. It examined an issues related to the trends in the agricultural productivity, particularly with reference to individual crops grown in the major states of India. The study has also been examined the temporal and spatial variations in the TFPG for major crops of India.

Thorat *et al.* (2006) studied the total factor productivity in horticultural crops in Konkan region of Maharashtra. Period wise comparative picture of TFP growth has revealed that the magnitude of TFP growth varied from 1.3 per cent per annum during 1990s to 6.2 per cent per annum during 1980s. The TFP has been found to be grown at the rate of 5.4 per cent per annum during the entire period of study. On the basis of the results of the present study the divergent picture of a horticultural growth in the Konkan region have been seen. Major source of TFP growth was the investment on research. The IRR of 119 per cent indicates the high pay-off returns to horticultural research.

Chandel (2007) studied sustainability of total factor productivity of oilseeds in India? The findings of the study revealed that the TFP of rapeseed and mustard grew at a significant rate while in case of groundnut, sunflower and soybean it was close to zero. The TFP declined substantially in case of sesamum and safflower. The rate of increase in output index was higher than the input index of rapeseed, mustard, groundnut and sunflower. In case of sesamum and safflower the declining trend of TFP growth was observed in these crops. Increasing input index than output index in soybean crop reflected production inefficiencies causing TFP to be almost stable. The state of Rajasthan registered higher growth rate in TFP for oilseeds production in the country followed by Uttar Pradesh. In case of other states of the country the overall TFP of oilseeds to be stagnant except in Karnataka where it significantly declined. The overall

growth rate of TFP index declined by 1.21 per cent per annum it indicates that the overall unsustainable behavior of total factor productivity growth of oilseeds in India.

Karim and Talukder (2008) studied the total factor productivity of wheat in Bangladesh. Results revealed that the growth rate of output price was always less than the growth rate of input price. The growth rate of inputs used was found higher during second period as compared to first period. The growth rate of total factor productivity was highest during second period. The wheat production in second period was most cost effective and the growth rate of productivity was found 0.2 per cent. Among all the periods only second period was considered as the golden revolutionary period in the history of wheat in Bangladesh since 1980. Technological change in wheat production in the golden revolutionary period was relatively benefited to the consumers more than the producers. It was observed that the research, mechanization and market were the most important sources of growth in total factor productivity. The extent of annual fluctuation of wheat productivity can be minimized by more efficient inputs use.

Kumar *et al.* (2008) examined the agricultural growth accounting and total factor productivity in South Asia. It was observed that the encouraging TFP growth was noticed for crop and livestock sectors in Bangladesh and Pakistan. Large number of cases of deceleration in total factor productivity growth was reported in India, except for rice in its Eastern and Southern states. Negative growth rate was observed in Sri Lanka.

Mahmood and Afza (2008) studied the total factor productivity growth in East Asia: A Two Pronged Approach. It was observed that the secondary education was the only variable that had a positive impact on TFP growth and efficiency growth while it was insignificant for technical change. On the other hand, trade openness and foreign direct investment were seen to be inconsequential as determinants of TFP growth and its components. It was observed that the internal technological improvements as opposed to foreign capital and technologies were the main determinant of TFP growth and improvements in efficiency.

Kumar and Managi (2009) studied the productivity and convergence in India: state level analysis. The findings of the study revealed that in the beginning of the liberalization era, improvement in technical efficiency contributes to the growth of TFP. In case of other periods, the TFP growth was governed by the growth in technical

progress. It was observed that the variation across states in efficiency and technical change was almost constant up to 1999-2000, but after that it was increasing. It was also found that the states with better quality of life are more productive in terms of resources using efficiently.

Tripathi (2010) studied the total factor growth in Indian agriculture. It was observed that during the year 1969 and 2005, agricultural growth mostly dependent entirely on increased in conventional factors while productivity growth was negative. The TFP growth was positive only during initial periods of reforms. The stagnation in growth of total factor productivity has considerable implications for the long term performance of Indian agriculture. In the 21st century, it will be difficult to expand convention factors of production such as agricultural land and labour and without the growth in TFP, agricultural output will continue to stagnate or grow only very slowly. It will further erode the profitability of agriculture and speed the drain of resources away from agriculture and rural areas to other sectors of the economy. It will be undermine the important role of agricultural growth in reducing poverty and generating broad based economic growth for the Indian economy.

Chand *et al.* (2011) examined the total factor productivity and contribution of research investment to agricultural growth in India. It was observed that the considerable variations in growth in TFP across crops and regions. The wheat crop has enjoyed the highest benefit of technological breakthrough during the past three decades with its TFP growth about 2 per cent. Rice crop has far behind the wheat crop, while maize crop has witnessed growth rate of TFP at the rate of around 0.67 per cent per annum. Lower growth rate was observed in case of major cereals, namely wheat, paddy and maize after the mid-1990s. During 1995-05 the growth rate of TFP of hybrid sorghum was declined. While bajra is a highly rainfed crop even though the growth rate in TFP was highly impressive. More than half of the total growth in output of wheat and around one-fourth in other cereals have been contributed by the growth in respective TFP.

Kannan (2011) studied the total factor productivity growth and its determinants in Karnataka agriculture. It was observed that most of the crops have registered low growth in productivity across these periods. During 2000-01 to 2007-08 all

crops have showed a positive growth rate in TFP. It also showed that the sources of growth rate of TFP are government expenditure on research, education and extension, canal irrigation, rainfall and balanced use of fertilizers are the important drivers of crop productivity in Karnataka. It is necessary that both the public and private investment should be enhanced in agricultural research and technology and rural infrastructure for sustaining productivity growth in the long run.

Chand *et al.* (2012) studied the total factor productivity and returns to public investment on agricultural research in India. The growth of total factor productivity has shown variations across crops in different states and at all-India level during the period 1975-2005 and these variations have indicates that technological gains have not been experienced in a number of crops in many states. In case of cereals the growth rate of TFP has helped to reduce the real cost of production in the range of 1.0-2.3 per cent annually. It has helped in keeping the prices of cereals low for consumers and providing benefits to producers through a decline in the real cost of production.

Chaudhary (2012) examined the total factor productivity in Indian agriculture: state level evidence using non-parametric sequential Malmquist Index. In very few states productivity improvements was observed. In most of the states the improvements in efficiency was observed to be low and decline in efficiency was observed in several states implying huge gains in production possible even with the existing technology. The suggestions of the study was to achieve higher productivity, it is essential to increase efficiency level as well as achieve a more even spread of new technology.

Immanuelraj and Atteri (2013) studied the total factor productivity of sugarcane in Maharashtra. Divisia Tornquist Index was used for estimation of Total Fator Productivity. It was found that the increased productivity of sugarcane in Maharashtra was due to the increased in resources and not due to the improved in technology.

Gerald and Raphael (2014) examined the total factor productivity effects of agricultural policies and climate change using production function models. Research on growth of total factor productivity informs policy design. Trends in short run and long run productivity are often diverging. On the basis of the results of the study it is

necessary to formulate the policies related to productivity which consider both more immediate and extended outcomes and trends.

Karunakaran (2014) estimated the total factor productivity growth of the crop sector in Kerala and observed that the stagnation in the growth of total factor productivity of crop sector i.e. negative and very low growth rate of TFP per annum in Kerala and a similar pattern was observed in all districts. On the basis of the results of the study that the TFP changes across the districts and states and share of total factor productivity in output growth of the crop sector in Kerala showed a clear sign of unsustainability of the crop sector. It was revealed that the share of TFP in output growth was negative except the districts Kollam, Idukki, Wayanad and Palakkad during the time period 1980-81 to 2009-10. The period wise analysis also derived deceleration in the growth of total factor productivity.

Saha (2014) estimated the total factor productivity trends in India: A Conventional Approach. The findings of the study revealed that on an average the growth rate of TFP was 1.49 per cent during the study period but it was erratic in nature. Even though the growth rate of TFP was found positive during 1960s, it was very low and near about close to zero. Similarly, during 1970s the economy experienced technological regress instead of technical progress due to negative growth of total factor productivity. The reason behind the low productivity during these periods may be the external shocks like war, drought, oil price-hike along with rigid rules and regulations during these periods. Whereas after the initiation of economic reforms measures during 1980s the overall productivity of economy has increased considerable. From the initiation of external economic reforms the economy experiencing continuous rise in growth of total factor productivity. It was observed that the estimates of total factor productivity in India are not sensitive to factor shares.

Saikia (2014) analyzed the total factor productivity in agriculture: A review of measurement issues in the Indian context. Findings of the study revealed that the growth of total factor productivity in Indian agriculture was very low during the pre green revolution period and it was declined during 1970s. During 1980s the growth rate of TFP has marginally improved but it has again declined during the 1990s.

Das (2015) estimated the total factor productivity growth of Jowar and Bajra in India: A Comparative Analysis Using Different Methods of TFP Computation. The growth of total factor productivity (TFP) was estimated by using the different methods viz. Solow index method, Törnqvist Theil index method and the Malmquist index method. The initial two methods have imposed certain theoretical constraints while calculating growth of TFP. These constraints can be overcome by using third method, viz. the Malmquist index method. In case of Jowar and Bajra are the rainfed crops, rainfall has been considered as one of the major input in the production of these coarse cereals in the Malmquist index method. Hence, it is recommended that for the measurement of TFP growth Malmquist Index method may be more preferable because it gives reliable estimates of total factor productivity.

Olayiwola *et al.* (2015) examined the total factor productivity of major crops in central India. It was observed that the variability in total output index and total input index was may be due to the exploitation of available production potential in the state. Malmquist method of TFP index explained the various stages of production in Madhya Pradesh over a period of time. It was observed that the post global and combine periods were better than the pre global period. TFP is a comprehensive measure of productivity and has gained acceptance among government officers, policy makers, productivity specialist and economist.

Sanap *et al.* (2015) studied the total factor growth of sugarcane crop in Maharashtra. Results indicated that the area and production of sugarcane crop was increased but productivity growth was very less in Marathwada as well as in the Maharashtra state. There was no substantial growth recorded in sugarcane output in the region. The usage of inputs has been increased like chemical fertilizers viz. nitrogen 1.53 per cent, phosphorous 2.92 per cent, potash 11.33 per cent and the number of irrigations 10.96 per cent in sugarcane cultivation, increased in the region. Over the period of time use of inputs fluctuated around some constant value. Growth in total factor productivity of sugarcane crop was observed in sub sector in Maharashtra state. Area under irrigation, high yielding varieties and a number of tractors and road density had a positive and significant impact on total factor productivity of sugarcane crop in Maharashtra.

Suresh and Chandrakant (2015) studied the total factor productivity and returns to investment in Ragi (finger millet) crop research in Karnataka state, India. It was observed that the growth of total factor productivity of Ragi crop grew at the rate of 4.75 per cent per annum. In growth of TFP of ragi crop, public research contributed significantly. In Karnataka it was observed that there was substantial growth rate in total factor productivity of ragi crop. Therefore, the government has to allocate the substantial funds to public research in ragi crop for productivity improvement to provide food security to masses.

Sharma and Dupare (2016) examined the total factor productivity growth and returns from research investment on soybean in India. The total factor productivity growth was estimated by using the Tornqvist Theil Index. The moderate growth rate of TFP (1.2 % per year) in soybean crop was observed and the TFP share in output growth was 10.5 per cent. In case of decade wise analysis has revealed that the growth rate of TFP and the share of TFP in output growth in the recent decade. In the recent decade the TFP growth and TFP share in output growth in the soybean crop is increasing.

Suresh and Reddy (2016) studied the total factor productivity of major pulse crops in India: Implications for Technology Policy and Nutritional Security. It was observed that the capita consumption of pulses has declined over the years. The productivity of pulse crop in general has stagnated over the years. Among the pulse crop under the study, chickpea and green gram have exhibited improvement in TFP. It is also revealed that pulse crop are the cheapest source of proteins among all foods and because of this it place at significant level in improving nutrition at individual level as well as country level.

Surya (2016) examined the total factor productivity growth of wheat and paddy in post-green revolution era in India: Parametric and Non-Parametric Analysis. Numerical findings of the analysis indicated that the high yielding states like Punjab has resulted decline in growth of total factor productivity of wheat and paddy crops in recent times, which gives an indication of the long-term sustainability of wheat and paddy production system in this green revolution star state.

Dhandhalya *et al.* (2017) examined the revolution in wheat production and total factor productivity in Gujarat: The Contribution of Research Investment. The

findings of the study indicated that moderate growth rate of output and input indices of wheat crop in Gujarat at the rate of 1.53 and 1.05 per cent per annum, respectively in 2000s. This was contributed by the improved varieties of wheat *viz.* GW-496 and GW-503 in 1989, GW 273 in 1997, GW-322 in 2002, GW-366 in 2006, along with the proper agronomical practices as well plant protection measures by the then GAU and SAUs in the state, which helped remarkably increased the productivity of wheat in first decade of 21st Century.

Jain *et al.* (2017) studied the total factor productivity growth in Indian crop sector. It was noticed that the average annual growth rate of TFP in recovery phase of agriculture, *i.e.* during 2004-05 to 2011-12 as high as 5.41. The share of TFP growth in output has been nearly about 88 per cent at economic prices. The study has concluded that the recent growth in agriculture is going to be sustainable.

Rajni *et al.* (2017) examined the total factor productivity growth in Indian crop sector. The average annual growth rate of TFP was 5.41 during recovery phase of agriculture *i.e.* during 2004-05 to 2011-12. The major contribution of the study is estimation of TFP index at alternate price scenarios like market price, input price and with exclusion and inclusion of labour wages bill. Share of TFP in output has been nearly about 88 per cent at economic prices. Thus, the conclusion of the paper is that recent growth in agriculture is going to be sustainable.

Singh *et al.* (2017) examined the impact of total factor productivity and returns to investment on research for sustainable agriculture growth: a case study of South Gujarat region. Findings of the study revealed that the considerable growth rate of TFP in South Gujarat occurred in paddy, wheat, tur, cotton, sugarcane and banana. Highest TFP growth was observed in case of cotton means more than 3 per cent it indicates that cotton has enjoyed highest benefit of technological innovations during past twenty four years.

Dhandhalya *et al.* (2018) examined the research contribution for rice productivity growth in Gujarat: As Reflected by TFP and RRI. For estimating the TFP indices the Tornvuiist Theil Index was used. During 1990s the growth rate of TFP of rice was stagnant (0.35 %) and the input and output index were increased at lower rates. Moderate growth rate of TFP was observed during 2000s at the rate of 1 per cent per

annum. Due to the technological change, the growth rate of output index increased at the rate of 1.48 per cent during 1990-91 to 2011-12. It helped to keep the real cost of production near about stagnant from 2000s onwards, which was increased by 1.5 per cent per annum in 1990s. The share of TFP in output growth for rice crop remained high about 92.16 per cent during last two decades in Gujarat. This reveals that Gujarat has shown an outstanding performance of TFP growth in rice. This is credited to the release of popular varieties viz., GR-101 in 1984, GR-103 in 1990, GR-6 in 2010, in the state by the then GAU and SAUs, remarkably increased the productivity of paddy.

Niranjan *et al.* (2018) estimated the total factor productivity growth and trend in production of gram in Central India. The findings of the study revealed that the overall growth of input, output and TFP index was positive during 1992-2011. It was observed that the input as a source of growth for gram crop was declined related to manure, human labour and animal labour indicates that the ratio of output to input declined over the period of time but still seed and fertilizer are the major source of for gram crop in Madhya Pradesh.

Shanmugan and Baria (2018) examined the total factor productivity in Indian agriculture: An exploratory analysis based on literature review. It was noticed that there are various thought evoking issues associated with total factor productivity but proofs are very conflicting, sometimes controversial and subjected to further detailed investigation.

Vilhekar *et al.* (2018) studied the growth and total factor productivity change of cumin in Gujarat. Results shows that there were moderate growth rates of output and TFP indices was observed at the rate of 2.94 and 1.46 per cent per annum, respectively in last two decades. TFP growth was remained low about 0.99 per cent per annum during the period 1995-96 to 2004-05, this improved remarkably during 2004-05 to 2015-16 at the rate of 1.51 per cent per annum. This happens mainly due to the release of high yielding varieties in Gujarat *i.e.* MC-43 in 1970, GC-1 in 1982, GC-2 in 1992 and GC-4 in 2003, released by the state agricultural universities, which are performing well in the state.

Vilhekar *et al.* (2018) examined the growth and total factor productivity change of fennel in Gujarat. The moderate growth rates of output and TFP indices of

fennel crop were observed at the rate of 1.11 and 3.01 per cent per annum, respectively during last decades. TFP growth rate remained low about 0.96 per cent per annum during 1995-96 to 2004-05; it was increased remarkably about 2.29 per cent per annum during 2004-05 to 2015-16. This happens may be due to the release of high yielding varieties in Gujarat *i.e.* Fennel-1 in 1984, GF-2 in 1997, GF-11 in 2004 and GF-12 in 2015 by the then GAU and SAU's of Gujarat increased remarkably the yield of fennel in Gujarat. Along with technical innovation like drip irrigation and farm management contributed in the improvement in productivity in the state.

Choudhari *et al.* (2020) studied the role of technological change in enhancing the income of rainfed farmers: A study of Bajra crop in Western Maharashtra. The numerical findings of the study revealed that there were increasing trend was observed in case of input, output and TFP indices during both the periods and in all divisions of Western Maharashtra. Based on the results it is concluded that the modern inputs such as (Shanti, Saburi, *etc.*), integrated nutrient management (organic manure + chemical fertilizer + biofertilizer), *etc.* contributed major in growth of total factor productivity in Western Maharashtra.

Kulkarni *et al.* (2019) examined the total factor productivity and returns to investment in paddy research in Western Maharashtra. Findings of the study revealed that the output index of the paddy increased from 0.88 in 1993-94 to 1.60 in 2013-14. The average annual output index was 1.48 for twenty one years. The highest output index was observed in 2006 *i.e.* 2.15. The average annual input index of paddy for twenty one year was 0.80. In 2006-07 the highest TFP index was noticed *i.e.* 3.33. The growth rate of total factor productivity index was increased at the rate of 5.98 per cent per annum. The public research significantly contributed (0.27) to growth of total factor productivity of paddy.

Suresh (2019) examined the total factor productivity of sorghum in North Eastern Karnataka, India. It was observed that the TFP index of sorghum crop increased substantially over the years and the average annual TFP index for 22 years was 1.39, which shows the growth in TFP may be due to the factors such as research, extension, soil types, rainfall and infrastructure facilities, *etc.*

Zhang *et al.* (2020) examined the dual challenge in China's sustainable total factor productivity growth. From the decomposition analysis, it was found that

China tackled a dual provocation in growth of total factor productivity: firstly the growth of capital productivity exhibits a considerable slowdown after the mid 1990s; second even though labour productivity has continuously expanding, the relative labour efficiency among territory has deteriorated since the 2000s. On the basis the results imply that the government not only advocate upgrading the industrial structure but also consider equal regional developmental policies for China's sustainable growth.

2.3 Contribution of agricultural research and extension and rate of returns to investment

Ananth *et al.* (2006) examined the impact of research investment on technology development and total factor productivity in major field crops of peninsular India. On the basis of the analysis it was observed that the agricultural research investment had impact on released varieties of crop and other technologies. The rate of return to agriculture was estimated by using total factor productivity indicates the high rate of return in case of rice and sugarcane, medium for finger millet, cotton and sorghum and negative in red gram, groundnut and sunflower.

Sheng *et al.* (2011) analyzed the public investment in R and D and extension and productivity in Australian broad acre agriculture. Public investment in research and development and extension has generated rates of return that could be as high as 28 and 47 per cent a year, respectively. While little is known about the opportunity cost of public investment in research, development and extension this rate of return is comparable to rates of return estimated for other developed countries. Further, the growth in domestic public R and D and extension knowledge stocks arising from this investment has accounted for 0.33 and 0.27 per cent, respectively, of TFP growth annually in the broad acre sector (an aggregate of 0.6 %).

Chand *et al.* (2012) estimated the total factor productivity and returns to public investment on agricultural research in India. It was observed that the returns to investment on agricultural research were estimated at 42 per cent. It was found that about one fourth growth in output of wheat and cotton, one fifth in case of pearl millet, and near about one eighth in paddy and maize each have achieved due to investments on agricultural research. During 2005-06, the contribution of research in crop output has been estimated to be 10.4 MT for wheat and 6.3 MT for rice. In case of monetary terms

the contribution of research in the value of selected crop has been computed as 1552 Crore. The study has concluded that there is need of higher allocation of resources for development of agriculture in the country and for attainment of national food and nutritional security.

Joshi *et al.* (2015) examined the public investment in agricultural research and extension in India. The study reveals that returns to investments differed significantly according to geography, with the states that had a higher share of total factor productivity growth in their output growth faring better than the rest in relative terms. The R and E investment in the crop sub-sector in India has been especially rewarding, generating returns that are close to 50 per cent.

Sharma and Dupare (2016) estimated the total factor productivity growth and returns from research investment on soybean in India. Research investment and irrigation are the variables which significantly contributed to the growth of TFP. Although, the estimated value of marginal product of research has been found less than one, the internal rate of return (IRR) for research investment is increasing in recent decades. On the basis of the results it is suggested there is need to invest in research and irrigation infrastructure for improvement in productivity and edible oil security in the country.

Suresh and Chandrakant (2016) estimated the economic efficiency of improved red gram variety (BRG-2) in Karnataka: a DEA Analysis. The results showed that the net return with red gram and pure crop was higher (5, 629 per acre) for BRG2 red gram farms than (3,936 per acre) for check variety farms, with a difference of 1,692, by 30 per cent. DEA analysis showed that farmers of BRG 2 have greater economic efficiency, allocative efficiency than check variety farmers using inputs such as seed, farm yard manure, chemical fertilizers, human labour, bullock labour, machine labour and plant protection chemicals. The BRG 2 red gram variety was economically performing well in field conditions and offering higher returns to farmers compared to the check varieties.

Dhandhalya *et al.* (2017) estimated the revolution in wheat production and total factor productivity in Gujarat: The Contribution of Research Investment. Findings of study revealed that the moderate growth rates of output and TFP indices was observed at

the rate of 1.53 and 1.05 per cent per annum, respectively during 2000s. This was mainly due to the released of high yielding varieties viz., GW-496 and GW-503 in 1989, GW 273 in 1997, GW-322 in 2002, GW-366 in 2006, along with proper agronomical practices as well as plant protection measures by the then state agricultural universities, considerably increased the productivity of wheat in first decade of 21st Century. The investment in wheat research generated 29 per cent internal rate of return (IRR) which was highly paying proposition during study period. Growth in productivity indicated that the government expenditure on research in agriculture and education, balance use of fertilizers and development of ground water as well as canal irrigation in the state, and good monsoon has positive and significant impact on TFP.

Singh *et al.* (2017) examined impact of total factor productivity and return to investment on research for sustainable agriculture growth: a case study of South Gujarat region. The findings of the study revealed that the one rupee investment in research has generated additional income of Rs 7, indicating high rates of returns to public investments. The marginal internal rate of return to agricultural research was estimated between 35 and 54 per cent it shows that investment in agricultural research during the past 24 years has given the attractive returns.

Suresh and Chandrakant (2017) studied the economic impact of improved finger millet variety (GPU 28) in Karnataka-An Economic Surplus Approach. The findings of the study revealed that the net present value because of a growing of high yielding variety of finger millet i.e. GPU 28 was 556.91 Crores at 5 per cent discount rate yielding an internal rate of return (IRR) of 79 per cent indicating economic worthiness of investment made on research in finger millet for developing variety GPU 28. GPU 28 finger millet variety has covered more 50 per cent area under total area of finger millet in Karnataka.

Dhandhalya *et al.* (2018) studied the research contribution for rice productivity growth in Gujarat: As reflected by TFP and RRI. It was observed that the investment on paddy research generated annually 34.70 per cent IRR indicating high paying proposition in study period. The variables like public investment in agricultural research, transfer of technology (extension), good monsoon and irrigation development has significantly contributed in the growth of total factor productivity or rice.

Pokharkar *et al.* (2018) studied the economic impact of pomegranate research and extension on farm economy. The estimated value of marginal return was Rs 20.87 it indicated that the investment of one rupee in pomegranate research generated additional income of Rs 20.87 and Internal Rate of Return (IRR) was estimated to be 39.61 per cent depicting investment in pomegranate research generated substantial return to the pomegranate growers. Hence, it is recommended that the Government should allocated the funds to public research in pomegranate for improvement in productivity of pomegranate crop.

Kulkarni *et al.* (2019) studied the total factor productivity and returns to investment in paddy research in Western Maharashtra. The growth of total factor productivity of paddy crop was observed at the rate of 5.98 per cent per annum. The public research contributed significantly (0.27***) in the growth of TFP of paddy crop. The estimated value of marginal product was at Rs 3.04 indicating that one rupee investment in paddy research generated an additional income of Rs 3.04 and internal rate of return was 19.10 per cent indicating substantial rate of returns to investment in paddy crop in Maharashtra. The growth of total factor productivity of paddy crop registered a considerable growth with profitable returns in Maharashtra. Therefore, the government has to allocate the funds in paddy research for productivity improvement and providing food security to masses.

Ananth *et al.* (2006), Sheng *et al.* (2011), Chand *et al.* (2012), Sharma and Dupare (2016), Suresh and Chandrakant (2016), Dhandhalya *et al.* (2017), Singh *et al.* (2017), Suresh and Chandrakant (2017), Dhandhalya *et al.* (2018), Pokharkar *et al.* (2018), Joshi *et al.* (2019), Kulkarni *et al.* (2019) suggesting a contribution of investment in agricultural research resulted a significantly contributed in improvement in productivity.

2.3 Partial budgeting and Upscaling the technology

Hussain *et al.* (2003) studied the rice research, technological progress and impacts on the poor: the Bangladesh case (summary report). The findings of the study revealed that for households with access to land there have been direct adoption impacts in the form of increased yields and higher profits. However, since rice now only represents around 20 per cent of most households overall income, non-agricultural

income is found to have gained dramatically in importance for rural households. While the profitability has declined over time, rice contributes to improved food security and provides a “springboard” for both rich and poor farm households moving into non farm income generation and employment.

Jirawat (2007) estimated the economic impact of public rice research in Thailand. The findings of the study revealed that the increment in technical knowledge in rice increases the productivity of land and also facilitates the changes in production structure of rice. The public rice research considered as an important driving force for encouraging the growth of production. For estimating the public investment in rice research the Marshallian concept was used. Based on the results it reveals that the cumulative economic surplus was quite high. The benefit cost ratio indicates that investments generate a benefit of 6.92, 6.25 and 5.68 Baht for every Baht spent by 5, 10 and 15 per cent discount rate, respectively.

Suresh (2013) examined the economic impact of public sector agricultural research in ragi and redgram in Karnataka. It was observed that the gross return realized by the BRG 2 red gram cultivators as pure crop per acre was Rs 18,513, whereas it was Rs 16,082 from counterfactual variety (TTB 7) growers with a difference of Rs 2430 per acre, about higher by 15 per cent. The gross return experienced by the GPU 28 growers was Rs 18,236 whereas it was Rs 14,389 by counterfactual growers higher by 27 per cent. The calculated economic surplus due to adoption of improved of BRG 2 redgram variety in Karnataka was Rs 56.47 crores for the period 1995-2010. Due to Ragi GPU 28 variety the economic surplus was Rs 1540 crores from 1986 to 2010. By using the partial budgeting technique the economic impact of research on red gram and ragi crop, the economic benefits realized by adopting improved variety i.e. BRG 2 red gram variety in Karnataka was estimated as Rs 3.84 crores per year and Rs 115.44 crores per year for GPU 28 variety of ragi.

Deep (2014) assessed the partial budget analysis for sorghum farm in Sinai Peninsula, Egypt. To assess the cost and benefits associated with a particular or partial change in a sorghum farm, the partial budget analysis was used on a unit, so data were collected from one sorghum farm in Sahl El Tina. On the basis of the results it was observed that the marginal rate of return of changing from treatment 1 (100 kg N/Feddan)

to Treatment 2 (200 kg N/Feddan) was 9.61, and a changing from Treatment 2 (200 kg N/Feddan) to Treatment 3 (300 kg N/Feddan) gave marginal rate of return of 0.72, so Treatment 2 of (200 kg N/Feddan) was recommended.

Wander (2014) examined the economic analysis of farm change using the partial budget. It was observed that by using the partial budget analysis only those costs and benefits that change with a proposed business adjustment need to be considered. Partial budget analysis can be used for estimating many practical farm management problems such as substituting crop and livestock enterprises, changing input levels or types of inputs, changing the size of enterprises in the business and buying new or used machinery, equipment, building and facilities.

Tesfaye *et al.* (2015) studied the impact of improved wheat technology adoption on productivity and income in Ethiopia. For impact assessment the propensity score matching method was used. It was observed that 56 per cent of adoption of improved wheat varieties in 2013. On the basis of the Probit model, the sex of household headship and livestock ownership enhanced the adoption of improved varieties, while the educational level of the household head negatively affected in enhancing the adoption of improved wheat varieties. On the basis of the results of the propensity score matching method, adoption of improved wheat variety increased the average wheat productivity of adopter by about 1 to 1.1 t/ha than the non adopters. Similarly, the results of the propensity score matching estimates indicate that the average income of adopters was 35 to 50 per cent higher than the non-adopters. The findings of the study give empirical evidence that agricultural technology adoption can contribute to productivity improvement and raising the income of farm households.

Assima *et al.* (2016) examined the impacts of improved sorghum varieties on farm families in Mali: A Multivalued Treatment Effects approach. The findings of the study showed that the impact of hybrids use on yields is large and significant, positively affecting household dietary diversity and contributing to a greater share of the harvest sold. However, use of hybrids, as well as improved varieties, is associated with a shift toward consumption of other cereals. Findings support on-farm experimental evidence concerning yield advantages, and suggest that encouraging the use of well-adapted sorghum hybrids may contribute to crop commercialization by smallholders.

Robert (2016) assessed the partial budgeting is useful in the decision process for farm owners and managers use to decide on alternative uses of resources they have in their business. Partial budgeting is a systematic approach that assists the user in making informed evidence-based decisions; however, the budgeting process might only estimate possible financial impact, it does not assure it. Management aspects and chance can easily change or skew the projections. The specific numbers used in partial budget analysis may not reflect realistic possibilities, resulting in better or worse than expected performance. Careful assessment of possible operational changes will help prevent inaccurate projections of the overall impact to the agricultural business.

Suresh and Chandrakant (2016) examined the Economic efficiency of improved red gram variety (BRG-2) in Karnataka. The results showed that the net return (with red gram as pure crop) was the higher (` 5, 629 per acre) for BRG2 red gram farms than (` 3,936 per acre) for check variety farms, with a difference of ` 1,692, by 30 per cent. DEA analysis shows that farmers of BRG 2 have greater economic efficiency, allocative efficiency than check variety farmers using inputs such as seed, farm yard manure, chemical fertilizers, human labour, bullock labour, machine labour and plant protection chemicals. The BRG 2 red gram variety is economically performing well in field conditions and offering higher returns to farmers compared to the check varieties. Hence, the State Department of Agriculture, GOK can popularize and encourage the widespread adoption of red gram BRG variety for improving the nutritive capacity of farmers and consumers.

Singh *et al.* (2016) examined the impact assessment of pigeon pea variety NA-2 through FLDS in Ghazipur district of eastern Uttar Pradesh. The results showed that the improved practices recorded higher yield as compared to farmer's practices. The improved technology recorded higher yield of 18.06 over farmers practice 12.14 q/ha. In spite of increase in yield of pigeon pea, technology gap, extension gap and technology index existed. The improved technology gave higher gross return (49313 Rs/ha), net return (32293 Rs/ha) with higher benefit cost ratio (2.97) as compared to farmer's practices. The variation in per cent increase in the yield was found due to the lack of knowledge, and poor socio economic condition. It is concluded that the FLDs

programmes were effective in changing attitude, skill and knowledge of improved package and practices of HYV of pigeon pea adoption.

Suresh and Chandrakant (2017) examined the economic impact of improved finger millet variety (GPU 28) in Karnataka-An Economic Surplus Approach. The findings of the study revealed that the total economic surplus due to growing of improved variety of finger millet *i.e.* GPU 28 was 1540.38 crores for the period 1986 to 2010. In case of consumers and producers surplus it was formed about 56.13 per cent and 43.87 per cent, respectively. Thus, consumers are more benefited as compare to producers.

Elsheikh *et al.* (2018) examined impact assessment of adoption of improved varieties of groundnut and sesame in North Kodofan state: Sudan. Treatment effect regression method was used to assess the impact of adoption of improved varieties of groundnut and sesame. Adoption degrees of the improved varieties varied considerably from year to year depending on availability and distribution of improved varieties. Results showed that the productivity of all improved varieties of food and cash crops were higher than the local varieties. The household expenses of adopters of improved varieties were higher than the non-adopters by 19 per cent. The factors which significantly and positively affected farmers decision to adoption of improved varieties of groundnut were education of respondents (0.414**) and male family members (0.073). Income from farm increased by 29876 SDG per year as a result of adoption improved varieties of groundnut. Area of improved varieties would increase by 9.57 hectare per year as a result of adoption of improved varieties of groundnut. Factors which significantly and positively affected farmers' decision to adoption improved varieties of sesame were male family members (0.058*) and age of respondents (0.024**). Income from farm increased by 7533.7 SDG per year as a result of adoption improved varieties of sesame.

Elsheikh *et al.* (2018) examined impact assessment of adoption of improved varieties of millet in North Kordofan state Sudan. Treatment effect regression was used to assess the impact of improved varieties of millet in the study area. Factors which positively affected farmer's decision to adoption of improved varieties of millet were education (0.016), attending training (0.223), family member's male (0.004) and sex

of HH (0.198), income from farm increased by 29727.86 SDG per year as a result of adoption of millet improved varieties. Area of improved varieties would increase by 9.63 hectare per year as a result of adoption of improved varieties of millet.

Jaijit *et al.* (2018) assessed economic and social impact assessment of rice research funding in Thailand using the structural equation modeling technique. Rice crop productivity, farmer's income, rice production cost and the number of rice farmers are the impact factors. The results showed that the economic impact of rice breeding funding was larger than rice crop processing funding. This may be due to the Thailand has a large agricultural sector. The main focus of rice research and development studies has been on cultivation rather than processing technology development. Increases in rice crop productivity and farmers income were more affected by the breeding research funding than the processing funding. Whereas, the production cost and the number of rice farmers were inversely influenced by rice breeding funding, while crop processing funding still provided a positive impact on these two dimensions. It may be due to the fact that the number of rice farmers has been decreasing substantially while breeding for funding has been increasing annually over the past decade.

Pande *et al.* (2018) estimated the economic viability of drumstick based agri-horticulture system to replace tobacco in Central Gujarat: A modified partial budgeting approach. Partial budgeting technique was used for examining the drumstick based cropping system which is averse to soil conservation. By saving in irrigation water, the cropping system increased the returns over the variable cost, saving in soil nutrients about Rs 657/ha and also sustains soil carbon build up valued at Rs 3696/ha. These environmental benefits generated by drumstick cropping 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.

Pokharkar *et al.* (2018) examined the economic impact of pomegranate research and extension on farm economy. It was observed that the total additional cost of university released varieties over the counterfactual variety was Rs 29230.31 per hectare. While in case reduced cost or savings due to university released varieties over the counterfactual variety was Rs 127846.4 per hectare. Thus, the total economic worthiness

of university released pomegranate varieties over the counterfactual varieties of pomegranate in the studied region was Rs 98616.07 per hectare. The results were comparable to the earlier studies.

Melese *et al.* (2018) studied the farm partial budget analysis of pepper (*Capsicum annum L.*) to the application of NP fertilizer and farmyard manure in Raya Azebo District, Norther Ethiopia. The combination of 25, 50, 75 and 100 per cent of recommended inorganic fertilizer at national level and 10t/ha farmyard manure along with four control treatments *i.e.* unfertilized, 100 per cent farmyard manure, 100 per cent and blended fertilizer/NPS were used in the study. On the basis of the findings of study it was observed that this fertilizer rate could be used in the study area for the cultivation of variety under irrigation. Therefore, to get optimum economic return the cultivation of pepper in the study area, it is recommended to apply an integrated fertilizer management approach.

Adhale (2019) estimated the impact analysis of investment in sugarcane research in Maharashtra. The findings of the study revealed that the gross and net economic impact of Co-86032 variety of sugarcane to the sugarcane growers in Maharashtra for 22 years was Rs 100787.32 crores and Rs 11059.40 crores, respectively. While gross and net economic impact of CoM-265 sugarcane variety to the sugarcane growers in Maharashtra was Rs 31681.32 crores and Rs 2215.03 crores. Together the net economic impact of both the varieties *i.e.* Co-86032 and CoM-265 is Rs 13274.43 crores and gross economic impact of Rs 132468.60 crores, respectively to the sugarcane growers in Maharashtra.

Islam *et al.* (2019) assessed the impact of BRRI released modern rice varieties adoption on farmers' welfare in Bangladesh: application of panel treatment effect model. Analysis revealed that BRRI released wet (Aman) season rice technology has a robust and positive effect on small farmers' welfare in Bangladesh as indicated by the level of increases in per capita household real income, increases in real "aman" rice income and also increases in yield and decreases both in poverty gap and squared poverty gap over time. The marginal and near landless farmers have not gained significantly through adopting BRRI released modern variety over non-adopters in terms of all the indicators except aman rice yield. However, only yield of BRRI released modern wet

(Aman) season rice technology has positive and significant impact on the marginal and near landless farmers. As such, BRRI variety adoption seemed to be conducive in increasing the level of yield of marginal and near-landless farms but it hardly helps them to overcome the poverty level, unless other equity-enhancing policy measures are undertaken. Overall, there was large scope for enhancing adoption of BRRI released rice variety in order to reduce the poverty level in rural areas. The current rice policy (rice self-sufficiency) appears to be supportive to help Bangladesh rice sector for achieving food security in the country.

3. MATERIAL AND METHODS

Methodological and technical aspects forms the base for achieving the research investigation are mentioned in this chapter. Any research problem needs a very well structured investigation using specific methods and procedures in order to reach at actual, impartial and empirical conclusions. The methodological section for the present study entitled “Impact Analysis of Investment on Research and Extension of University Released Citrus Varieties” is discussed under the following heads:

- 3.1 Crop Covered
- 3.2 Selection of Research Station and Study Area
- 3.3 Data and its Sources
- 3.4 Period of Study
- 3.5 Tools and Techniques

3.1 Crop Covered

The present study was conducted on acid lime and sweet orange fruit crop. The *Sai Sharbati* and *Phule Sharbati* are the improved varieties of acid lime, which were developed by the Mahatma Phule Krishi Vidyapeeth, Rahuri in the year 1994 and 2008, respectively. Mosambi Nuseller and *Phule Mosambi* are the improved varieties of sweet orange. The *Phule Mosambi* was developed in the year 2008 and Mosambi Nuseller variety is recommended by MPKV, Rahuri.

3.2 Selection of Research Station and Study Area

The study area is confined to the state of Maharashtra. Maharashtra is the third largest state of India in both area and population. Food, horticultural crops and cash crops are grown in the state. The main crops of Maharashtra are mango, grapes, banana, orange, acid lime, sweet orange, wheat, rice, jowar, bajra, pulses, groundnut, cotton, sugarcane, turmeric tobacco, *etc.*

Area under acid lime and sweet orange fruit crop was dominantly covered by the varieties released by the All India Coordinated Research Project on Fruits, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. Therefore, the All India Coordinated Research Project on Fruits, MPKV, Rahuri has purposively selected. The research centre was established as Citrus Dieback Research Centre at Pune in 1956. In 1959 the research centre was shifted to Shrirampur as Citrus Dieback

Research Centre. In the year 1989 the research centre was shifted to Mahatma Phule Krishi Vidyapeeth, Rahuri and renamed as All India Coordinated Research Project on Tropical Fruits. Again the name of the research centre was changed as All India Coordinated Research Project on Fruits in 2014. Both primary and secondary data were used for the study. The data related to research and extension expenditure on acid lime and sweet orange crop was collected from the financial records of the research station.

3.3 Data and its sources

The present study based on both primary and secondary data. The data related to area, production and productivity of acid lime and sweet orange fruit crop for the state of Maharashtra and India was collected from various secondary sources i.e. Department of Horticulture, Government of Maharashtra, Pune, and Horticulture Statistics at a glance, Pocket Book of Agricultural Statistics, Government of India, Department of Agriculture and Cooperation, Horticulture Statistics Division, New Delhi, Socio Economical Statistical Information about India (India Stat), *etc.*

The data regarding year wise expenditure on research, extension, salary, contingency, *etc.* were collected from the office of AICRP (All India Coordinated Research Project) on Fruit, MPKV, Rahuri research unit and used in the analysis of the present study. Year wise data on sale of seedlings of improved varieties of acid lime and sweet orange varieties were collected from the AICRP (All India Coordinated Research Project) on fruits, MPKV, Rahuri research unit and government nurseries, private nurseries and Krishi Vikas Kendra.

The data regarding non inputs *viz.*, rainfall, temperature, NIA, road density, N to P ratio, literacy, *etc.* were collected from various government publication for estimating the sources of TFP. The time series data on input costs and returns for acid lime and sweet orange for the period of 1994-95 to 2018-19 was collected and compiled from the quick estimate reports of Central Comprehensive Scheme, Government of India, Department of Agricultural Economics, MPKV, Rahuri. Besides the detailed cost of cultivation of acid lime and mosambi with their competent variety were collected by survey method with the help of special designed questionnaire from 60 farmers (30 for university released variety and 30 from competent variety) for acid lime and sweet orange, respectively.

3.4 Period of Study

Acid Lime

The period of the study was considered as per the availability of data. The compound growth rates of area, production and productivity of acid lime fruit crop in India were estimated for the period from 1991-92 to 2018-19 this period was subdivided into three sub periods as Period-I (1991-92 to 1999-00), Period-II (2000-01 to 2009-10) and Period-III (2010-11 to 2018-19). The region wise and district wise compound growth rates and instability index of area, production and productivity of acid lime in Maharashtra were estimated for the period from 2006-07 to 2019-20. The whole period was subdivided into three sub periods as Period-I (2006-07 to 2012-13), Period-II (2013-14 to 2019-20) and overall period (2006-07 to 2019-20). Varietal status of acid lime varieties at farmer's field was examined for the year 2019-20. The growth of input, output and TFP index of acid lime was estimated for the period 1994-95 to 2018-19. The sources of TFP growth was estimated for the same period of TFP index. The returns to investment in acid lime research and total economic impact of acid lime were estimated for the period from 1995-96 to 2019-20.

Sweet Orange

The compound growth rates of area, production and productivity of sweet orange fruit crop in India were estimated for the period from 1994-95 to 2018-19 this period was divided into two sup periods i.e. Period-I (1994-95 to 2005-06) and Period-II (2006-07 to 2018-19). The region wise and district wise compound growth rates and instability index of area, production and productivity of sweet orange in Maharashtra were estimated for the period from 2000-01 to 2019-20 this period was divided into two sub period as period-I (2000-01 to 2009-10) and period-II (2010-11 to 2019-20). The varietal status of sweet orange varieties on farmer's field was estimated for the year 2019-20. The input, output and TFP index and the source of TFP growth in sweet orange fruit crop was estimated for the year 1994-95 to 2018-19. The returns to investment in sweet orange research was estimated for the period from 1995-96 to 2018-19 and total economic impact of sweet orange was estimated for the period from 1990-91 to 2019-20.

3.5 Analytical Tools and techniques

A. Compound annual growth rate

Compound annual growth rates were estimated to study the percentage increase or decrease in the selected parameter. The following exponential type of function was used

$$Y = ab^t e$$

Where,

Y = Dependent variable for which growth was estimated i.e. area (ha), production (tonnes) and productivity (t/ha).

a = Intercept or constant

b = Regression/trend coefficient

t = Periods in years (1, 2, 3...n)

e = Error terms

Instability Analyses

Instability in area, production, productivity of acid lime and sweet orange was examined by using two different measures of instability such as Coefficient of Variation and Cuddy-Della Valle Index.

Coefficient of Variation

Although Coefficient of Variation (C.V) is the simplest measure of instability, it over-estimates the level of instability in time series data which are characterized by long-term trends. CV can be calculated as follows:

$$(C.V) = (\text{Standard Deviation} / \text{Mean}) * 100$$

Instability Index: Cuddy-Della Valle Index:

The instability in area, production and productivity of acid lime and sweet orange fruit crop was examined by using the Cuddy – Della Valle Index. The Cuddy-Della Valle Index corrects the coefficient of variation in long term trend.

The Cuddy Della Valle Index de-trends shows the exact direction of the instability. Therefore, it is a better measure to capture instability in agricultural production. A low value of this index indicates low instability in area, production, productivity 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. was the Coefficient of Variation in per cent, and R^2 was 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 = 15 to 30
- High instability = 30 and above

A. Extent of investment in research and extension

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

- i. Total Factor Productivity
- ii. Sources of TFP growth
- iii. Returns to Investment and
- iv. Partial Budgeting

i. Total Factor Productivity (TFP)

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

a. Growth accounting approach (GAA)

Solow (1957) was the first to propose a growth accounting framework. In this approach, TFP is measured as a residual factor, which attributes to that part of growth in the output that is not accounted for by the growth in the basic factor inputs. This approach approximates the technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices. The TFP index is measured as the ration of the index of net output and the index of total factor inputs. The index of total factor inputs is derived as weighted average of indices of labour inputs, capital inputs and land inputs with relative income shares of the three factors as respective weights. The key feature of the GAA is separation of change in

production on account of changes in the quantities of factors of production from residual influences, which include technological progress, learning by doing, *etc.* Basically there are three main indices used in the GAA: (i) Kendrick Index (KI), (ii) Solow Index (SI), and (iii) Translog Index (TLI).

The Solow residual is defined as $[g_y - a \times g_k - (1-a) \times g_l]$, where g_y is the growth rate of output, g_k is the growth rate of capital, g_l is the growth rate of labour and a and $(1-a)$ stand for share of capital and labour, respectively. The Solow residual accurately measures TFP growth if (i) the production function is neoclassical, (ii) there is perfect competition in factor markets, and (iii) the growth rates of the inputs are measured accurately.

The Divisia-Tornqvist Theil index or translog index of TFP is commonly used for computing the total output, total input, and TFP indices can be specified as:-

$$\text{Total Output index: } TOI_t / TOI_{t-1} = U_j (Q_{jt} / Q_{jt-1})^{(R_{jt} + R_{jt-1})/2} \quad \dots(1)$$

$$\text{Total Input index: } TII_t / TII_{t-1} = U_i (X_{it} / X_{it-1})^{(S_{it} + S_{it-1})/2} \quad \dots(2)$$

Where,

U_j = Product

R_{jt} = Share of j^{th} output in total output in the t^{th} year

R_{jt-1} = Share of j^{th} output in total output in the $(t-1)^{\text{th}}$ year

Q_{jt} = Output of the j^{th} commodity in the t^{th} year

Q_{jt-1} = Output of j^{th} commodity in $(t-1)^{\text{th}}$ year

S_{it} = Share of the i^{th} input in total input cost in t^{th} year

S_{it-1} = Share of the i^{th} input in total input cost in $(t-1)^{\text{th}}$ year

X_{it} = Quantity of the i^{th} input used in j^{th} output in t^{th} year

X_{it-1} = Quantity of the i^{th} input used in j^{th} output in $(t-1)^{\text{th}}$ year

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

$$TOI(t) = TOI(1) \cdot TOI(2) \dots TOI(t-1) \quad \dots(3)$$

$$TII(t) = TII(1) \cdot TII(2) \dots TII(t-1) \quad \dots(4)$$

Finally, the TFP index is computed as

$$TFP_t = TO/TH, \quad \dots(5)$$

However, Kendrick index and Solow index suffer from some limitations. In contrary, the Translog index is superior to both Kendrick and Solow indices because Translog index numbers are symmetric in data of different time periods and also satisfy the factor reversal test approximately. It is based on Translog Production Function characterized by constant returns to scale. It allows for variable elasticity of substitution and does not require the assumption of Hicks-neutrality.

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

TFP is defined as the ratio of an index of aggregate output to an index of aggregate input. One of the most defensible methods of aggregation in productivity measurement is Divisia aggregation-Divisia indices have two important attractive properties: (i) they satisfy the time reversal and factor reversal tests for index numbers, and (ii) it is a discrete of the components, so that aggregate could be obtained by the aggregation of sub aggregates. For discrete data, the most commonly used approximation to the (continuous) Divisia index is the Tornqvist approximation. The DivisiaTornqvist 'or' translog index of TFP is commonly used for computing the total output, total input and TFP indices by commodity/farm system/sector, etc. under different locations as outlined below.

For the productivity measurement over a long period of time, chaining indices 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.

As the use of inputs increased, to a certain level or extent it allows the agricultural sector to move towards the production surface. The modern inputs usage may

shift the production function in an upward direction as technological change embodied in them. The total factor productivity (TFP) shows the total output increased which is not accounted for by increase in total inputs use. The total factor productivity is estimated as the ratio of an output index to the input index. The trend in TFP indicates whether the growth in production is taking place in a cost effective and sustainable manner or not. Growth in output can be experienced by using more and more level of inputs, it may not be sustainable in the long-run necessities a higher growth in output as compared to inputs used. Total factor productivity serves as a very good indicator of the performance of any production system and sustainability of the growth process. TFP Growth mostly influenced by the changes in technology, institutional reform, infrastructural development, THT resource development and other factors. The crop related to technology changes that are often embodied in seed adoption by the farmer can be divided into two components: “qualify” and “quantity” reflects the research output that is determined by the investment in research and is an exogenous variable in explaining TFP. The “quantity” of technology is linked to its adoption and is affected by the extension, literacy, infrastructural development, as well as on-farm and off-farm characteristics (Kumar *et al.*, 2008).

In the present study the Tornqvist Theil Index was used for estimating the total output, total input and TFP index. These indices were estimated as follows:

i. Total Output Index (TOI)

$$TOI_t/TOI_{t-1} = \Pi_j (Q_{jt}/Q_{jt-1})^{(R_{jt} + R_{jt-1})/2}$$

R_{jt} will be calculated as follows

$$R_{jt} = \frac{\text{Value of } j^{\text{th}} \text{ crop output in } t^{\text{th}} \text{ year}}{\text{Aggregate crop output value in } t^{\text{th}} \text{ year}}$$

$$R_{jt} = Q_{jt} \times P_{jt} / \sum_{j=1}^n Q_{jt} \times P_{jt}$$

Where,

Q_{jt} = Output of j^{th} crop in t^{th} year

P_{jt} = Post/farm harvest price of j^{th} crop in t^{th} year.

ii. Total Input Index (TII)

$$TII_t/TII_{t-1} = \Pi_i (X_{it}/X_{it-1})^{(S_{it} + S_{it-1})/2}$$

S_{it} will be calculated as follows :

$$S_{it} = \frac{\text{Value of } i^{\text{th}} \text{ crop input in } t^{\text{th}} \text{ year}}{\text{Total input cost in } t^{\text{th}} \text{ year}}$$

$$S_{jt} = X_{jt} \times P_{jt} / \sum_{j=1}^n X_{jt} \times P_{jt}$$

Where,

X_{it} = Quantity of i^{th} input in t^{th} year.

P_{it} = Farm rental price of i^{th} input in t^{th} year.

Total Factor Productivity Index (TFPI)

Total factor productivity indices was computed as the ratio of total output index (TOI) to total input index (TII).

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

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,

Q_{jt} = Output of j^{th} crop in t^{th} year.

Q_{jt-1} = Output of j^{th} crop in $(t-1)^{\text{th}}$ year.

R_{jt} = Output share of j^{th} crop in total revenue in t^{th} year.

R_{jt-1} = Output share of j^{th} crop in total revenue in $(t-1)^{\text{th}}$ year.

X_{it} = Quantity of i^{th} input used in j^{th} crop in t^{th} year.

X_{it-1} = Quantity of i^{th} input used in j^{th} crop in $(t-1)^{\text{th}}$ year.

S_{it} = Share of input 'i' in total input cost in t^{th} year.

S_{it-1} = Share of input 'i' in total input cost in $(t-1)^{\text{th}}$ year.

By specifying TOI_{t-1} , TII_{t-1} and IPI_{t-1} equal to 100 in the initial year, the above equation provides the total output, total input, total factor productivity and input price indices for the specified period 't'.

iii. Sources of TFP Growth

The variables responsible or sources of TFP growth in agriculture can be explained through TFP decomposition analysis with the help of multiple regressions by

using pooled cross section time series data with the correction of serial correlation and heteroscedasticity (Kmenta, 1981). The TFP can influence by the factors such as research investment, rural literacy, rainfall, road density, cropping intensity, maximum temperature, minimum temperature, N to P ratio, *etc.* As an input to public investment decisions, it is useful to understand the relative importance of these productivity-enhancing factors in determining productivity growth (Chand *et al.*, 2011). In the present study the variables like research investment (Rs/ha), rainfall (mm), temperature (Max), temperature (min), rural literacy (%), road density (km), N to P ratio, gross irrigated area (%) are used in the study to understand or identify the sources of growth of TFP in the acid lime and sweet orange. By clubbing together of above variables the regression analysis was carried out. To identify the contribution of research and extension in TFP, the Cobb-Douglas Production function was used. The functional relationship as given below:

$$Y = a_1 x_1^{b_1} x_2^{b_2} x_3^{b_3} x_4^{b_4} x_5^{b_5} x_6^{b_6} x_7^{b_7} x_8^{b_8} e^u$$

Where,

Y = Total Factor Productivity Index (TFP)

a = Constant term

X₁ = Research Investment (Rs/ha)

X₂ = Rural Literacy (%)

X₃ = Rainfall (mm)

X₄ = Temperature (Min.) (°C)

X₅ = Road Density (km of road per 100 sq. km of land area)

X₆ = N to P ratio

X₇ = Temperature (Max.) (°C)

X₈ = Temperature (Min.) (°C)

X₉ = Cropping Intensity (%)

T = Time variable (years 1, 2, 3...n)

u = Error term

(b₁, b₂, b₃ and b_n are regression coefficients of respective variables)

iv. Returns to investment on Acid Lime and Sweet Orange research

Estimated Value of Marginal Product (EVMP)

With the aim of estimation of Total Factor Productivity (TFP), the TFP index was regressed on research and development investment per hectare of area and per

year basis, which was trend variable. The estimated value of marginal product more than “1” indicates that research in that particular commodity has been generating enough output to justify investment. There is need to change the focus of research in such commodity or crops where marginal rate of return was less as compared to other commodity or crops to get higher returns from research investment. Research investment is a significant determinant in growth of TFP. With the help of elasticity of TFP with respect to research investment, we estimated the value of marginal product of research investment by using the following formula,

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

Where,

- R : Research investment (Per ha)
- b : TFP Elasticity of research investment
- V : Value of production associated With Tfp
- EVMP : Estimated Value of Marginal Product

Internal Rate of Return

Alternative name of internal rate of return is marginal efficiency of capital or yield on the investment. The estimation of the returns to research investment indicates the direction of returns. It provides the justification to the previous funding and has presented a sound base for future funding, based on the level of returns of research investment. Research is an essential contributor to productivity growth. The results of the internal rate of return have clearly guided the future investments in agriculture will provide reasonable returns and will lead to agricultural development in the country. In economic terms, the IRR was the interest rate earned on the unrecovered balance over an investment's life so that the unrecovered balance at the end of that time was zero. IRR is the discount rate which equates the present value of future cash flows of an investment with the initial investment. It is one of the measures used for the investment appraisal. To accept the an investment decision, the IRR must be greater than minimum attractive rate of return, and to accept the borrowing decision the IRR must be less than the Marginal Internal Rate of Return (MIRR). IRR is also used for determining the project is economical viable or not. IRR can be estimated after examining the lower and higher discount rate at which Net Present Value (NPV) becomes equals to zero or negative. IRR can be estimated by using the following formula,

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)

$$IRR = r_a + NPV_a / (NPV_a - NPV_b) (r_b - r_a)$$

Where,

NPV_a = Net Present Value at r_a

NPV_b = Net Present Value at r_b

r_a = Lower discount rate

r_b = Higher discount rate

v. **Partial Budget Approach**

Partial budgeting was used to find the economic viability of partial change in the farm such as use of new variety or new technology or new innovation or new practice or new equipment or new service. To estimate the impact of research outcome on income generation the partial budgeting method was used. The partial budgeting approach is organizing the experimental data and information about the costs and benefits from some changes made in the technologies being used on the farm. The aim behind the using of partial budgeting method was to identify whether the proposed change has made profit or loss in the farm business. Partial budget method does not estimate the total income and expenses for each of the alternative plan but list only those items of incomes and expense that change. It measures the changes in income 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/cost side**

Item of added expenditure due to cultivation of improved varieties

This includes additional cost on account of human labour, machine labour, seed, manure, irrigation, management, risk premium, research and extension, etc.

Reduced returns due to cultivation of improved varieties

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**

Reduced costs (or saving) due to cultivation of university released variety

It includes saving on cost of human labour, machine labour, seed, manure and irrigation, etc.

- **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. Economic worthiness of university released varieties were estimated by using partial budgeting technique which indicates the economic impact of university released variety over the other competing varieties in the Maharashtra.

A. Area Under University Released Acid Lime and Sweet Orange Varieties

To estimate the area under university released acid lime and sweet orange varieties, the seed sale of acid lime and sweet orange historical data was collected from All India Coordinated Research Project on Fruits, MPKV, Rahuri, private nurseries, government nurseries and Krishi Vigyan Kendra. Grand total of seed sale of acid lime and budded plants of sweet orange fruit crop divided by number of plants per hectare area gives the area under acid lime and sweet orange university released varieties in hectares in Maharashtra. The farmers to farmers seedlings diffusion especially for improved varieties of acid lime fruit crop were also been considered for estimating the area under university released acid lime varieties.

B. Up-scaling the Economic Impact

Partial budgeting was applicable for wider area under university released acid lime and sweet orange varieties, linear extrapolation of the benefit per ha was not justifiable due to operation of the law of diminishing marginal returns at an early stage in agriculture. Accordingly, to reflect the operation of Law of Diminishing Marginal Returns (LDMR), three parameters such as I -Probability performance of the technology, II- Rate of adoption of the citrus varieties and III- Depreciation in the technology were applied in linear extrapolation. These completely capture the operation of the LDMR since the field conditions are not similar to the lab conditions and the farmer was different from the researcher. Upscaling technique was defined as an activity in which information on a lower spatial scale was translated into information at a higher spatial scale. In upscaling technique, the economic worthiness of university released varieties was multiplied by the depreciation, rate of adoption and probability of actual yield of variety which gave the net return from the concern variety.

4. RESULTS AND DISCUSSION

This chapter presents and discusses the findings of the current study, "Impact Analysis of Investment on Research and Extension of University Released Citrus Varieties". The results and discussion section is based on the numerous findings of the current study's analytical section. This chapter describes the analytical tools used in this study, such as compound annual growth rates (CAGR), stability analysis (CV and Cuddi Della Vella Index), growth of total factor productivity index (TFPI), Cobb Douglas production function, Estimated Value of Marginal Product (EVMP), Internal Rate of Return (IRR), partial budgeting, upscaling the technology, the economic impact of university released varieties, and so on.

The All India Coordinated Research Project on Fruits was chosen as the crop specific research station for this investigation. The following are the results for each objective for each crop, namely acid lime and sweet orange, as well as their economic impact. The following subheads have been used to discuss the findings in relation to the study's various objectives:

- 4.1 Area, production and productivity of Acid Lime and Sweet Orange in the World, Nation and State level
- 4.2 Compound Annual Growth Rates (CAGR) of Area, Production and Productivity of Acid Lime and Sweet Orange
- 4.3 Instability Analysis of Area, Production and Productivity of Acid Lime and Sweet Orange
- 4.4 Varietal Status of Acid Lime and Sweet Orange on farmer's field
- 4.5 Growth of Input, Output and TFP index of Acid Lime and Sweet Orange
- 4.6 Sources of growth of Total Factor Productivity (TFP) of Acid Lime and Sweet Orange
- 4.7 Returns to Investment in Agricultural Research i.e. in Acid Lime and Sweet Orange fruit crop
- 4.8 Economic Impact of University Released Acid Lime and Sweet Orange Varieties

4.1 Area, production and productivity of Acid Lime in World, India and Maharashtra

Table 4.1 and Fig 4.1 indicate the countries that produced the most acid lime in the world during 2016-17. India stood at first position both in case of area and production among the major acid lime producing countries in the world contributing 32.13 and 20.40 per cent, respectively. However, regarding productivity of Acid Lime fruit crop India stands at 10th position.

Table 4.1. Major Acid Lime producing countries in the World (2016-17)

Sr. No.	Country	Area		Production		Productivity (MT/Ha)
		(M Ha)	% to World	(MT)	% to World	
1	India	0.26	32.13	2.98	20.40	11.46
2	Mexico	0.16	19.77	2.43	16.98	15.18
3	China	0.11	13.69	2.33	16.28	21.18
4	Argentina	0.05	6.18	1.68	11.74	33.60
5	Brazil	0.05	6.18	1.26	8.80	25.20
6	Spain	0.04	4.94	0.86	6.00	21.50
7	Turkey	0.03	3.7	0.85	5.93	28.33
8	USA	0.03	3.7	0.82	5.73	27.33
9	Iran	0.03	3.7	0.46	3.21	15.33
10	Italy	0.02	2.47	0.38	2.65	19.00
11	Others	0.029	3.5	0.26	1.81	8.96
	World	0.809	100	14.31	100	19.08

Source: Horticultural Statistics at a Glance (2018)

Table 4.2 and Fig 4.2 showed the state wise area, production and productivity of Acid Lime in India during 2019-2020. Gujarat placed first position in case of area under Acid Lime fruit crop in India contributing 15.19 per cent to the total area. In case of production Andhra Pradesh is in first position, contributes 19.04 per cent to the total Acid Lime production in India. Maharashtra stands at 3rd position both in case of area and production of Acid Lime in India contributing 10.46 and 12.10 per cent, respectively. While in case of productivity Maharashtra stands at 5th position.

District wise area, production and productivity of Acid Lime in Maharashtra state during 2019-2020 indicated in Table 4.3. Jalgaon district stands at first position in case of area and production of Acid Lime contributing 28.9 and 47.92 per cent, respectively to the total districts of Maharashtra. Ahmednagar stands at second

position in case of both area and production of Acid Lime contributing 22.72 and 18.58 per cent, respectively to the total districts of Maharashtra.

Table 4.2. State-wise Area, Production and Productivity of Acid Lime in India (2019-2020)

Sr. No.	States / UT	Area		Production		Productivity (MT / Ha)
		(M Ha)	% to Total	(MT)	% to Total	
1	Andhra Pradesh	43.17	13.67	690.74	19.04	16
2	Arunachal Pradesh	0.18	0.06	0.12	0.00	0.67
3	Assam	15.87	5.02	158.25	4.36	9.97
4	Bihar	19.41	6.14	115.31	3.18	5.94
5	Chhattisgarh	12.14	3.84	103.19	2.84	8.5
6	Gujarat	47.98	15.19	625.59	17.25	13.04
7	Himachal Pradesh	11.83	3.75	9.06	0.25	0.77
8	Jammu and Kashmir	5.27	1.67	11.13	0.31	2.11
9	Jharkhand	7.29	2.31	88.51	2.44	12.14
10	Karnataka	14.27	4.52	332.81	9.17	23.32
11	Kerala	1.17	0.37	1.21	0.03	1.03
12	Madhya Pradesh	22.8	7.22	348.41	9.60	15.28
13	Maharashtra	33.03	10.46	438.84	12.10	13.29
14	Manipur	6.09	1.93	58.64	1.62	9.63
15	Meghalaya	1.2	0.38	4.95	0.14	4.13
16	Mizoram	8.12	2.57	25.9	0.71	3.19
17	Nagaland	0.77	0.24	6.19	0.17	8.04
18	Odisha	25.61	8.11	281.81	7.77	11
19	Punjab	2.66	0.84	21.3	0.59	8.01
20	Rajasthan	2.8	0.89	23.24	0.64	8.3
21	Tamil Nadu	9.45	2.99	13.33	0.37	1.41
22	Telangana	8.74	2.77	150.73	4.16	17.25
23	Tripura	5.01	1.59	24.17	0.67	4.82
24	West Bengal	10.87	3.44	93.61	2.58	8.61
25	Others	0.15	0.05	0.55	0.02	3.67
	India	315.87	100	3627.58	100	11.48

Source : Socio Economical Statistical Information about India, 2020.

Table 4.3. District wise area, Production and Productivity of Acid Lime of Maharashtra state during (2019-2020)

Sr. No.	District	Area		Production		Productivity (MT / Ha)
		(M Ha)	% to Total	(MT)	% to Total	
1	Ahmednagar	7.25	22.72	72.5	18.58	10
2	Akola	2.67	8.36	25.679	6.58	9.599
3	Amaravati	0.475	1.48	4.26	1.09	8.96
4	Aurangabad	0.39	1.22	2.953	0.75	7.498
5	Beed	1.885	5.9	10.06	2.57	5.34
6	Bhandara	0.0062	0.01	0.0322	0.08	5.19
7	Bhuldhana	0.51	1.59	5.17	1.32	10
8	Chandrapur	0.015	0.04	0.10	0.00	7
9	Dhule	0.16	0.5	2.83	0.72	17.58
10	Gadchiroli	0.25	0.78	1.75	0.44	6.86
11	Gondiya	0.02	0.06	0.075	0.01	3.75
12	Hingoli	0.055	0.17	0.66	0.16	12
13	Jalgaon	9.223	28.9	186.99	47.92	20.27
14	Jalna	0.054	0.16	0.353	0.09	6.53
15	Kolhapur	0.018	0.05	0.09	0.02	5
16	Latur	0.049	0.15	0.45	0.11	9.18
17	Nagpur	0.243	0.76	1.653	0.42	6.8
18	Nanded	0.266	0.83	5.49	1.4	20.65
19	Nandurbar	0.041	0.12	0.40	0.1	9.91
20	Nashik	0.08	0.25	0.576	0.14	7.2
21	Osmanabad	0.475	1.48	9.25	2.37	19.47
22	Palghar	0.017	0.05	0.147	0.03	8.316
23	Parbhani	0.715	2.24	3.604	0.92	5.04
24	Pune	1.425	4.46	14.25	3.65	10
25	Sangli	0.085	0.26	0.85	0.21	10
26	Satara	0.069	0.21	0.765	0.19	11
27	Sindhudurg	0.015	0.04	0.207	0.05	13.8
28	Solapur	4.962	15.55	36.666	9.39	7.389
29	Thane	0.0046	0.01	0.05	0.01	10.82
30	Wardha	0.215	0.67	0.967	0.24	4.497
31	Washim	0.15	0.47	0.725	0.18	4.833
32	Yavatmal	0.086	0.26	0.598	0.15	6.593
33	Total	31.90	100	390.19	100	301.49

Source: Department of Horticulture, Pune (2020)

4.1.2 Area, Production and Productivity of Sweet Orange in India and Maharashtra

Horticulture production in India has increased throughout the years. Area expansion has made significant progress, resulting in increased production. The area under horticulture has expanded by 2.6 per cent per year over the last decade, while annual production has climbed by 4.8 per cent. Horticulture crops produced 311.71 MT from a total area of 25.43 thousand hectares in 2017-18 (Horticultural Statistics at a Glance, 2018).

Table 4.4. State-wise Area, Production and Productivity of Sweet Orange in India (2019-2020)

Sr. No.	States / UT	Area		Production		Productivity (MT / ha)
		M Ha	% to total	MT	% to total	
1.	Andhra Pradesh	95.98	48.06	2303.56	62.48	24.00
2.	Assam	0.19	0.10	3.21	0.09	16.89
3.	Bihar	0.45	0.23	4.65	0.13	10.33
4.	Chhattisgarh	0.52	0.26	3.42	0.09	6.58
5.	Himachal Pradesh	1.86	0.93	3.34	0.09	1.80
6.	Jammu and Kashmir	3.27	1.64	7.00	0.19	2.14
7.	Karnataka	0.87	0.44	15.40	0.42	17.70
8.	Madhya Pradesh	6.73	3.37	115.57	3.13	17.17
9.	Maharashtra	60.73	30.41	668.07	18.12	11.00
10.	Mizoram	1.59	0.80	4.94	0.13	3.11
11.	Nagaland	0.22	0.11	1.86	0.05	8.45
12.	Punjab	2.79	1.40	24.18	0.66	8.67
13.	Rajasthan	0.30	0.15	11.50	0.31	38.33
14.	Tamil Nadu	0.14	0.07	0.84	0.02	6.00
15.	Telangana	22.36	11.20	517.03	14.02	23.12
16.	Tripura	1.19	0.60	2.40	0.07	2.02
	India	199.2	100	3687	100	18.51

Source: Socio Economical Statistical Information about India, 2020.

State wise area, production and productivity of sweet orange in India during 2019-2020 are given in Table 4.4 and Fig 4.3, respectively. Table 4.4 reveals that Andhra Pradesh stands at first position in area and production of Sweet Orange in India

during 2019-2020. Telangana at first placed in productivity of sweet orange during 2019-2020. While, Maharashtra stands at second position both in area and production of sweet orange fruit crop contributing 30.41 and 18.12 per cent, respectively. However, Maharashtra stands 7th in productivity of sweet orange fruit crop in India.

Table 4.5 indicates the district wise area, production and productivity of sweet orange in Maharashtra state during 2019-2020. Aurangabad placed at first in area and production of sweet orange contributing 38.89 and 46.19 per cent, respectively to the all districts of Maharashtra. While Jalna district placed at second position in area and production of Sweet Orange contributing 26.21 and 20.69 per cent, respectively to the all districts of Maharashtra. However, Nanded district stands 1st in productivity of sweet orange in Maharashtra.

Table 4.5. District wise area, production and productivity of sweet orange of Maharashtra state during (2019-2020)

Sr. No.	District	Area		Production		Productivity (MT / ha)
		(M Ha)	% to Total	(MT)	% to Total	
1	Ahmednagar	0.420	0.76	3.36	0.52	8.00
2	Akola	0.143	0.26	0.858	0.13	6.00
3	Amaravati	3.688	6.74	41.07	6.37	11.13
4	Aurangabad	21.250	38.89	297.5	46.19	14.00
5	Beed	1.610	2.94	14.05	2.18	8.72
6	Bhandara	0.002	0.00	0.14	0.02	6.55
7	Buldhana	0.315	0.57	3.16	0.4	10.00
8	Chandrapur	0.002	0.003	0.01	0.00	5.09
9	Dhule	0.144	0.26	2.88	0.4	20.00
11	Gondia	0.001	0.001	0.015	0.00	15.00
12	Hingoli	0.135	0.002	1.3	0.2	9.62
13	Jalgaon	2.310	4.22	28.79	4.47	12.46
14	Jalna	14.325	26.21	133.25	20.69	9.3
16	Latur	0.010	0.00	0.06	0.00	6.00
17	Nagpur	6.116	0.11	45.87	7.12	7.5
18	Nanded	1.282	0.02	51.25	7.95	39.98
19	Nandurbar	0.007	0.00	0.038	0.00	5.00
20	Nashik	0.005	0.009	0.029	0.00	5.8
21	Osmanabad	0.080	0.001	0.96	0.14	12.00

Table 4.5 contd....

Sr. No.	District	Area		Production		Productivity (MT / ha)
		(M Ha)	% to Total	(MT)	% to Total	
22	Palghar	0.002	0.03	0.016	0.00	8.00
23	Parbhani	0.515	0.94	5.108	0.79	9.91
24	Pune	0.109	0.19	1.014	0.15	9.3
28	Satara	0.004	0.007	0.039	0.00	11.00
32	Wardha	1.690	3.09	9.295	1.44	5.5
33	Washim	0.170	0.31	1.355	0.21	7.97
34	Yavatmal	0.310	0.56	2.632	0.4	8.49
35	Total	54.647	100	643.94	100	11.78

Source: Department of Horticulture, Pune (2020)

4.2 Compound Annual Growth Rates of Area, Production and Productivity

4.2.1 Compound annual growth rates of area, production and productivity of Acid Lime

Table 4.6 shows the compound growth rates that were calculated to assess changes in acid lime area, production, and productivity in India. Period II had the highest growth rate of area and acid lime production in compared to the previous periods, according to the period-by-period analysis. The increased area and production of acid lime in second period may be due to the implementation of National Horticulture Mission in 2005-06 (10th plan) in India (similar observations were reported by Singh and Nimmy, 2013). The main aim behind the initiation of National Horticulture Mission (NHM) is to provide holistic growth of horticulture sector in India and to enhance horticulture production. In terms of productivity, the first and second periods saw a downward trend, whereas the third and overall periods saw a rise of 1.7 and 0.39 per cent per year, respectively. In Maharashtra, the compound growth rate of area, production, and productivity of acid lime was estimated and given in Tables 4.7 and 4.8 by district and region.

The time series data on area (A), production (P) and productivity (Y) were divided into three sub period as period I (2006-07 to 2012-13), period II (2013-14 to 2019-20) and overall period (2006-07 to 2019-20). The growth rates of area, production, and productivity were positive and considerable for the entire period (2006-07 to 2019-

Table 4.6. Compound Growth Rates of Area, Production and Productivity of Acid Lime in India

Sr. No.	India											
	Period I (1991-92 to 1999-2000)			Period II (2000-01 to 2009-10)			Period III (2010-11 to 2018-19)			Overall Period (1991-92 to 2018-19)		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1.	8.13 ^{***}	5.61 ^{***}	-2.33 ^{**}	9.74 ^{***}	9.03 ^{***}	-0.65 ^{NS}	2.69 ^{**}	4.44 ^{**}	1.7 ^{**}	4.76 ^{***}	5.16 ^{***}	0.39 [*]

(***, ** and * significant at 1, 5 and 10 per cent, respectively)

Table 4.7. District wise Compound Growth Rates of Area, Production and Productivity of Acid Lime in Maharashtra

Sr. No.	District	Period I(2006-07 to 2012-13)			Period II (2013-14 to 2019-20)			Overall Period (2006-07 to 2019-20)		
		A	P	Y	A	P	Y	A	P	Y
1.	Jalgaon	-2.46	-2.57	-0.41*	22.85***	29.85	5.7	14.52***	15.38***	0.77
2.	Ahmednagar	-1.2*	-5.06	-3.9	2.07**	-3.64	-5.6	-0.99**	-9.44***	-8.53***
3.	Pune	3.69***	0.91	-2.68	18.82***	20.2	1.16	5.19***	1.61	-3.4***
4.	Solapur	-7.61	-12.37	-5.15	5.8	1.17*	2.23	-0.59	4.92	4.13*
5.	Satara	-4.31**	4.69	9.4	-3.33	-0.39***	3.05	-17.54***	-9.72***	9.49***
6.	Sangli	1.82**	1.71	-0.1	-35.88***	-34.75	1.78	-15.28***	-14.54***	0.87
7.	Jalna	4.23	-18.8	-22.09	-14.08**	-1.58**	14.55	-11.09***	-12.17**	-1.22
8.	Beed	-27.01**	-31.48	-6.12	17.52***	34.39	14.36	-0.69	-4.93	-4.27*
9.	Aurangabad	69.81***	66.67	-3.06	-1.63	-0.59***	1.85	26.14***	25.89***	0.26
10.	Osmanabad	-6.19	48.36	58.14	-4.78	7.54	12.94	0.62	29.74***	28.94***
11.	Latur	-17.56**	-24.97	-8.98	-10.94**	7.02	20.17	-18.58***	-24.55***	-7.33
12.	Nanded	29.2**	30.31	0.86	30.82***	73.71	32.78	29.25***	47.48***	14.11***
13.	Parbhani	6.02***	4.69	-1.26	0.41	-1.03	-1.44	1.38	0.65	-0.72
15.	Washim	24.66**	30.49	4.67	2.94***	-3.5	-6.26	-15.89***	-14.73**	1.38
16.	Amravati	-3.98**	-7.73	-3.9	-3.87	1.19**	5.27	8.91**	15.07***	5.66***
17.	Yavatmal	1.84**	1.5	-0.33**	8.38***	5.99	-2.2	4.93***	14.18***	8.82***
18.	Wardha	-0.24	0.08**	0.32	6.2***	4.1	-1.98	-1.41	-3.9**	-2.52**
19.	Nagpur	6.54***	3.48	-2.87	0.5	0.5	0.01	9.03***	12.91***	3.56**
20.	Bhandara	3.72	1.63*	-2.01	-12.45	-9.67	3.18	-5.84**	-7.4**	-1.66
21.	Gondia	-9.92**	45.27	61.27	7.96*	12.15	3.88	-1.44	19.64***	21.39***
22.	Gadchiroli	66.7**	60.92	-3.47	0.35**	5.36	4.99	22.06***	29.78***	6.32***
23.	Chandrapur	40.59**	45.34	3.38	-16.52*	-13.26	3.91	2.24	4.79	2.49***
24.	Buldhana	-0.67	12.87	13.63	10.06**	32.33	20.23	-0.37	12.83***	13.25***
25.	Kolhapur	20.08***	21.08	0.83***	1.27	8.28	6.93	4.43**	-7.75*	-11.66***
26.	Dhule	2.25*	-1.37	-3.54	2.57***	13.76	10.91	-14.74***	-10.92***	4.49***
27.	Nasik	-2.5	5.16	7.85	1.78	-9.93	-11.51	-7.82***	-8.49***	-0.73
28.	Sindhudurg	-3.46*	-9.78	-6.55	-0.23	8.19	8.43	-2.01***	-6.81***	-4.9**

(***, ** and * significant at 1, 5 and 10 per cent, respectively)

Table 4.8. Region wise Compound Growth Rates of Area, Production and Productivity of Acid Lime in Maharashtra State

Sr. No.	Region	Period I (2006-07 to 2012-13)			Period II (2013-14 to 2019-20)			Overall Period (2006-07 to 2019-20)		
		A	P	Y	A	P	Y	A	P	Y
1.	Marathwada	-12.5**	-16.6	-4.68	8.51***	18.02	8.77	-0.43	-0.93	-0.51
2.	Vidarbha	27.47***	35.21	6.07	22.96***	33.14	8.28	4.44	10.76**	6.06***
3.	Western Maharashtra	-1.74*	-2.35	-0.62	8.35***	6.59	-1.63	-1.32	-2.15	-0.85
4.	Maharashtra State	-0.3	-1.95	-1.65	10.01***	9.7	-0.29	-0.71	-1.23	-0.52

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

20). The production of acid lime was enhanced in Nanded, Amaravati, Yavatmal, Nagpur, and Gadchiroli due to both area expansion and productivity improvements.

While the production of acid lime has positively increased only due to area expansion for Jalgaon and Aurangabad district. In case of Osmanabad, Gondia and Buldhana districts growth rates of production was significant and positive only due to improvement in productivity. The growth rate of area, production and productivity was negative and non-significant in remaining regions *viz.* Marathwada, Konkan and Western Maharashtra. Importantly the area under Acid Lime was significantly increased during the period-II (2013-14 to 2019-20) in all the regions of Maharashtra. As a result, the area, output, and productivity of acid lime have varied throughout time in all districts and regions. Among the regions of Maharashtra and entire Maharashtra state, the production in Vidarbha region recorded positive and significant growth only due to improvement in productivity for the whole period.

4.2.2 Compound annual growth rates of area, production and productivity of sweet orange

Table 4.9 shows the compound growth rates of sweet orange in terms of area, production, and productivity in India. The entire period was split up into two sub periods i.e. period I (1994-95 to 2005-06), period II (2006-07 to 2018-19) and overall period (1994-95 to 2018-19). The analysis by time period revealed that during first period the production has positive and significantly increased only due to the area expansion however in the case of second period the production of sweet orange was discovered to be positive and significantly increased due to only productivity improvement. Throughout the period, output was positive and increased significantly due to the expansion of the area.

In Maharashtra, the compound growth rates of area, production, and productivity of sweet orange were estimated and given in Tables 4.10 and 4.11, respectively. The time series data on area (A), production (P) and productivity (Y) were divided into three sub period as period I (2000-01 to 2009-10), period II (2010-11 to 2019-20) and overall period (2000-01 to 2019-20).

During the entire period, sweet orange output in Wardha district was favorable and significant, thanks to both area growth and productivity development. While the growth rate of output in the Aurangabad, Nagpur, and Akola districts was

Table 4.9. Compound Growth Rates of Area, Production and Productivity of Sweet Orange in India

Sr. No.	India											
	Period I (1994-95 to 2005-06)			Period II (2006-07 to 2018-19)			Overall Period (1994-95 to 2018-19)			Overall Period (1991-92 to 2018-19)		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1.	12.28***	8.91***	-3	-3.11	9.99*	13.52**	6.1***	7.29***	1.13	4.76***	5.16***	0.39*

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

Table 4.10. District wise Compound Growth Rates of Area, Production and Productivity of Sweet Orange in Maharashtra

Sr. No.	District	Period I (2000-01 to 2009-10)			Period II (2010-11 to 2019-20)			Overall Period (2000-01 to 2019-20)		
		A	P	Y	A	P	Y	A	P	Y
1.	Jalgaon	-3.82	-6.72	-3.02	16.64 ***	7.61 **	-7.75 ***	2.57	3.19 *	0.6
2.	Nasik	-	-	-	-	-	-	-41.13***	-49.68***	-14.53***
3.	Ahmednagar	-23.91 **	-10.88	17.13	-20.61 **	-24.17 ***	-4.49	-3.49	0.26	3.88
4.	Pune	-18.41 ***	-14.62 *	4.64	-12.23 ***	-18.38 ***	-7.01 ***	-12.02 ***	-11.38 ***	0.73
5.	Solapur	-	-	-	-	-	-	-10.7	-13.34	-2.95
6.	Aurangabad	-13.07 **	-9.97 **	3.57 *	23.84	22.01	-1.48	8.32 *	9.49 *	1.08
7.	Jalna	7.36 *	10.31 *	2.75	-2.66	10.74	13.77	6.05 ***	3.64	-2.27
8.	Beed	14.7 **	25.66 ***	12.96 ***	6.26 **	10.42 **	4.02	2.49	2.86	0.32
9.	Latur	-	-	-	-	-	-	-9.76 **	-16.05 ***	-6.86
10.	Osmanabad	-	-	-	-	-	-	-27.19 ***	-31.3 ***	-5.65 ***
11.	Nanded	-18.83 ***	-28.64 ***	-12.09	28.55 **	34.09 ***	4.31	-8.67 **	-2.8	6.43**
12.	Parbhani	-5.47	-37.15 *	-33.51 **	-4	-19.47	-16.07 ***	0.39	-4.71	-5.08
13.	Hingoli	6.01	-20.16 *	-3.18	-30.67 ***	21.44	5.99	-12.89 ***	-16.08 *	0.08
15.	Amravati	6.49 **	11.64 **	4.84	-0.39	-1.32	-0.93	1.51	2.17	0.65
16.	Satara	-	-	-	-	-	-	-60.2 ***	-46.65 ***	34.05 ***
17.	Nagpur	19.9 ***	23.02 ***	2.6	8.83 ***	9.02 **	-0.01	13.01 ***	9.83 ***	-2.81 **
18.	Buldhana	-	-	-	-	-	-	-6.31	-13.35***	0.45
19.	Akola	-	-	-	-	-	-	34.38 ***	30.82 ***	-2.6 **
20.	Washim	-	-	-	-	-	-	-14.3 **	-12.7 *	1.79
21.	Yavatmal	-	-	-	-	-	-	0.84 ***	-0.26	-1.08
22.	Wardha	-	-	-	-	-	-	5.84 *	39.75***	24**

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

Table 4.11. Region wise Compound Growth Rates of Area, Production and Productivity of Sweet Orange in Maharashtra State

Sr. No.	Region	Period I			Period II			Overall Period		
		A	P	Y	A	P	Y	A	P	Y
1.	Marathwada	1.17	0.8	-0.36	2.57	5.43	2.79	5.19***	5.54***	0.33
2.	Vidarbha	17.22	22.85**	4.8	4.09***	6.42*	2.24	10.79***	9.07***	-1.55
3.	Western Maharashtra	-7.6	-3.17	4.79*	-14.54***	-13.32***	1.43	-2.9	-2.98	-0.09
4.	Maharashtra	1.34	2.45	1.09	0.62	2.49	1.86	4.32***	4.35***	0.04

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

positive and significant during the time, this was attributable to the expansion of the sweet orange area. The production in the districts of Nagpur and Akola was found to be significant yet negative. The growth rates of area, production, and productivity was significant but negative in the districts of Nasik, Osmanabad, and Satara.

Among the regions of Maharashtra, Vidarbha and Marathwada region the production growth rate during the overall period was found positive and significant which was mainly due to the area expansion. As a result, the productivity, area, and production of sweet orange have varied throughout time in all districts and regions. Similar trends were found in case of entire Maharashtra during the overall period.

4.3 Instability in Area, Production and Productivity

Table 4.12a, 4.12b and 4.12c show the coefficient of variation and Cuddy Della Valle Index of area, production, and productivity of acid lime for the years 2006-07 to 2019-20 for districts, regions, and Maharashtra as a whole. The Cuddy-Della Valle Index and the Coefficient of Variations (CV) were used to calculate fluctuations in area, production, and productivity. The time series data on area (A), production (P) and productivity (Y) were divided into three periods as period I (2006-07 to 2012-13), period II (2013-14 to 2019-20) and whole period (2006-07 to 2019-20).

4.3.1 Instability in Area, Production and Productivity of Acid Lime

It was observed that at the entire period the area under acid lime was highly consistent and stable for the districts *viz.* Ahmednagar (5.53), Parbhani (12.49), Yavatmal (7.76), Wardha (11.58), Nagpur (13.51) and Sindhudurg (6.28) except the districts which were highly instable such as Jalgaon (32.85), Solapur (49.12), Satara (31.41), Jalna (31.57), Beed (51.70), Aurangabad (52.14), Washim (75.55), Amaravati (48.99), Bhandara (37.26), Gadchiroli (37.36), Chandrapur (68.04) and Dhule (37.14).

Among the region, in Western Maharashtra (14.16) region the area under acid lime crop was discovered to be more stable and consistent while highly instability in area and production under the acid lime was found in Vidarbha and Marathwada region. In Vidarbha (6.83) and Western Maharashtra (14.1) region the productivity of acid lime was found more stable and consistent. However, in the case of entire Maharashtra, area (15.68) and production (20.66) of acid lime was found highly instable while more stability was found in case of productivity (11.47) under acid lime.

Table 4.12. District wise Instability in Area, Production and Productivity of Acid Lime in Maharashtra

Sr. No.	Period	District																	
		Jalgaon			Ahmednagar			Pune			Solapur			Satara			Sangli		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I																		
	CV (%)	17.28	21.98	6.98	3.72	13.42	10.31	8.65	10.79	11.59	61.06	67.92	19.7	11.27	16.29	31.86	4.46	4.15	0.47
	CDVI	16.54	21.98	6.98	2.72	13.42	1031	3.27	1079	11.59	59.66	67.92	19.7	7.08	16.29	31.86	2.22	4.15	0.47
2	Period II																		
	CV (%)	43.28	51.5	12.87	5.51	13.11	17.46	38.95	39.49	10.55	19.43	19.35	29	15.35	18.39	7.99	80.68	74.97	13.93
	CDVI	13.12	51.5	12.87	3.31	13.11	17.46	13.62	39.49	10.55	14.5	19.35	29	13.81	18.39	7.99	18.99	74.97	13.93
3	Overall																		
	CV (%)	69.38	76.85	10.04	6.89	42.62	37.38	34.31	27.77	19.16	49.17	44.83	34.15	72.85	50.76	37.37	50.46	48.07	10.47
	CDVI	32.85	39.98	9.55	5.53	15.32	12.4	24.4	27.07	12.66	49.12	43.31	29.89	31.41	31.41	14.93	30.2	29.45	9.81

Table 4.12 contd....

Sr. No.	Period	District																	
		Jalna			Beed			Aurangabad			Osmanabad			Latur			Nanded		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I																		
	CV (%)	26.59	45.81	38.89	63.31	70.02	14.97	169.69	199.36	23.97	25.82	133.71	115.07	37.36	46.11	23.01	61.78	63.79	6.31
	CDVI	24.77	45.81	38.89	39.25	70.02	14.97	81.04	199.6	23.97	23.55	133.71	155.07	22.47	46.11	23.01	30.36	63.79	6.31
2	Period II																		
	CV (%)	49.29	78.8	42.95	38.07	64.69	38.04	26.46	40.7	18.08	22.93	19.36	33.89	34.09	53.31	42.54	49.07	80.43	56.33
	CDVI	31.84	78.8	42.95	13.82	64.69	38.04	26.16	40.7	18.08	19.90	19.36	33.89	19.85	53.31	42.54	17.35	80.43	56.33
3	Overall																		
	CV (%)	54.49	71.2	39.37	51.75	73	32.31	87.05	108.38	20.37	24.85	71.72	73.38	81.31	103.65	43.69	93.3	140.24	76.44
	CDVI	31.57	58.03	39.28	51.7	70.69	28.67	52.14	68.03	20.35	24.75	41.35	39.53	25.64	56.49	38.97	21.96	39.6	42.23

Table 4.12 contd....

Sr. No.	Period	District																	
		Parbhani			Washim			Amravati			Yavatmal			Wardha			Nagpur		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I																		
	CV (%)	14.16	10.81	5.51	55.73	63.59	11.28	10.15	17.8	9.63	4.93	18.65	15.32	1.35	2.71	2.23	15.41	19.73	16.68
	CDVI	6.67	10.81	5.51	29.32	63.59	11.28	5.3	17.8	9.63	2.86	18.65	15.32	1.25	2.71	2.23	6.21	19.73	16.68
2	Period II																		
	CV (%)	11.93	15.19	8.04	6.53	16.06	20.42	38.67	41.25	13.7	17.14	12.78	6.42	13.26	19.77	20.02	1.72	1.72	0.02
	CDVI	11.9	15.19	8.04	1.86	16.06	20.42	38.22	41.25	13.7	4.16	12.78	6.42	3.63	19.77	20.02	1.36	1.72	0.02
3	Overall																		
	CV (%)	12.83	12.79	6.83	103.97	107.88	18.57	60.93	79.69	28.49	22.57	55.45	40.64	12.83	23.12	16.16	36.28	51.14	20.02
	CDVI	11.5	12.49	6.1	75.55	81.38	17.57	48.99	55.72	17.01	7.76	23.74	23.94	11.58	17.94	12.69	13.51	24.15	15.25

Table 4.12 contd....

Sr. No.	Period	District																	
		Bhandara			Gondia			Gadchiroli			Chandrapur			Buldhana			Kolhapur		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I																		
	CV (%)	26.7	31.74	10.77	24.42	82.51	108.2	102.23	96.88	13.75	80.41	86.24	9.55	8.84	35.31	32.09	44.38	88.28	45.96
	CDVI	25.05	31.74	10.77	15.95	82.51	108.2	52.76	96.88	13.75	42.33	86.24	9.55	8.71	35.31	32.09	19.38	88.28	45.96
2	Period II																		
	CV (%)	65.97	83.2	23.6	21.31	30.45	18.09	0.96	18.27	18.11	54.03	49.06	14.06	27.85	56.94	38.07	4.27	28.44	26.43
	CDVI	51.98	83.2	23.6	14.03	30.45	18.09	0.59	18.27	18.11	36.67	49.06	14.06	16.76	56.94	38.07	3.38	28.44	26.43
3	Overall																		
	CV (%)	46.39	56.29	18.39	23.02	60.02	62.16	57.74	68.23	33.19	68.66	69.41	14.21	19.81	66.87	56.06	29.29	108.29	76.68
	CDVI	37.26	45.56	17.47	22.37	31.09	37.27	37.36	32.94	21.64	68.04	66.93	8.85	19.75	34.58	19.73	23.92	95.59	54.44

Table 4.12 contd....

Sr. No.	Period	District								
		Dhule			Nasik			Sindhudurg		
		A	P	Y	A	P	Y	A	P	Y
1	Period I									
	CV (%)	7.13	6.08	9.58	11.62	12.03	22.37	9.59	22.29	15.53
	CDVI	5.11	6.08	9.58	10.53	12.03	22.37	6.61	22.29	15.53
2	Period II									
	CV (%)	5.87	32.18	27.52	10.18	55.06	65.96	3.19	24.69	26.76
	CDVI	2.36	32.18	27.52	9.45	55.06	65.96	3.15	24.69	26.76
3	Overall									
	CV (%)	67.49	55.68	29.17	38.94	43.71	49.08	10.63	38.93	30.28
	CDVI	37.14	38.08	20.78	20.89	28.31	48.88	6.28	26.8	23.46

Table 4.12b. Region wise Instability in area, production and productivity of Acid Lime in Maharashtra

Sr. No.	Period	Region								
		Marathwada			Vidarbha			Western Maharashtra		
		A	P	Y	A	P	Y	A	P	Y
1	Period I									
	CV (%)	30.70	36.67	15.3	51.43	60.14	13.77	5.09	9.33	7.19
	CDVI	14.98	36.84	15.3	22.5	60.14	13.77	3.41	9.33	7.19
2	Period II									
	CV (%)	20.68	37.95	19.18	48.49	61.02	17.24	18.04	27.71	20.32
	CDVI	8.90	37.95	19.18	19.04	61.02	17.24	4.84	27.71	20.32
3	Overall									
	CV (%)	25.19	36.17	17.09	48.92	60.24	25.67	15.07	21.54	14.56
	CDVI	25.13	35.99	16.98	45.82	46.47	6.83	14.16	19.61	14.1

Table 4.12c. Instability in Area, Production and Productivity of Acid Lime in Maharashtra

Sr. No.	Period	Maharashtra		
		A	P	Y
1	Period I			
	CV (%)	4.68	9.22	6.54
	CDVI	4.63	9.22	6.54
2	Period II			
	CV (%)	21.29	29.16	15.98
	CDVI	4.60	29.16	15.98
3	Overall			
	CV (%)	15.92	21.29	11.69
	CDVI	15.68	20.66	11.47

4.3.2 Instability in Area, Production and Productivity of Sweet Orange

For the period 2000-01 to 2019-20, the coefficient of variation and Cuddy Della Valle Index of sweet orange area, production, and productivity were calculated and given in Tables 4.13a, 4.13b and 4.13c for districts, regions, and Maharashtra as a whole.

It was observed that area under sweet orange was highly consistent and stable for the Yavatmal (7.76) district while medium level of consistency and stability was found in the districts like Jalna (26.4), Latur (29.70), Nagpur (21.55) and Wardha (22.55) and other districts were found more instable. Medium level of consistency and stability in production of sweet orange was found in Nagpur (28.62) district and other districts were found highly instable. In case of productivity highly consistency and stability was found in Akola (9.46) and Washim (12.44) district while medium level of consistency and stability was found in Osmanabad (17.58) and Amravati (29.55) districts and highly instability was found in other districts.

Table 4.13a. District wise Instability in Area, Production and Productivity of Sweet Orange in Maharashtra

Sr. No.	Period	District																	
		Jalgaon			Nashik			Ahmednagar			Pune			Solapur			Aurangabad		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I																		
	CV (%)	59.56	39.15	31.53	45.04	41.03	20.68	75.01	127.94	72.61	55.28	74.38	49.72	-	-	-	37.44	32.39	18.95
	CDVI	58.52	34.03	30.74	35.12	34.79	18.25	57.64	125.36	68.65	25.58	58.29	48.16	-	-	-	24.59	25.08	15.64
2	Period II																		
	CV (%)	41.05	25.88	31.48	157.19	160.76	59.2	107.79	104.17	60.35	42.18	69.13	30.12	-	-	-	45.29	60.81	36.03
	CDVI	24.00	18.97	18.10	57.50	49.25	27.95	71.04	45.00	59.50	21.61	32.2	17.41	-	-	-	40.17	55.99	35.96
3	Overall																		
	CV (%)	49.22	35.95	33.25	88.65	87.8	42.36	96.02	112.58	64.68	83.14	93.85	39.64	79.78	156.75	98.81	74.31	94.25	32.41
	CDVI	47.62	32.34	33.1	44.84	48.55	38.36	94.29	112.57	63.48	32.59	55.07	39.44	75.45	142.06	97.85	67.69	84.99	32.16

Table 4.13a contd....

Sr. No.	Period	District																	
		Jalna			Beed			Latur			Osmanabad			Nanded			Parbhani		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I																		
	CV (%)	43.82	57.35	26.5	66.77	97.99	53.23	-	-	-	-	-	-	56.19	75.81	46.78	65.78	65.27	168.16
	CDVI	34.06	46.63	25.13	44.89	50.52	31.25	-	-	-	-	-	-	28.87	48.48	42.24	65.32	52.42	111.39
2	Period II																		
	CV (%)	17.51	50.75	52.93	24.62	46.18	29.65	-	-	-	-	-	-	65.76	84.23	243.35	79.71	124.56	62.21
	CDVI	15.43	49.41	50.46	16.27	33.53	27.94	-	-	-	-	-	-	45.13	52.66	242.05	79.27	109.38	31.28
3	Overall																		
	CV (%)	41.76	56.67	39.79	51.85	87.32	47.35	40.89	64.1	36.3	94.66	103.45	25.96	81.57	77.89	314.07	71.83	116.12	153.33
	CDVI	26.45	55.37	39.38	48.67	84.27	47.3	29.7	42.9	31.11	50.76	57.07	17.58	71.14	77.84	287.95	71.82	114.8	148.34

Table 4.13a contd....

Sr. No.	Period	District														
		Hingoli			Amravati			Satara			Nagpur			Buldhana		
		A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
1	Period I															
	CV (%)	53.49	51.3	33.24	25.85	43	35.89	-	-	-	55.12	57.59	32.49	-	-	-
	CDVI	46.33	39.82	31.64	18.4	31.87	33.21	-	-	-	23.89	29.21	31.74	-	-	-
2	Period II															
	CV (%)	134.82	194.54	147.47	55.27	74.57	23.98	-	-	-	27.58	28.93	6.96	-	-	-
	CDVI	84.55	191.6	146.95	55.27	74.53	23.79	-	-	-	17.27	20.52	6.96	-	-	-
3	Overall															
	CV (%)	88.2	105.33	150.61	51.95	69.59	29.79	140.18	202.15	67.01	60.94	48.77	36.62	79.53	76.43	36.34
	CDVI	65.43	97.34	150.61	51.67	68.94	29.55	75.32	104.52	45.18	21.55	28.62	31.66	75.95	76.4	35.64

Table 4.13a contd....

Sr. No.	Period	District														
		Akola			Washim			Yavatmal			Wardha					
		A	P	Y	A	P	Y	A	P	Y	A	P	Y			
1	Period I															
	CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CDVI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Period II															
	CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CDVI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Overall															
	CV (%)	96.61	92.39	13.25	83.93	89.38	13.43	2.68	46.33	47.81	27.72	64.05	504			
	CDVI	30.00	33.93	9.46	59.4	71.77	12.44	0.96	46.33	47.81	22.55	47.34	46.76			

Table 4.13b. Regions wise instability in area, production and productivity of Sweet Orange in Maharashtra

Sr. No.	Period	Region								
		Marathwada			Vidarbha			Western Maharashtra		
		A	P	Y	A	P	Y	A	P	Y
1	Period I									
	CV (%)	16.29	26.39	18.95	148.31	127.62	29.25	59.51	82.86	23.48
	CDVI	15.79	26.27	18.92	124.79	94.86	26.01	55.47	81.97	18.9
2	Period II									
	CV (%)	15.00	33.11	26.66	15.55	27.62	17.65	56.57	61.61	16.78
	CDVI	13.32	30.99	25.74	9.63	22.73	16.85	25.84	36.38	16.44
3	Overall									
	CV (%)	34.24	46.08	22.67	80.72	79.18	31.02	56.65	74.01	21.18
	CDVI	17.57	34.43	22.6	54.14	59.13	29.62	54.09	70.55	21.17

Table 4.13c. Instability in Area, Production and Productivity of Sweet Orange in Maharashtra

Sr. No.	Period	Maharashtra		
		A	P	Y
1	Period I			
	CV (%)	27.05	33.04	16.64
	CDVI	26.66	32	16.33
2	Period II			
	CV (%)	8.07	23.85	19.99
	CDVI	7.87	23	19.34
3	Overall			
	CV (%)	29.79	35.88	17.94
	CDVI	18.88	26.56	17.94

In Marathwada (17.57) region medium level of stability and consistency in area under sweet orange crop was observed while in case of other region highly stability was observed. Highly instability in production of sweet orange was found in Vidarbha, Marathwada and Western Maharashtra regions of Maharashtra. While medium level of stability and consistency was observed in productivity of sweet orange in Vidarbha (29.62), Marathwada (22.60) and Western Maharashtra (21.17) region.

In case of entire Maharashtra state medium level of stability and consistency was observed in area (18.88), production (26.56) and productivity (17.94) of sweet orange.

4.4 Varieties developed by universities and varietal status on farmer's field

4.4.1 Acid Lime

Table 4.14 indicates the varieties developed by All India Coordinated Research Project on Fruits, MPKV, Rahuri. The AICRP on Fruits, MPKV, Rahuri has released two varieties of acid lime i.e. *Sai Sharbati* and *Phule Sharbati* which were developed in the year 1994 and 2008, respectively. *Sai Sharbati* was a selection from natural clone population of kagzi lime identified during survey of kagzi lime gardens from Indapur area of Pune District in 1985. Distinguishing qualities of this variety were more fruit weight (49.87 g), low seed content (7.9 seeds/fruit), high juice content (54.51 %), high TSS (7.93 %), high vitamin C content (28.43 mg/100 ml juice), high acidity (7.29 %) and less rind thickness (1.52 mm). This variety was tolerant to canker and tristeza under field conditions. Early flowering at the 4th year after planting and the extent of *hasta bahar* was 27.47 per cent.

While *Phule Sharbati* was a selection of seedlings from the natural clonal population of acid lime orchards surveyed from Indapur area of Pune district were raised in the orchard of Department of Horticulture, M.P.K.V., Rahuri since 1993 and evaluated for better plant growth, high yield potential, good fruit quality, having reasonable cropping in summer and better reaction to pests and diseases. Characteristics of the fruit were round in shape, thin skin (1.95 mm), greenish yellow colour, weight (49.77 g/fruit), high juice content (52.52 %), high acidity (6.48 %), high TSS (7.34 %), high vitamin "C" content (27.73 mg/100 ml juice). Production condition of this variety was early flowering at the third year of planting, high yield potential including 25 per cent in summer cropping.

Table 4.14. Acid Lime Varieties Developed by All India Coordinated Research Project on Fruits, MPKV, Rahuri

Sr. No.	Variety	Year of Release	Place
1	<i>Sai Sharbati</i>	1994	AICRP on Fruits, Department of Horticulture, MPKV, Rahuri
2	<i>Phule Sharbati</i>	2008	AICRP on Fruits, Department of Horticulture, MPKV, Rahuri

4.4.1.1 Varietal status of acid lime varieties on farmer's field

Table 4.15 shows the proportion of the area under acid lime varieties covered by different acid lime varieties on farmer's field for the year 2019-20. Among all the varieties of acid lime Kagzi Lime (local) variety still contributing 30.54 per cent area to the total area of acid lime. University released *Sai Sharbati* and *Phule Sharbati* varieties individually contributing 20.16 and 17.27 per cent area, respectively to the total area of Acid Lime. Thus together total area under university released acid lime variety contributed to 37.43 per cent. PDKV Lime variety of Dr. PDKV, Akola University also contributes 16.03 per cent of the total area under all varieties.

Table 4.15. Varietal status of acid lime varieties on farmer's field ((2019-20)

Sr. No.	Variety	Area (Ha)	Per cent to the total	Total area under university released acid lime varieties (%)
1	Sai Sharbati (1994)	10.93	20.16	37.43
2	Phule Sharbati (2008)	9.36	17.27	
3	Kagzi Lime (Local)	16.55	30.54	
4	PDKV Lime (2004)	8.68	16.03	
5	PDKV Chakradhar (2014)	4.67	8.63	
6	PDKV Trupti (2017)	0.87	1.62	
7	PDKV Bahar (2017)	0.72	1.33	
8	Konkan Lemon (2007)	2.4	4.42	
Total		54.18	100.00	

4.4.2 Sweet Orange

The details of sweet orange varieties developed by All India Coordinated Research Project on Fruits are given in Table 4.16. Nucellar Mosambi is widely growing sweet orange variety recommended by the Mahatma Phule Krishi Vidyapeeth, Rahuri. Another Phule Mosambi was the variety developed by the All India Coordinated Research Project on fruits in the year 2008. Phule Mosambi was the clonal selection from Nucellar Mosambi. Quality standards of the produce were medium fruit size (57.69 cm²), high juice per cent (47.37 %) and excellent TSS, acid ratio (19.98 %). This variety was less susceptible to greening, tristeza, leaf miner back fly and aphids. Production condition of this variety was high yield potential (72.95 kg/plant) and fruit weight about 240.96 g.

Table 4.16. Sweet Orange Varieties Developed by All India Coordinated Research Project on Fruits, MPKV, Rahuri

Sr. No.	Variety	Year of Release	Place
1	Nucellar Mosambi	-	Recommended by MPKV, Rahuri
2	Phule Mosambi	2008	AICRP on Fruits, Department of Horticulture, MPKV, Rahuri

4.4.2.1 Varietal Status of sweet orange varieties on farmer's field

Varietal status of sweet orange varieties on farmer's field presented in Table 4.17. Among all the varieties of sweet orange, local variety contributed 16.00 per cent to the total area covered by all the variety. Katol Gold is the variety developed by the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola which has contributed 39.6 per cent to the total area of sweet orange varieties. Nucellar Mosambi has contributed 24.39 per cent to the total area of sweet orange varieties. Phule Mosambi variety developed by All India Coordinated Research Project on Fruits, MPKV, Rahuri in 2008 which contributed 20.01 per cent to the total area of sweet orange varieties. Together Nucellar Mosambi and Phule Mosambi share 44.40 percentage of area to the total area of sweet orange varieties on farmer's field in Maharashtra.

Table 4.17. Varietal Status of sweet orange varieties on farmer's field

Sr. No.	Variety (N = 60)	Area (Ha)	Per cent to the total	Total area under university released sweet orange varieties
1	Local	14.13	16.00	
2	Katol Gold (2005)	34.98	39.60	
3	Nucellar Mosambi	21.54	24.39	44.40
4	Phule Mosambi (2008)	17.67	20.01	
Total		88.32	100	

4.5 Growth of Input, Output and TFP Index of Acid Lime and Sweet Orange

Total factor productivity analysis is to measure the amount of increase in total yield, which is not accounted for, by increase in total input use. TFP index is a ratio of output index to input index. Growth in Total Factor Productivity represents the effect of non-input factors such as technology, improved variety, infrastructure development,

knowledge, skill, *etc.* to the total output. Present study analyzed the growth of total output index, total input index and total factor productivity growth of acid lime and sweet orange was calculated by using the Tornqvist Theil Index. Magnitude of growth of TFP was given by Chand *et al.* (2011), was presented in Table 4.18.

Table 4.18. Magnitude of growth in TFP

	TFP Growth				
Magnitude of growth in TFP	Negative Growth	Stagnant Growth	Low Growth	Moderate Growth	High TFP Growth
	< 0	Positive but < 0.5 per cent	0.5 to 1.0 per cent	1.0 to 2.0 per cent	> 2 per cent

Source: Chand *et al.* (2011)

4.5.1 Growth of Total Factor Productivity of Acid Lime

The output index, input index and TFP index, input share and TFP share from 1994-95 to 2018-19 is presented in Table 4.19. By using the Tornqvist Theil Index the output, the input and TFP index during the study period 1994-95 to 2018-19.

The output index falls within the range between 0.61 in 1998-99 and 2.23 in 1999-00. Similarly, Total input index was at lowest in 2006-07 (0.62) and it was at elevated in the year 2004-05 (2.36). TFP indices varied between 0.63 in 2004-05 to 2.25 in 2015-16. The average annual output index was 1.33 for the study period which was slightly more than the average annual input index (1.02). As a result, the annual TFP index averaged 1.40. It indicates that during the research period, there was a technological change in the acid lime fruit production. The release of improved varieties such as Sai Sharbati (1994), PDKV Lime (2004), Konkan Lemon (2007), Phule Sharbati (2008), PDKV Chakradhar (2014), PDKV Trupti (2017), and PDKV Bahar (2017) by state agricultural universities in Maharashtra during the study period may have contributed to the reliable growth of TFP for acid lime fruit crop in Maharashtra during the study period. The contribution of increased in irrigation facilities also noted in the productivity growth. It has made a significant contribution to lowering the cost of cultivation, even though the input prices including labour charges increased remarkably during recent year. A positive shift in TFP growth (or technical change) is thought to

result in a reduction in real production costs (Kumar and Mruthyunjaya, 1992; Kumar and Rosegrant, 1994).

Table 4.19. Input Index, Output Index, TFP Index, Input Share and TFP Share of Acid Lime from 1994-95 to 2018-19

Sr. No.	Year	Input Index	Output Index	TFP Index	Input Share	TFP Share
1	1994-95	1	1	1	1	1
2	1995-96	0.98	1.64	1.65	59.75	40.24
3	1996-97	0.94	0.91	0.96	103.29	-3.29
4	1997-98	0.99	0.74	0.74	133.78	-33.78
5	1998-99	0.75	0.61	0.81	122.95	-22.95
6	1999-00	1.00	2.23	2.22	44.84	55.15
7	2000-01	0.84	1.36	1.60	61.76	38.23
8	2001-02	0.85	1.78	2.08	47.75	52.24
9	2002-03	1.75	1.27	0.72	137.79	-37.79
10	2003-04	0.69	1.93	2.78	35.75	64.24
11	2004-05	2.36	1.50	0.63	157.33	-57.33
12	2005-06	1.32	2.07	1.57	63.76	36.23
13	2006-07	0.62	1.14	1.83	54.38	45.61
14	2007-08	0.92	1.33	1.43	69.17	30.82
15	2008-09	0.89	0.74	0.83	120.27	-20.27
16	2009-10	0.67	0.87	1.28	77.01	22.98
17	2010-11	0.95	1.94	2.02	48.96	51.03
18	2011-12	1.06	0.77	0.72	137.66	-37.66
19	2012-13	0.91	1.95	2.13	46.66	53.33
20	2013-14	1.04	0.84	0.80	123.80	-23.80
21	2014-15	1.10	0.91	0.83	120.87	-20.87
22	2015-16	0.80	1.82	2.25	43.95	56.04
23	2016-17	0.83	1.60	1.92	51.87	48.12
24	2017-18	0.68	0.88	1.29	77.27	22.72
25	2018-19	1.63	1.46	0.89	111.64	-11.64
Average		1.02	1.33	1.40	82.13	13.94

The TFP shows the augment in total output which is not explained for by increase in total inputs. Using the TFP growth estimates, its contribution in growth of output was estimated. The output growth estimates were estimated only for those cases in which TFP growth was positive. For the agronomic crops and horticulture crops describe higher growth of TFP, in which the growth of output was largely attributed to technology.

In case of such a condition, the share of growth of TFP in output growth would consider a higher share in comparison to those crops where the technology induces a higher use of inputs. In case of acid lime fruit crop highest contribution of TFP in output growth was noticed in the year 2003-04 and average annual share of TFP in output growth was 13.94. It was observed that the input share was maximum in the year 2004-05 it reflects higher use of inputs in production process.

With the aim of assess the temporal performance of TFP of acid lime fruit crop in Maharashtra, the compound growth rates of output, input and TFP indices were worked out for 25 years from 1994-95 to 2018-19 to identify whether significant change has taken place in the TFP due to the research in acid lime fruit crop and various developmental activities or policies. The numerical findings of the equal have been presented in Table 4.20. TFP grew at a rate of 0.36 per cent each year over the study period (1994-95 to 2018-19), according to Table 4.20. During the same time span, the input index fell by 0.1 per cent per year, while the output index rose by 0.26 per cent per annum.

The output index was higher than the input index reason behind this may be because of the fact that the rate of increase in output prices was more than the input prices and by using high yielding improved varieties of Acid Lime i.e. Sai Sharbati and Phule Sharbati. Even though, findings of the sub periods were more revealing. The input index climbed at a pace of 4.2 per cent per annum from 1994-95 to 2005-06, whereas the output index increased at a rate of 6.46 per cent per annum. During Period-I, TFP growth was impressive, averaging 2.17 per cent per annum. While, in case of period-II growth rate of input index (2.68) was found more than the output index (1.87) as a result of which TFP index declines by 0.79 per cent per annum.

Table 4.20. Growth Rates of Input Index, Output Index and TFP Index of Acid Lime

Sr. No.	Period I (1994-95 to 2005-06)			Period II (2006-07 to 2018-19)			Overall Period (1994-95 to 2018-19)		
	Input Index	Output Index	TFP Index	Input Index	Output Index	TFP Index	Input Index	Output Index	TFP Index
1.	4.2	6.46*	2.17	2.68	1.87	-0.79	-0.1	0.26	0.36

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

Table 4.21. Trends in Total Factor Productivity Growth in Acid Lime Fruit Crop 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 (1994-95 to 2005-06)	--	--	--	--	High Growth
Period II (2006-07 to 2018-19)	Negative	--	--	--	--
Overall Period (1994-95 to 2018-19)	--	Positive	--	--	--

(Ref: Chand *et al.*, 2012)

From the Table 4.21 reveals that Acid Lime fruit crop has witnessed a highest growth in TFP (more than 2 %) for first period (1994-95 to 2005-06) and positive growth but stagnant growth rate was noted during overall period (1994-95 to 2018-19).

4.5.2 Total Factor Productivity Growth of Sweet orange

The indices of TFP, input, output and input and TFP share is presented in Table 4.22. It is noted that the TFP of sweet orange varied from 1.13 in 1995-96 to 1.68 in 2018-19. Maximum TFP index was noted in the year 2013-14 (2.51). The TFP index for 25 years was 1.28. In case of output index of sweet orange it was increased from 1.08 in 1995-96 to 1.53 in 2018-19. The highest output index was noted in the year 2005-06 (2.64). For 25 years the average annual of output index was 1.27. There were more fluctuations in input index; it was range between 0.43 in 2008-09 and 2.87 in 2005-06. The average annual of input index of sweet orange was 1.04 for 25 years. Share of TFP in output growth of sweet orange was estimated by deducting input share from 100. The estimated average annual TFP growth in output growth was 17.03. Average annual input share was 78.92 during 1994-95 to 2018-19.

Table 4.22. Input Index, Output Index, TFP Index, Input Share and TFP share of Sweet Orange

Sr. No.	Year	Input Index	Output Index	TFP Index	Input Share	TFP Share
1	1994-95	1	1	1	1	1
2	1995-96	0.95	1.08	1.13	87.96	12.04
3	1996-97	0.80	0.89	1.10	89.88	10.12
4	1997-98	0.75	0.84	1.11	89.28	10.72
5	1998-99	1.38	1.40	1.01	98.57	1.43
6	1999-00	1.20	1.58	1.31	75.94	24.06
7	2000-01	0.94	0.88	0.92	106.81	-6.81
8	2001-02	0.80	1.21	1.51	66.11	33.89
9	2002-03	0.88	1.06	1.20	83.01	16.99
10	2003-04	1.04	1.11	1.06	93.69	6.31
11	2004-05	0.67	0.96	1.42	69.79	30.21
12	2005-06	2.87	2.64	0.92	108.71	-8.71
13	2006-07	0.61	0.93	1.51	65.59	34.41
14	2007-08	1.01	0.99	0.98	102.02	-2.02
15	2008-09	0.43	0.70	1.61	61.42	38.58
16	2009-10	1.64	2.41	1.46	68.04	31.96
17	2010-11	0.66	1.43	2.13	46.15	53.85
18	2011-12	1.30	1.12	0.86	116.07	-16.07
19	2012-13	1.31	1.22	0.93	107.37	-7.37
20	2013-14	0.79	1.98	2.51	39.89	60.11
21	2014-15	1.14	1.26	1.10	90.47	9.53
22	2015-16	1.08	1.34	1.23	80.59	19.41
23	2016-17	0.89	1.10	1.22	80.90	19.10
24	2017-18	0.97	1.15	1.18	84.34	15.66
25	2018-19	0.91	1.53	1.68	59.47	40.53
Average		1.04	1.27	1.28	78.92	17.15

To analyze the productivity performance of TFP of sweet orange fruit crop in Maharashtra. The compound annual growth rates of sweet orange output, input, and TFP indices were estimated for 25 years, from 1994-95 to 2018-19, as well as for two additional sub periods, from 1994-95 to 2005-06 (Period-I) and 2006-07 to 2018-19

(Period-II) (period-II). Table 4.23 shows that the annual growth rate of TFP was 1.15 per cent per annum for the entire study period (1994-95 to 2018-19). For the same period, output index increased at the rate of 1.28 per cent per annum while growth rate of input index was 0.13 per cent per annum. The results were more revealing in sub periods *i.e.* Period-I and period-II. During Period I, the input index climbed by 3.28 per cent per year, whereas the output index increased by 4.07 per cent per year. During Period-I the growth rate of TFP was 0.77 per cent per year. In period-II, it was noticed that the rate of input index (2.43) was more than the rate of output index (2.27) it led to decline in the growth rate of TFP during period-II.

The improvement in TFP during first and overall period was because of non-input factors namely road length, markets, research and extension efforts, rainfall, better management practices, *etc.* The Mahatma Phule Krishi Vidyapeeth, Rahuri has released and recommends the improved varieties of sweet orange *i.e.* Nucellar Mosambi and Phule Mosambi to enhance the productivity which are tolerant or less susceptible to greening, tristeza, leaf miner, black fly and aphids. Therefore, the agricultural universities played a pivotal role in growth of TFP of sweet orange fruit crop.

Table 4.23. Growth rates of Input Index, Output Index and TFP Index of Sweet Orange

Sr. No.	Period I (1994-95 to 2005-06)			Period II (2006-07 to 2018-19)			Overall Period (1994-95 to 2018-19)		
	Input Index	Output Index	TFP Index	Input Index	Output Index	TFP Index	Input Index	Output Index	TFP Index
1.	3.28	4.07	0.77	2.43	2.27	-0.16	0.13	1.28	1.15

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

From the Table 4.24 reveals that Sweet Orange fruit crop has witnessed a medium growth in TFP between 1 to 2 per cent during the whole period (1994-95 to 2018-19). Low and negative growth was observed during first and second period.

Table 4.24. Trends in Total Factor Productivity growths in Sweet Orange fruit crop 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 (1994-95 to 2005-06)	--	--	Low Growth	--	--
Period II (2006-07 to 2018-19)	Negative	--	--	--	--
Overall Period (1994-95 to 2018-19)	--	--	--	Moderate Growth	--

(Ref: Ramesh Chand *et al.*, 2012)

4.6 Source of Total Factor Productivity Growth

4.6.1 Source of Total Factor Productivity Growth in Acid Lime

The TFP can be influenced by non-input factors such as research and extension investment, human resources, cropping intensity, balanced use of plant nutrient, infrastructural development, literacy level, climate, etc. The direction of statistical significant effect on TFP has been presented in Table 4.25 and it reveals that the research investment has been a significant source of TFP growth in acid lime fruit crop. Research investment for the transfer of technology has contributed positively towards TFP enhancement in acid lime fruit crop. The regression coefficient research investment was 0.18. It indicates that, if the research investment increase by one per cent, the TFP will increase by 0.18 per cent. The cropping intensity (1.25) along with balanced use of fertilizers (1.44) have also played significant role in increasing the TFP level. The variables like rural literacy (1.27), maximum temperature (10.50), minimum temperature (3.69) was positive but non-significant. The variables like rainfall (-0.001) and road density (-0.48) were found negative and non-significant contribution to TFP. The estimated R^2 value was 0.72, suggesting that the components included in the model explained 72 per cent of the variation in TFP, and the f value was significant, indicating a good fit of the model.

Table 4.25. Estimated Parameters of TFP for Acid Lime for the period 1994-95 to 2018-19

Sr. No.	Variable	Coefficients	Standard Error
1	Intercept (a)	19.22	22.00
2	Research Investment (x_1) (Rs/ha)	0.18***	0.04
3	Rural Literacy (X_2) (%)	1.27	2.85
4	Rainfall (X_3) (MM)	-0.001	0.80
5	Road Density (X_4) (KM per 100 sq. Km)	-0.48	0.94
6	N to P Ratio (X_5)	1.44*	0.71
7	Temperature (X_6) (Max)	10.50	15.96
8	Temperature (X_7) (Min)	3.69	11.69
9	Cropping Intensity (%)	1.25*	0.63
10	R^2	0.72	
11	F Value	6.24	
12	No. Of Observations (N)	25	

(***, ** and * significant at 1, 5 and 10 per cent, respectively)

4.6.2 Source of Total Factor Productivity in Sweet Orange

Table 4.26 shows the estimated TFP parameters for sweet orange for the period 1994-1995 to 2018-19. TFP growth rate was analyzed to quantify the contribution of various factors to TFP growth such as research investment, rural literacy, rainfall, road density, N to P ratio, maximum temperature, minimum temperature, gross irrigated area, *etc.* The findings indicated that research investment (0.09) and gross irrigated area (1.92) has significantly contributed to TFP growth in sweet orange. The nitrogen-to-phosphorous-nutrient ratio (0.97) was used as a proxy for fertilizer balance, and the coefficients are positive and significant. As a proxy for infrastructure, the road density (0.94) was used. This variable's coefficient was positive and significant. The variables of rural literacy (%) and rainfall (mm) were found to be negative and non-significant. Maximum temperature and minimum temperature was found positive and negative, respectively and both variables were found non-significant. The estimated R^2 value was 0.71, suggesting that the components included in the model explained 71% of the variation in TFP, and the f value was significant, indicating a good fit of the model.

Table 4.26. Estimated Parameters of TFP for Sweet Orange for the period 1994-95 to 2018-19

Sr. No.	Variables	Coefficients	Standard Error
1	Intercept (a)	12.14	12.31
2	Research Investment (X ₁) (Rs/ha)	0.09**	0.03
3	Rural Literacy (X ₂) (%)	-0.65	1.24
4	Rainfall (X ₃) (MM)	-0.10	0.43
5	Road Density (X ₄) (Km per 100 sq. Km)	0.94**	0.40
6	N to P Ratio (X ₅)	0.97**	0.46
7	Temperature (X ₆) (Max)	9.14	6.42
8	Temperature (X ₇) (Min)	-1.63	5.15
9	Gross Irrigated Area (X ₈) (%)	1.92*	1.01
10	R ²	0.71	
11	F Value	7.91	
12	No. Of observations	25	

(***, ** and * significant at 1, 5 and 10 per cent, respectively.)

4.7 Returns to Investment in Agricultural Research

Estimated Value of Marginal Product

The TFP index was regressed on research and development investment per hectare of area and per year basis, which was a trend variable, with the goal of estimating Total Factor Productivity (TFP). If the estimated marginal product is greater than "1," it means that research on that commodity has produced enough output to justify investment. There is need to change the focus of research in such commodity or crops where marginal rate of return was less as compared to other commodity or crops to get higher returns from research investment. Research investment is a significant determinant in growth of TFP. With the help of elasticity of TFP with respect to research investment, the value of marginal product of research investment was estimated by using the following formula,

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

Where,

b = TFP Elasticity of Research Investment

V = Value of Production associated with TFP

R = Research Investment

Internal Rate of Return

The estimation of the returns to research investment indicates the direction of returns. It provides the justification to the previous funding and has presented a sound base for future funding, based on the level of returns of research investment. Research is an essential contributor to productivity growth. The results of the internal rate of return have clearly guided the future investments in agriculture will provide reasonable returns and will lead to agricultural development in the country. The internal rate of return can be calculated by using the following formula,

$$\text{IRR} = (\text{Lower discount rate}) + (\text{Difference between the two discount rates}) * (\text{Present Worth of cash flow at the lower discount rate} / \text{Absolute difference between the present worth of the cash flow at the two discount rates})$$

4.7.1 Returns to Investment in Acid Lime

Table 4.27 shows the estimated value of the marginal product research investment on acid lime. The findings found that a one-rupee investment in acid lime research yielded an additional income of Rs 17.49, demonstrating that Maharashtra has very high rates of return on public investment.

Table 4.27. Estimated Value of Marginal Product of Acid Lime

Sr. No.	Year	Output Associated with TFP (₹/ ha)	Research Cost (₹/ ha)
1	1995-96	16180.17	1915.850035
2	1996-97	16749.66	1440.608853
3	1997-98	18819.84	978.850869
4	1998-99	19686.02	844.835237
5	1999-00	19627.14	563.067226
6	2000-01	19845.44	470.243553
7	2001-02	20501.49	589.677966
8	2002-03	21333.50	316.070324
9	2003-04	21902.97	437.352129
10	2004-05	22791.86	353.950535
11	2005-06	24720.02	144.649146
12	2006-07	26724.34	84.878106
13	2007-08	29759.85	95.073773
14	2008-09	34564.28	137.452184
15	2009-10	38404.76	116.367788

Table 4.27 contd....

Sr. No.	Year	Output Associated with TFP (₹/ha)	Research Cost (₹/ha)
16	2010-11	41835.25	155.232113
17	2011-12	46483.61	108.289749
18	2012-13	52583.27	158.772328
19	2013-14	56299.00	92.183919
20	2014-15	58890.17	149.121167
21	2015-16	61471.99	107.897598
22	2016-17	62854.80	127.137990
23	2017-18	64203.06	154.858380
24	2018-19	66994.50	145.275448
25	2019-20	69785.94	84.090487
Total		933012.94	9771.786903
Mean		37320.52	390.871476

Estimated value of Marginal Return of Acid Lime Research Unit

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

Where,

b = TFP Elasticity of Research Investment

V = Value of Production associated with TFP

R = Research Investment

$$EVMP(R) = 0.183 \cdot (37320.52 / 390.87) \\ = 17.49$$

An extra one rupee invested in acid lime research yields an additional income of Rs 17.49.

Acid Lime Research Expenditure Flexibility

The inverse of TFP elasticity with respect to research gives flexibility to research expenditure

$$\begin{aligned}
 \text{Research Expenditure Flexibility} &= 1/b_i \text{ (Research Elasticity)} \\
 &= 1/0.183 \\
 &= 5.46
 \end{aligned}$$

The estimated value was 5.46, implying that investments in acid lime research would need to be raised by 5.46 per cent to obtain a 1 per cent improvement in TFP.

Internal Rate of Returns for Acid Lime

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)

$$\begin{aligned}
 \text{IRR} &= 28+8*(14693.57/22923.37) \\
 &= 28+8*0.64 \\
 &= 28+5.12
 \end{aligned}$$

$$\text{IRR} = 33.12$$

Internal Rate of Return (IRR) to investment in acid lime research estimated to be 33.12 per cent.

The Internal Rate of Return (IRR) for acid lime research during the period 1995-96 to 2019-20 was 33.12 per cent. The investment made on in acid lime research is generating rate of returns by 33.12 per cent annually. The Internal Rate of Return (IRR) was greater than the borrowing rate. Hence, the investment in Acid Lime research found economical viable.

4.7.2 Returns to Investment in Sweet Orange Research

Table 4.28 shows the estimated value of marginal product of research investment on sweet orange. The findings found that a one-rupee investment in sweet orange research yielded an additional income of Rs 23.56, demonstrating that Maharashtra has exceptionally high rates of return on public investment.

Table 4.28. Estimated Value of Marginal Product of Sweet Orange

Sr. No.	Year	Output Associated with TFP	Research cost / ha
4	1995-96	17668.70	452.6068851
5	1996-97	19437.51	410.3706642
6	1997-98	20121.65	380.0860695
7	1998-99	22608.59	235.5214163
8	1999-00	23649.15	248.1926066
9	2000-01	23578.42	277.7902639
10	2001-02	23840.67	226.5499848
11	2002-03	24628.79	254.9040631
12	2003-04	25628.29	225.759175
13	2004-05	26312.41	95.07189454
14	2005-06	27380.24	103.8787093
15	2006-07	29696.58	98.06475362
16	2007-08	32104.41	103.7076201
17	2008-09	35751.01	96.98106094
18	2009-10	41522.66	85.62006218
19	2010-11	46136.29	94.97732097
20	2011-12	50257.39	79.80476765
21	2012-13	55841.55	99.02380072
22	2013-14	63169.17	77.79213344
23	2014-15	67632.95	78.13819662
24	2015-16	70745.76	66.01069958
25	2016-17	73847.35	72.72808352
26	2017-18	75508.54	74.4381933
27	2018-19	77128.23	89.18710938
28	2019-20	83835.03	82.03731413
Total		1058031.31	4109.242848
Mean		42321.25	164.3697139

Estimated value of Marginal Return of Sweet Orange Research Unit

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

Where,

b = TFP Elasticity of Research Investment

V = Value of Production associated with TFP

R = Research Investment

$$\begin{aligned} \text{EVMP(R)} &= 0.091448 * (42321.25 / 164.20) \\ &= 23.56 \end{aligned}$$

An additional one rupee invested in sweet orange research yields Rs 23.56 in additional income.

Sweet Orange Research Expenditure Flexibility

The inverse of TFP elasticity with respect to research gives flexibility to research expenditure

$$\begin{aligned} \text{Research Expenditure Flexibility} &= 1/b_i \text{ (Research Elasticity)} \\ &= 1/0.091448 \\ &= 10.93 \end{aligned}$$

The estimated value was 10.93, implying that investments in sweet orange research would need to increase by 10.93 per cent to obtain a 1 per cent increase in TFP.

Internal Rate of Returns for Sweet Orange

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)

$$\begin{aligned} \text{IRR} &= 40 + 5 * (30469256 / 30487468) \\ &= 40 + 5 * 0.99 \\ &= 44.99 \end{aligned}$$

The Internal Rate of Return (IRR) to investment in sweet orange research estimated to be 44.99 per cent.

The Internal Rate of Return (IRR) for sweet orange research during the period 1995-96 to 2019-20 was 44.99 per cent. The investment made on in sweet orange research was generating rate of returns by 44.99 per cent annually. Thus, the Internal Rate of Return (IRR) was greater than the borrowing rate indicating that the investment in sweet orange was found economical viable.

4.8 Economic Impact of University Released Acid Lime and Sweet Orange Varieties

The production of food grains expanded dramatically in Maharashtra following the green revolution. A large number of new agricultural technologies, practices, and innovations developed and released for the benefit of state farmers to

enable them to produce sufficient quantities and quality of agricultural produce while also ensuring remunerative returns for the betterment of farmers' socioeconomic lives. Economists are frequently tasked to determining the economic impact of new technologies in SAU/ICAR context. The discipline of economics provides the reasoning and methods for calculating the impacts of research, taking into account both tangible and intangible advantages. The present study for impact assessment of improved varieties, two improved varieties of acid lime and two improved varieties of sweet orange released by the AICRP (All India Coordinated Research Project) on fruits of Mahatma Phule Krishi Vidyapeeth, Rahuri selected purposively.

4.8.1 Economic impact of University Released Acid Lime varieties

The area under acid lime fruit crop varied from variety to variety. The improved varieties of acid lime were released by All India Coordinated Research Project (AICRP) on Fruits, Mahatma Phule Krishi Vidyapeeth, Rahuri *i.e.* Sai Sharbati (1994) and Phule Sharbati (2008) together contributed 37.43 per cent area to the total varietal area of improved varieties of acid lime during 2019-20. Appendix I contains thorough information on the estimation of area under university-released Acid Lime variants. Therefore, it was determined to assessed the economic impact of acid lime improved varieties *i.e.* Sai Sharbati and Phule Sharbati together. The partial budgeting technique was used to estimate the economic impact of acid lime variations. This technique is appropriate tool to assess the costs and benefits associated with a partial change on farm. Partial budgeting is a way for directing or guiding a farm business's planning and decision-making framework, which is used to analyze the costs and benefits of opportunities faced by a farm business. There are four aspect of partial budgeting *i.e.* addition of costs, addition to returns, reduction in returns and reduction in costs. Added costs in acid lime production process because of new variety considered *i.e.* Sai Sharbati and Phule Sharbati. It added the list of expenditures because of new variety over the alternative (counterfactual) variety. Alternative or counterfactual variety of acid lime was Kagzi Lime (local).

Another component is the added income or added returns may be received when the proposed changes or modification is the addition of a new variety over the counterfactual or check variety. Third component is the reduced costs is noticed when the

proposed changes or modification may reduce the cost of production process due to the fewer resources required. The fourth component of the partial budgeting method is reduced returns or reduced incomes due to the addition of new variety over the counterfactual variety. The summary, which is indicated by the difference between debit and credit, is the final phase in partial budgeting technique. Table 4.29 shows the economic impact of university released acid lime varieties *i.e.* Sai Sharbati and Phule Sharbati.

Table 4.29. Economic Impact of University Released Acid Lime Varieties (Sai Sharbati and Phule Sharbati)

Debit Side	Cost (₹/Ha)	Credit Side	Cost (₹/Ha)
Particulars		Particulars	
A. Items of Added Expenditure due to cultivation of Sai Shabati and Phule Sharbati improved Acid Lime Varieties		C. Items of Reduced Expenditure or Costs due to cultivation of Sai Sharbati and Phule Sharbati improved varieties of Acid Lime	
1. Human Labour	8134.05	Machine Labour	772.94
2. Manure	5587.48	Irrigation	422.62
3. Chemical Fertilizers	5924.40	Plant Protection	4955.09
4. Biofertilisers	555.65	Total saving returns due to cultivation of university released variety	6150.65
5. Weedicide	1083.73	Additional Yield from Sai Sharbati and Phule Sharbati variety 59.74 qtl. @ Rs 1460.78/qtls.	87,266.99
Total additional cost	23596.06		
Opportunity cost of capital @ 6 per cent	1415.76		
Management cost @ 5 per cent	1179.80		
Risk Premium @ 5 per cent	1179.80		
Research Cost	224.09		
Extension cost	15.70		
B. Reduced returns due to cultivation of improved acid lime varieties	0		
Total debit side	27611.21	Total Credit Side	93417.64
Economic impact	65806.42		
Economic impact of university released acid lime varieties over counterfactual varieties of acid lime in Maharashtra: 93417.64 - 27611.21 = Rs 65806.42 for the year 2019-20.			

The data on cost of cultivation of university released acid lime varieties (Sai Sharbati and Phule Sharbati) and counterfactual variety (Kagzi Lime) was collected by survey method for the year 2019-20. Table 4.29 shows the debit and credit sides of the partial budgeting technique. From the table it reveals that the additional cost (direct and indirect) of university released varieties over the counterfactual variety was Rs 27611.21 per hectare. While, the savings and additional returns due to university released varieties over the counterfactual varieties were Rs 93417.64. Thus, in the state of Maharashtra, the total economic worthiness of university released acid lime varieties *i.e.* Sai Sharbati and Phule Sharbati over the counterfactual variety was Rs 65806.42.

4.8.1.1 Upscaling the Economic Impact

The partial budgeting results are applicable to a larger area under university-released acid lime varieties, although linear extrapolation of the advantages of ` 65806.42 per ha is not justified due to the law of diminishing marginal returns in agriculture at an early stage. As a result, three factors are used in linear extrapolation to depict the operation of the Law of Diminishing Marginal Returns (LDMR): i) Probability performance of the technology, ii) Rate of adoption of acid lime varieties, and iii) Depreciation in the technology.

Table 4.30. Up scaling the economic impact of acid lime covering the area of adoption

Sr. No.	Economic impact of University Released Acid Lime Varieties	Value
1.	Probability performance of acid lime varieties	0.72
2.	Rate of adoption of acid lime varieties	0.75
3.	Depreciation of technologies (if, 1 no depreciation)	1
4.	Economic Worthiness of University Released Variety per ha (in ₹)	65806.42
5.	Economic impact of university released variety per ha (in ₹)	35535.47
6.	Area adopted university released varieties in 2019-20	17285.38
7.	Economic impact for the year 2019-20 (in ₹)	614244118
8.	Economic impact for the year 2019-20 (in Crore)	61.42

This completely captures the operation of the LDMR since the field conditions are not akin to the lab conditions and the farmer is different from the

researcher. Table 4.30 presenting the upscaling the economic impact of acid lime varieties. Therefore, the ultimate economic impact of acid lime research per hectare works out $65806.42 \times 0.72 \times 0.75 \times 1 = \text{` } 35535.47$. For the 2019-20 season, the university released improved varieties of acid lime i.e. Sai Sharbati and Phule Sharbati varieties spread over the 17285.38 ha of land. For the fiscal year 2019-20, the total economic impact on Maharashtra's farming community was 61.42 crores.

4.8.1.2 Total Economic Impact of Sai Sharbati and Phule Sharbati varieties of Acid Lime in Maharashtra

Table 4.31 shows the total economic impact of acid lime improved variants i.e. Sai Sharbati and Phule Sharbati from 1995-96 to 2019-20. For the year 2019-20, the gross and net gain from university released varieties over the counterfactual variety has been deflated by using the Consumer Price Index (CPI). According to the table, Sai Sharbati and Phule Sharbati had a gross and net economic impact of Rs 3822.21 and Rs 387.38 crores on the Maharashtra farming community over a 25-year period.

Table 4.31. Total Economic impact of Sai Sharbati and Phule Sharbati varieties of Acid Lime in Maharashtra during 1995-96 to 2019-20

Sr. No.	Year	Area (ha)	Gross Gain (₹)	Net Gain (₹)	Total gross economic impact (in Crores)	Total Net economic impact (in Crores)
1	1996-97	88.32	81291.93	8239.05	0.71	0.07
2	1997-98	187.82	84153.14	8529.03	1.58	0.16
3	1998-99	300.10	94554.09	9583.18	2.83	0.28
4	1999-00	397.63	98905.95	10024.25	4.93	0.39
5	2000-01	500.23	98610.12	9994.27	4.93	0.49
6	2001-02	895.60	99706.9	10105.43	8.92	0.90
7	2002-03	1416.02	103003	10439.49	14.58	1.47
8	2003-04	1941.95	107183.1	10863.16	20.81	2.10
9	2004-05	2532.74	110044.3	11153.14	27.87	2.82
10	2005-06	3149.59	114510.2	11605.76	36.06	3.65
11	2006-07	3770.83	124197.6	12587.59	46.83	4.74
12	2007-08	4412.54	134267.7	13608.21	59.24	6.00
13	2008-09	5107.08	149518.6	15153.91	76.36	7.73
14	2009-10	5907.25	173656.9	17600.36	102.58	10.39

Table 4.31 contd...

Sr. No.	Year	Area (ha)	Gross Gain (₹)	Net Gain (₹)	Total gross economic impact (in crores)	Total Net economic impact (in crores)
15	2010-11	6708.94	192952.1	19555.96	129.45	13.11
16	2011-12	7666.01	210187.4	21302.79	161.13	16.33
17	2012-13	8548.11	233541.6	23669.76	199.63	20.23
18	2013-14	9409.04	264187.3	26775.75	248.57	25.19
19	2014-15	10042.19	282855.8	28667.83	284.04	28.78
20	2015-16	11324.02	295874.3	29987.27	335.04	33.95
21	2016-17	14349.95	308845.5	31301.95	443.19	44.91
22	2017-18	15303.42	315793.3	32006.08	483.27	48.98
23	2018-19	16260.44	322567.2	32692.63	524.50	53.15
24	2019-20	17285.38	350616.5	35535.47	606.05	61.42
					3822.21	387.38

4.8.2 Economic impact of University Released sweet orange varieties

The varieties developed by All India Coordinated Research Project on Fruits, Mahatma Phule Krishi Vidyapeeth, Rahuri *i.e.* Nucellar (recommended by MPKV, Rahuri) and Phule Mosambi (2008) together contributed 44.40 per cent area to the total varietal area of improved varieties of sweet orange during 2019-20.

Therefore, it was determined to estimate the economic impact of improved sweet orange varieties *i.e.* Nucellar and Phule Mosambi. The partial budgeting technique was used to quantify the economic impact of sweet orange varieties. Katol Gold was a sweet orange variety that was alternative, counterfactual, or a check.

The data on cost of cultivation of university released sweet orange varieties (Nucellar and Phule Mosambi) and counterfactual varieties (Katol Gold) was collected by survey method for the year 2019-20. Debit and credit side of partial budgeting technique is presented in Table 4.32. From the table it reveals that the additional cost (direct and indirect) of university released Sweet Orange varieties over the counterfactual variety was Rs 22807.73 per ha. In comparison to the counterfactual varieties, the reduced cost or savings and added returns due to university released varieties was Rs 70474.11. Thus, the total economic worthiness of university released

sweet orange varieties *i.e.* Nucellar and Phule Mosambi over the counter factual variety (Katol Gold) in the state of Maharashtra was Rs 47667.08.

Table 4.32. Economic Impact of University Released Sweet Orange Varieties (Nucellar and Phule Mosambi)

Debit Side	Cost (₹/Ha)	Credit Side	Cost (₹/Ha)
Particulars		Particulars	
A. Items of Added Expenditure due to cultivation of Nucellar and Phule Mosambi improved sweet orange varieties		C. Items of Reduced Expenditure or Costs due to cultivation of Nucellar and Phule Mosambi improved varieties of sweet orange	
1. Human Labour	7895.20	Machine Labour	8.258
2. Bullock Labour	1492.34	Chemical fertilizer	6321.5
3. Manure	4487.01	Plant Protection	2109
4. Biofertiiser	1110.35		
5. Micro nutrient	3229.82		
6. Irrigation	502.04		
7. Weedicide	505.52	Total saving returns due to cultivation of university released variety	8438.75
		Additional Yield from Nucellar and Phule Mosambi variety 19.32 qtl. @ Rs 3210.94 / qtls.	62035.36
Total additional cost	19222.30		
Opportunity cost of capital @ 6 per cent	1153.33		
Management cost @ 5 per cent	961.11		
Risk Premium @ 5 per cent	961.11		
Research cost	482.03		
Extension cost	27.15		
B. Reduced returns due to cultivation of improved sweet orange varieties	0		
Total debit side	22807.03	Total credit side	70474.11
Economic impact of university released sweet orange varieties over counterfactual varieties of sweet orange in Maharashtra: 70474.11 – 22807.03 = Rs 47667.08 for the year 2019-20.			

4.8.2.1 Upscaling the economic impact

The partial budgeting results are applicable to a larger area under university released sweet orange varieties, although linear extrapolation of the advantage of Rs 47667.08 per ha is not justified because of the law of diminishing marginal returns in agriculture at an early stage in agriculture. As a result, three factors are used in linear extrapolation to depict the operation of the Law of Diminishing Marginal Returns (LDMR): i) Probability performance of the technology, ii) Rate of adoption of acid lime varieties, and iii) Depreciation in the technology.

This completely captures the operation of the LDMR since the field conditions are not akin to the lab conditions and the farmer is different from the researcher. Table 4.33 presenting the upscaling the economic impact of sweet orange varieties. Therefore, the ultimate economic impact of sweet orange research per hectare works out $47667.08 \times 0.78 \times 0.80 \times 1 = \text{Rs } 29744.25$. For the year 2019-2020, the university released improved varieties of sweet orange i.e. Nucellar and Phule Mosambi spread over the 31400.98 ha of land. For the fiscal year 2019-20, the total economic impact on Maharashtra's farming community was 93.39 crores.

Table 4.33. Upscaling the Economic Impact of Sweet Orange covering the area of adoption

Sr. No.	Economic impact of university released Sweet Orange Varieties	Value
1	Probability performance of sweet orange varieties	0.78
2	Rate of adoption sweet orange varieties	0.80
3	Depreciation of technologies (if, 1 no Depreciation)	1.00
4	Economic worthiness of university released variety per ha (in ₹)	47667.08
5	Economic impact of university released variety per ha (in ₹)	29744.25
6	Area adopted university released Sweet Orange in 2019-20	31400.98
7	Economic impact for the year 2019-20 (in ₹)	933998848
8	Economic impact for the year 2019-20 (in Crores)	93.39

4.8.2.2 Total Economic Impact of Nucellar and Phule Mosambi varieties of Sweet Orange in Maharashtra

Table 4.34 shows the total economic impact of sweet orange improved varieties i.e. Nucellar and Phule Mosambi from 1990-91 to 2019-20. For the year 2019-20, the gross and net gain university released varieties over the counterfactual variety has

been deflated by using the Consumer Price Index (CPI). According to the table, Nucellar and Phule Mosambi had a gross and net economic impact of Rs 6142.85 and 467.61 Crores on the Maharashtra farming community over a 30 years time period.

Table 4.34. Economic impact of Nucellar and Phule Mosambi varieties of Sweet Orange in Maharashtra during 1990-91 to 2019-20

Sr. No.	Year	Area	Gross Gain (₹)	Net Gain (₹)	Total Gross economic impact (in Crores)	Total Net Economic impact (in Crores)
1	1990-91	1089.314	44208.28	3365.26	4.81	0.36
2	1991-92	2357.61	54781.02	4170.09	12.91	0.98
3	1992-93	3817.76	62535.41	4760.37	23.87	1.81
4	1993-94	5397.37	64803.53	4933.03	34.97	2.66
5	1994-95	7179.68	73556.79	5599.35	52.81	4.02
6	1995-96	8985.53	82370.43	6270.27	74.01	5.63
7	1996-97	1089.31	90616.53	6897.99	9.87	0.75
8	1997-98	3085.56	93805.93	7140.78	28.94	2.20
9	1998-99	5339.65	105399.9	8023.34	56.27	4.28
10	1999-00	7723.41	110251	8392.62	85.15	6.48
11	2000-01	10347.43	109921.2	8367.52	113.74	8.65
12	2001-02	13016.35	111143.8	8460.58	144.66	11.01
13	2002-03	1089.32	114818	8740.27	12.50	0.95
14	2003-04	4029.56	119477.6	9094.98	48.14	3.66
15	2004-05	7155.46	122666.9	9337.76	87.77	6.68
16	2005-06	9357.26	127645.1	9716.71	119.44	9.09
17	2006-07	11783.28	138443.7	10538.73	163.13	12.41
18	2007-08	14300.3	169668.9	11393.22	214.03	16.29
19	2008-09	1089.32	166669.1	12687.33	18.15	1.38
20	2009-10	4267.41	193576.2	14735.58	82.60	6.28
21	2010-11	7644.28	215084.7	16372.87	164.41	12.51
22	2011-12	10424.64	234297	17835.37	244.24	18.59
23	2012-13	13427.53	260330	19817.07	349.55	26.60
24	2013-14	17670.74	294491	22417.50	520.38	39.61
25	2014-15	1089.32	315300.8	24001.61	34.34	2.61
26	2015-16	6669.85	329812.6	25106.29	219.98	16.74
27	2016-17	12651.29	344272	26206.98	435.54	33.15
28	2017-18	18857.35	352016.4	26796.50	663.80	50.53
29	2018-19	24903.62	359567.3	27371.30	895.45	68.16
30	2019-20	31400.98	390834	29744.25	1227.25	93.39
Total			5232365	398302.83	6142.85	467.61

5. SUMMARY AND CONCLUSIONS

Agriculture has a crucial part in the economic development of developing countries like India. Agricultural development is an intrinsic part of overall economic growth. At the time of independence agriculture was the main source of national income and occupation in India. In India, research has been the driving force behind agricultural development. During 19th Century; the first institutions were set up with the establishment of Department of Revenue, Agriculture and Commerce in the imperial and provincial Governments, along with bacteriological laboratory and five veterinary colleges. After that in 1905, the Imperial Agricultural Research Institutes (IARI) was established now it is known as Indian Agricultural Research Institutes (IARI) together with six agricultural colleges. Then many commodity committees were formed to develop commercial crops from 1921 to 1958. In 1965, the Indian Council of Agricultural Research (ICAR) was the major body in charge of coordinating and encouraging agricultural research in India. The ICAR currently manages the agricultural research and education system, which includes a number of institutes and a state agriculture university. ICAR offers funding and establishes a strong network for agricultural research. ICAR also oversees a significant number of AICRPs, which include scientists from both ICAR and SAU universities. Additionally, National Agricultural Research System (NARS) which is part of ICAR or SAU system *i.e.* there are non-agricultural universities and organizations that support or conduct agricultural research either directly or indirectly.

Estimating the contribution of agricultural innovations has proven to be a difficult task for economists and technology generators, especially when policymakers are looking for evidence on macro-level effects. The discipline of economics provides the reasoning and methods for estimating the impacts of research, taking into account both tangible and intangible advantages of research. The purpose of this study is to determine the economic impact of acid lime and sweet orange research in Maharashtra's farm economy in order to develop policies and design programmes for university researchers and the state to develop research strategies that benefit farmers. The following are the study's objectives:

1. To estimate the growth rates of area, production and productivity of citrus (acid lime and sweet orange) in India and Maharashtra.

2. To study the extent of investment in research and extension activities of citrus (acid lime and sweet orange) at the (AICRP on fruits) MPKV, Rahuri.
3. To assess the impact of university released variety on income of citrus grower in Maharashtra.
4. To quantify the contribution of investment on research and extension in Maharashtra.

Primary as well as secondary data have been used for accomplishing the objectives.

5.1 Summary of Findings

1. AICRP on Fruits, MPKV, Rahuri has released improved varieties of acid lime and sweet orange since its establishment. Acid lime varieties *viz.* Sai Sharbati and Phule Sharbati which were released in the year 1994 and 2008, respectively. While sweet orange varieties are Nucellar and Phule Mosambi have been released in the year 2008, respectively. The seedling of the improved varieties of acid lime and sweet orange were largely demanded by the acid lime and sweet orange growers in Maharashtra.
2. The area under acid lime varieties released by AICRP on fruits, MPKV, Rahuri was 37.43 per cent of the entire area under acid lime varieties in Maharashtra at the present time. Farmers preferred the Kagzi Lime (local) variety of acid lime the most 30.54 per cent, followed by Sai Sharbati 20.16 per cent, and Phule Sharbati 17.27 per cent.
3. The area under sweet orange varieties released by the AICRP on fruits, MPKV, Rahuri currently accounts for 44.40 per cent of Maharashtra's total area under sweet orange varieties. Farmers preferred Katol Gold 39.60 per cent followed by Nucellar 24.39 per cent and Phule Mosambi 20.01 per cent.
4. India ranks second in both area and production among the world's top acid lime producing countries, with contributions of 24.07 and 17.17 per cent, respectively. While India is ranked 10th in terms of productivity of acid lime fruit crop.
5. Maharashtra stands at second place both in terms of area and production of sweet orange fruit crop contributing 30.40 and 21.00 per cent, respectively. However, Maharashtra stands 6th in productivity of Sweet orange fruit crop in India.

Andhra Pradesh stands at first position in terms of area, production and productivity of Sweet orange in India.

6. In case of Sweet orange Maharashtra stands at 3rd and 6th place in terms of area and production of Acid lime in India contributing 9.52 and 7.96 per cent, respectively. While in terms of productivity Maharashtra stands at 8th position. Gujarat placed in first position in terms of area and production of Acid lime in India contributing 16.17 and 19.23 per cent, respectively.
7. Jalgaon district stands at first place in terms of area and production of acid lime contributing 28.9 and 47.92 per cent, respectively to the entire Maharashtra. Ahmednagar stands at second position regarding both area and production of acid lime contributing 22.72 and 18.58 per cent, respectively to the entire Maharashtra.
8. Aurangabad placed at first regarding both area and production of sweet orange contributing 38.89 and 46.19 per cent, respectively to the entire Maharashtra. While Jalna district placed at second position in terms of area and production of Sweet orange contributing 26.21 and 20.69 per cent, respectively to the entire area under Maharashtra. However, Nanded district stands 1st in productivity of sweet orange in Maharashtra.
9. The compound annual growth rates of area, production and productivity of acid lime during the overall period in India was increased positively and significantly at the rate of 4.76, 5.16 and 0.39 per cent, respectively.
10. The compound annual growth rate of area and production during the overall study period of sweet orange in India was increased positively and significantly at the rate of 6.1 and 7.29 per cent, respectively while productivity was increased but statistically non-significant.
11. Among the four regions of Maharashtra the production of acid lime in Vidarbha region was observed positive and significant only due to the improvement in Productivity.
12. At the overall period, among the four regions of Maharashtra, in Marathwada and Vidarbha region the growth rate of production was noticed positive and significant which was due to the area expansion. Similar results were found for the state of Maharashtra during the overall period of study.

13. The growth rates of production of acid lime during entire period of study (2006-07 to 2019-20) were positive and significant mainly due to expansion in area and improvement in productivity particularly in the districts *viz.* Nanded, Amaravati, Yavatmal, Nagpur and Gadchiroli. While growth rate of production was positive only due to area expansion for Jalgaon and Aurangabad district. In the districts of Osmanabad, Gondia and Buldhana growth rates of production was positive and significant only due to improvement in productivity. As a result, the acreage, production, and productivity of Acid lime have fluctuated over time in each district.
14. The production of sweet orange was found to be positive and significant in Wardha district during the study period, because of both expansion in area and productivity improvements. Only due to expansion in area the growth rate of production of sweet orange was found positive and significant in the districts Aurangabad, Nagpur and Akola. The productivity in Nagpur and Akola districts was found to be significant but negative. In this district, which includes Nasik, Osmanabad, and Satara, the growth rates of area, production, and productivity of sweet orange were found to be significant but negative. As a result, the acreage, production, and productivity of sweet oranges have fluctuated over time in all of the districts.
15. The area under acid lime is highly consistent and stable for the districts *viz.* Ahmednagar, Parbhani, Yavatmal, Wardha, Nagpur and Sindhudurg except the districts which are highly instable such as Jalgaon, Solapur, Satara, Jalna, Beed, Aurangabad, Washim, Amaravati, Bhandara, Gadchiroli, Chandrapur and Dhule. The area under acid lime crop was found to be more stable and consistent in Western Maharashtra, whereas the area and production under acid lime crop were found to be highly unstable in Vidarbha and Marathwada. Acid lime productivity was found to be more stable and consistent in Vidarbha and Western Maharashtra. While the acreage and production of acid lime fruit crop in Maharashtra were found to be highly unstable, productivity under acid lime fruit crop was found to be more steady.
16. The area under sweet orange fruit crop was highly consistent and stable for the Yavatmal district while medium level of stability was found in the districts like

Jalna, Latur, Nagpur and Wardha and other districts were found more unstable. Medium level of consistency and stability in production of sweet orange was found in Nagpur district and other districts were found highly instable. In terms of productivity stability was found in Akola and Washim district while medium level of consistency and stability was found in Osmanabad and Amravati districts and highly instability was found in other districts. In Marathwada region medium level of stability in area under sweet orange crop was observed while in terms of other region highly instability was observed. Highly instability in production of sweet orange was noted in Vidarbha, Marathwada and Western Maharashtra regions of Maharashtra. While medium level of stability and consistency was observed in productivity of sweet orange in Vidarbha, Marathwada and Western Maharashtra region. In terms of entire Maharashtra state medium level of stability and was observed in area, production and productivity of sweet orange.

17. For the study period 1994-95 to 2018-19, the Tornqvist Theil Index was used to estimate the input, output, and TFP indices of the acid lime fruit crop. TFP for Acid lime was lowest in the year 2004-05 i.e. 0.63, and highest in the year 2015-16 i.e. 2.25.
18. TFP expanded at a rate of 0.36 per cent per annum from 1994-95 to 2018-19. During the same time period, the input index fell by 0.1 per cent per annum, while the output index increased by 0.26 per cent per annum. Output index was higher than the input index reason behind this that the rate of increase in output prices was faster than the rate of increase in input prices.
19. The Acid lime fruit crop had a high TFP growth rate of 2.17 per cent per year throughout the period – I (1994-95 to 2005-06), which could be attributed to the adoption of university-released improved acid lime varieties such as Sai Sharbati and Phule Sharbati.
20. For the study period 1994-95 to 2018-19, the Tornqvist Theil Index was used to estimate the input, output, and TFP index of the Sweet orange fruit crop. The lowest total factor productivity of sweet orange was 0.86 in 2011-12 and the highest was 2.51 in 2013-14.
21. TFP rose at a rate of 1.15 per cent each year over the whole study period (1994-95 to 2018-19). The input and output index climbed at 0.13 and 1.28 per cent per

annum, respectively, during the same time. Because of the adoption of university released improved sweet orange cultivars, such as Nucellar and Phule Mosambi, TFP index of sweet orange recorded moderate growth rate.

22. Research investment (0.18) and cropping intensity (1.25) has contributed positively towards TFP enhancement in acid lime fruit crop. Balanced use of fertilizers (1.44) was considered as proxy have played significant role in increasing the TFP level. The variables like rural literacy (1.27), maximum temperature (10.50), minimum temperature (3.69) was positive but non-significant. The variables like rainfall (-0.001) and road density (-0.48) was found negative and non-significant contribution to TFP. The estimated R^2 value was 0.72, indicating that the components in the model explained 72 per cent of the variation in TFP.
23. TFP growth in sweet orange was aided by research investment (0.09) and total irrigated area (1.92). The nitrogen-to-phosphorous-nutrient ratio (0.97) was used as a proxy for fertilizer balance, and the coefficients are positive and significant. The positive and significant road density (0.94) was used as a proxy for infrastructure. The variables of rural literacy (%) and rainfall (mm) were found to be negative and non-significant. Both the maximum and minimum temperatures were determined to be positive and negative, respectively and both variables were found to be non-significant. The estimated R^2 value was 0.71, indicating that the independent variables in the model jointly explained 71 per cent of the variation in TFP.
24. The acid lime fruit crop's estimated value of marginal return was 17.49. The findings found that a one-rupee investment in acid lime research yielded an additional income of Rs 17.49, demonstrating that there are very high rates of returns to public investment in Maharashtra. The inverse of TFP elasticity in terms of research gives more flexibility in research expenditure. The estimated value was 5.46, implying that investments in acid lime research would need to be raised by 5.46 per cent to obtain a 1 per cent improvement in TFP.
25. The Internal Rate of Return (IRR) for acid lime research during the period 1995-96 to 2019-20 was 33.12 per cent. The IRR is greater than borrower rate which indicate the economic viability of the research project.

26. The sweet orange fruit crop's estimated value of marginal return was 23.56. It was discovered that a one-rupee investment in sweet orange research yielded an additional income of Rs 23.56, showing that Maharashtra has very high rates of return to public investment. The inverse of TFP elasticity in terms of research gives more flexibility in research spending. The estimated value was 10.93, implying that investments in sweet orange research would need to increase by 10.93 per cent to obtain a 1 per cent increase in TFP.
27. The Internal Rate of Return (IRR) for sweet orange research during the period 1995-96 to 2019-20 was 44.99 per cent. The investment made on in sweet orange research is generating rate of returns of 44.99 per cent annually.
28. The total additional cost (direct and indirect) of university released Acid lime varieties over counterfactual or check variety worked out to be Rs 27611.21 per ha. Whereas, the reduced costs or savings and added returns due to university released improved variety as compared to the counterfactual or competing variety was Rs 93417.64. For the year 2019-20, the total economic worthiness of university released acid lime varieties i.e. Sai Sharbati and Phule Sharbati as compared to the counterfactual variety in Maharashtra was Rs 65806.42.
29. After upscaling the economic worthiness of university released Acid lime varieties was worked to be 61.42 Crores for the year 2019-20.
30. For the 25 years, the university released improved varieties, namely Sai Sharbati and Phule Sharbati, to the farming community in Maharashtra, the gross and net economic impact was 3822.21 and 387.38 crores, respectively.
31. Over the counterfactual variety, the total additional cost (direct and indirect) of university released sweet orange varieties was Rs 22807.03 per ha. In comparison to the counterfactual varieties, the reduced cost or savings and added returns owing to university released variety was Rs 70474.11. In the state of Maharashtra, the total economic worthiness of university released sweet orange varieties i.e. Nucellarand Phule Mosambi over the counterfactual variety for the year 2019-20 was Rs 47667.08.
32. After upscaling the economic worthiness of university released sweet orange varieties was worked to be 93.39 Crores for the year 2019-20.

33. For the 30 years, the university released improved varieties, namely Nucellar and Phule Mosambi, to the farming community in Maharashtra, the gross and net economic impact was 6142.85 and 467.61 crores, respectively.

5.2 Conclusions

1. The growth rates of area, production and productivity of acid lime in India during entire period of study was found to be positive and significant. It denotes that the production of Acid lime was increased by both area expansion and improvement in productivity. Whereas, growth rates of area and production of Sweet orange during the study period was found positive and significant but productivity was found positive but not statistically significant. It means the production of Sweet orange was increased by area expansion and not due to the productivity improvement.
2. In Maharashtra the area and production of acid lime fruit crop was highly instable and more stability was found in case of productivity. Among the region of Maharashtra, in Western Maharashtra area under Acid lime was found more stable while high instability in area and production if Acid lime was observed in Vidarbha and Marathwada region.
3. Medium level of stability was noticed in area, production and productivity of Sweet orange fruit crop in Maharashtra state. Among the region of Maharashtra, medium level of stability was found in area under sweet orange fruit crop in Marathwada region. High instability was observed in case of production of Sweet orange in Vidarbha, Marathwada and Western Maharashtra. Medium level of stability was found in productivity of Sweet orange in Vidarbha, Marathwada and Western Maharashtra region.
4. During the study period (1994-95 to 2018-19), a stagnation in growth rate of TFP was detected under the Acid lime fruit crop.
5. Moderate growth rate of TFP was found under the Sweet orange fruit crop during the study period (1994-95 to 2018-19).
6. Research investment (0.18) and cropping intensity (1.25) has contributed positively towards TFP enhancement in Acid lime fruit crop.
7. TFP growth in Sweet orange was strongly influenced by research investment (0.09) and gross irrigated area (1.92).

8. Research investment (0.09) and gross irrigated area (1.92) significantly contributed to TFP growth in Sweet orange.
9. An additional one-rupee investment in Acid lime and Sweet orange research resulted in additional income of Rs 17.49 and Rs 23.56, respectively.
10. The Internal Rate of Return (IRR) for Acid lime and Sweet orange research during the period 1995-96 to 2019-20 was 33.12 per cent and 44.99 per cent, respectively. It indicates the economic viability of the research project.
11. The gross and net economic impact of the university released acid lime improved varieties i.e. Sai Sharbati and Phule Sharbati, on the Maharashtra farming community during a 25-year period was 3822.21 and 387.38 crores, respectively.
12. The gross and net economic impact of university released sweet orange varieties i.e. Nucellar and Phule Mosambi to the farming community in Maharashtra state for the 30 years was 6142.85 and 467.61 Crores, respectively.

5.3 Policy Implications

1. The acreage and production of acid lime in Maharashtra were highly unstable. In the instance of Sweet orange, there was a medium level of area, output, and productivity instability. As a result, the government must set aside substantial funds for public research in order to stabilize the area and production of the acid lime and sweet orange fruit crop.
2. The positive and moderate growth rate of TFP was observed under the Acid lime and Sweet orange fruit crop. It has serious implications for the long run performance of the horticulture sector. It requires more investment in Acid Lime and Sweet Orange Research. Return to research investment in acid lime and sweet orange was Rs 17.49 and Rs 23.56, respectively. The net economic impact of university released varieties of acid lime and sweet orange was 387.38 crore and 467.61 crore. Hence, future research investment should be increased in acid lime and sweet orange research. It requires more investment in Acid lime and sweet orange Research.
3. Non input factor such as research investment, GIA, Cropping Intensity, N to P ratio, road density, *etc.* in Acid lime and Sweet orange was major and important source of enhancement of total factor productivity. Hence, the non-input factor may be considered by policymakers and researchers while framing the policies of agricultural development.

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7. APPENDICES

Thesis Title: Impact Analysis of Investment on Research and Extension of University Released Citrus Varieties

Establishment of Citrus research unit:

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

1. Varieties developed since establishment of the research unit

Sr. No.	Variety	Year of release	Place
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

1. **Area covered under University released Citrus varieties since establishment of the research unit**

(Area in ha.)

Sr. No.	Year	Citrus varieties					
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

2. Variety wise sale of Citrus seedlings by University since establishment of the research unit

(No.)

Sr. No.	Year	Sale of Citrus seedlings					
							Other
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
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17							
18							
19							
20							
21							
22							
23							
24							
25							

Area under university released Acid Lime varieties during 1995-96 to 2019-20

Sr. No.	Year (1)	Private Nurseries (2)	University (3)	Government Nurseries (4)	KVK (5)	Sub total (6)	Private Nurseries (7)	University (8)	Government Nurseries (9)	KVK (10)	Sub Total (11)	Total (12)
1	1995	8200	0	0	0	8200	0	0	0	0	0	8200
2	1996	15100	0	0	0	15100	0	0	0	0	0	15100
3	1997	26250	0	0	0	26250	0	0	0	0	0	26250
4	1998	28300	320	1000	0	29620	0	0	0	0	0	29620
5	1999	17200	5530	3000	0	25730	0	0	0	0	0	25730
6	2000	15200	10768	1100	0	27068	0	0	0	0	0	27068
7	2001	90000	12200	2100	0	104300	0	0	0	0	0	104300
8	2002	90000	44739	2555	0	137294	0	0	0	0	0	137294
9	2003	85230	50000	3515	0	138745	0	0	0	0	0	138745
10	2004	78933	70000	6923	0	155856	0	0	0	0	0	155856
11	2005	82132	75348	5250	0	162730	0	0	0	0	0	162730
12	2006	95095	59733	9060	0	163888	0	0	0	0	0	163888
13	2007	90210	70000	9080	0	169290	0	0	0	0	0	169290
14	2008	99500	70201	6500	0	176201	0	5526	1500	0	7026	183227
15	2009	50410	80000	8122	0	138532	0	50000	22560	0	72560	211092
16	2010	55400	95652	7402	0	112356	20000	58835	20302	0	99137	211493
17	2011	40200	90000	5390	0	135590	22320	64576	30000	0	116896	252486
18	2012	32500	60121	3405	0	96026	21230	80450	35000	0	136680	232706
19	2013	5200	99200	4200	0	108600	10320	79200	29000	0	118520	227120
20	2014	54321	50000	2500	0	106821	10210	40000	10000	0	60210	167031
21	2015	55210	75000	7550	0	137760	40200	80200	80000	0	200400	338160
22	2016	70213	181236	7673	0	259122	80000	389147	70000	0	539147	798269
23	2017	23421	21401	13936	0	58758	100000	2777	90000	0	192777	251535
24	2018	28456	19785	9808	0	58049	95000	4421	95000	0	194421	252470
25	2019	44532	8611	7246	0	60389	120000	0	90000	0	210000	270389

contd....

Sr. No.	Year	5% total (13)	Grant Total (14)	Cumulative Total (15)	Area in Ha (16)	MH Area (17)	% To MH (18)
1	1995	410	8610	8610	31.083	6900	0.450
2	1996	755	15855	24465	88.321	8500	1.039
3	1997	1312.5	27562.5	52027.5	187.824	8500	2.209
4	1998	1481	31101	83128.5	300.102	8600	3.489
5	1999	1286.5	27016.5	110145	397.635	19300	2.060
6	2000	1353.4	28421.4	138566.4	500.239	7300	6.852
7	2001	5215	109515	248081.4	895.600	10000	8.956
8	2002	6864.7	144158.7	392240.1	1416.029	12900	10.976
9	2003	6937.25	145682.25	537922.35	1941.957	34000	5.711
10	2004	7792.8	163648.8	701571.15	2532.747	34000	7.449
11	2005	8136.5	170866.5	872437.65	3149.594	35700	8.822
12	2006	8194.4	172082.4	1044520.05	3770.830	36100	10.445
13	2007	8464.5	177754.5	1222274.55	4412.543	37300	11.829
14	2008	9161.35	192388.35	1414662.9	5107.086	37700	13.546
15	2009	10554.6	221646.6	1636309.5	5907.254	41500	14.234
16	2010	10574.65	222067.65	1858377.15	6708.942	43000	15.602
17	2011	12624.3	265110.3	2123487.45	7666.019	45000	17.035
18	2012	11635.3	244341.3	2367828.75	8548.118	45000	18.995
19	2013	11356	238476	2606304.75	9409.042	48157	19.538
20	2014	8351.55	175382.55	2781687.3	10042.192	20100	29.960
21	2015	16908	355068	3136755.3	11324.026	20080	36.390
22	2016	39913.45	838182.45	3974937.75	14349.955	23760	30.400
23	2017	12576.75	264111.75	4239049.5	15303.427	27270	26.120
24	2018	12623.5	265093.5	4504143	16260.444	29264	35.560
25	2019	13519.45	283908.45	4788051.45	17285.384	32970	32.420

Area under university released Sweet Orange varieties during 1995-96 to 2019-20

Sr. No.	Year (1)	Private Nurseries (2)	University (3)	Government Nurseries (4)	KVK (5)	Total 1 (6)	Private Nursery (7)	University (8)	Government Nurseries (9)	KVK (10)	Total 2 (11)	Grant Total (12)
1	1990	266740	0	35000	0	301740	0	0	0	0	0	301740
2	1991	300320	0	51000	0	351320	0	0	0	0	0	351320
3	1992	353962	0	50500	0	404462	0	0	0	0	0	404462
4	1993	392350	0	45200	0	437550	0	0	0	0	0	437550
5	1994	447301	0	46400	0	493701	0	0	0	0	0	493701
6	1995	446020	0	54200	0	500220	0	0	0	0	0	500220
7	1996	527936	0	57400	0	585336	0	0	0	0	0	585336
8	1997	509844	1665	41450	0	552959	0	0	0	0	0	552959
9	1998	570498	3645	50240	0	624383	0	0	0	0	0	624383
10	1999	598345	5607	56350	0	660302	0	0	0	0	0	660302
11	2000	687068	365	39420	0	726853	0	0	0	0	0	726853
12	2001	683823	4241	51200	0	739264	0	0	0	0	0	739264
13	2002	710816	6690	55500	0	773006	0	0	0	0	0	773006
14	2003	749060	6288	59100	0	814448	0	0	0	0	0	814448
15	2004	798392	12483	55000	0	865875	0	0	0	0	0	865875
16	2005	538913	9164	61820	0	609897	0	0	0	0	0	609897
17	2006	595980	8526	67500	0	672006	0	0	0	0	0	672006
18	2007	618669	22506	56040	0	697215	0	0	0	0	0	697215
19	2008	659113	16518	73408	0	749039	0	119	0	0	119	749158
20	2009	775138	34154	69320	0	878612	0	1720	0	0	1720	880332
21	2010	837461	46091	49496	0	933048	0	2344	0	0	2344	935392
22	2011	676220	32473	58600	0	767293	0	2866	0	0	2866	770159
23	2012	771110	16170	41820	0	829100	0	2700	0	0	2700	831800
24	2013	1098760	10195	61320	0	1170275	0	5093	0	0	5093	1175368
25	2014	1295667	5275	58632	0	1359574	0	3397	0	0	3397	1362971
26	2015	1449959	12141	73747	0	1535847	0	9958	0	0	9958	1545805
27	2016	1591877	4252	52635	0	1648764	0	8094	0	0	8094	1656858
28	2017	1625517	18086	67622	0	1711225	0	7855	0	0	7855	1719080
29	2018	1590432	11203	68825	300	1670760	0	4055	0	0	4055	1674815
30	2019	1709114	12110	78046	500	1799770	0	0	0	0	0	1799770

Contd...

Sr. No.	Year	Cumulative Total (13)	Area (Ha) (14)	MH Area (15)	% to MH (16)
1	1990	301740	1089.314	6900	15.787
2	1991	653060	2357.617	7000	33.680
3	1992	1057522	3817.769	8900	42.896
4	1993	1495072	5397.372	9300	58.036
5	1994	1988773	7179.686	10900	65.868
6	1995	2488993	8985.534	12600	71.313
7	1996	301741	1089.318	14100	7.725
8	1997	854700	3085.560	14900	20.708
9	1998	1479083	5339.650	15000	35.597
10	1999	2139385	7723.412	19900	38.811
11	2000	2866238	10347.430	32100	32.234
12	2001	3605502	13016.250	34500	37.728
13	2002	301742	1089.321	36900	12.120
14	2003	1116190	4029.567	81400	4.950
15	2004	1982065	7155.469	81400	8.790
16	2005	2591962	9357.264	91600	10.215
17	2006	3263968	11783.280	93600	12.588
18	2007	3961183	14300.300	98400	14.532
19	2008	301743	1089.325	99000	10.030
20	2009	1182075	4267.419	108100	13.210
21	2010	2117467	7644.285	107000	7.144
22	2011	2887626	10424.640	107000	9.742
23	2012	3719426	13427.530	99000	13.563
24	2013	4894794	17670.740	95000	18.600
25	2014	301744	1089.329	61800	11.760
26	2015	1847549	6669.852	54260	12.292
27	2016	3504407	12651.290	32330	39.131
28	2017	5223487	18857.350	55180	34.174
29	2018	6898302	24903.620	43755	56.916
30	2019	8698072	31400.980	49467.5	63.478

8. VITAE

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in
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कागदी लिंबू : फुले शरबती

Kaghzi lime : Phule Sharbati



● Salient Features ●

- Early Precocity : From 3rd year
- High yield potential : 52.19 t/ha/year
- More summer cropping : 25.42 %
- Rounded fruit with thin rind: 1.95 mm
- High juice content : 52.52 %
- Vigorous canopy volume: 86.50 m³
- Field tolerance to pests and disease, particularly to citrus canker

● ठळक वैशिष्ट्ये ●

- लवकर बहार : तिसऱ्या वर्षापासून उत्पादन सुरू
- जास्त उत्पादनक्षमता : ५२.१९ टन/हे./वर्ष
- जास्त उन्हाळी पिक : हस्तबहार २५.४२ टक्के
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- रसाचे जास्त प्रमाण : ५२.५२ टक्के
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All India Coordinated Research Project on Fruits
Department of Horticulture, MPKV, Rahuri

SIDDHI-3403189240

Plate 3. Salient features of the University Released Acid Lime Variety i.e. Phule Sharbati



मोसंबी : फुले मोसंबी

Sweet orange : Phule Mosambi



● Salient Features ●

- Vigorous plant growth : Canopy 27.03 m³
- High yield potential : 72.95 kg/plant & 20.12 t/ha/year
- High juice : 47.37 % with lower acidity- 0.40 % & high TSS - 9.66 °Brix
- Field tolerance to pests and diseases

● ठळक वैशिष्ट्ये ●

- झाडांची जोमदार वाढ : आकारमान २७.०३ घनमीटर
- अधिक उत्पादनक्षमता : ७२.९५ किलो/झाड व २०.१२ टन/हे./वर्षे
- रसाचे प्रमाण : ४७.३७ टक्के
- कमी आम्लता : ०.४० टक्के
- जास्त विद्राव्य घटक : ९.६६ अंश ब्रिक्स
- रोग आणि किडीस जादा सहनशील

अखिल भारतीय समन्वित फळपिके संशोधन प्रकल्प,
उद्यानविद्या विभाग, मफुकृवि, राहुरी
All India Coordinated Research Project on Fruits
Department of Horticulture, MPKV, Rahuri

SIDDHI-9403189240

Plate 4. Salient features of the University Released Sweet Orange Varieties i.e. Phule Mosambi



कागदी लिंबू : साई शरबती

Kaghzi lime : Sai Sharbati



● Salient Features ●

- Yield : 46.90 t/ha/year
- Fruit weight : 49.87 g
- Juice percent : 54.51 %
- Rind thickness : 1.52 mm
- Summer cropping : 24.47 %
- Seeds/fruit : 6.16
- Oval smooth fruits with thin rind and uniform size
- Tolerant to canker

● ठळक वैशिष्ट्ये ●

- जास्त उत्पादन : ४६.९० टन/हे./वर्षे
- फळाचे वजन : ४९.८७ ग्रॅम
- रसाचे जास्त प्रमाण : ५४.५१ टक्के
- फळे आकाराने लंब गोलाकार व : १.५२ मि.मी. पातळ सालीची
- उन्हाळी उत्पादन : २४.४७ टक्के
- कॅंकरसाठी सहनशील

अखिल भारतीय समन्वित फळपिके संशोधन प्रकल्प,
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All India Coordinated Research Project on Fruits
Department of Horticulture, MPKV, Rahuri

SIDDHI-2403189240

Plate 2. Salient features of the University Released Acid Lime Variety i.e. Sai Sharbati



Plate 1. All India Coordinated Research Project on Fruits, MPKV, Rahuri



Plate 5. Primary Data Collection of Cost of Cultivation of Acid Lime varieties



Plate 5a . Primary Data Collection of Cost of Cultivation of Acid Lime varieties

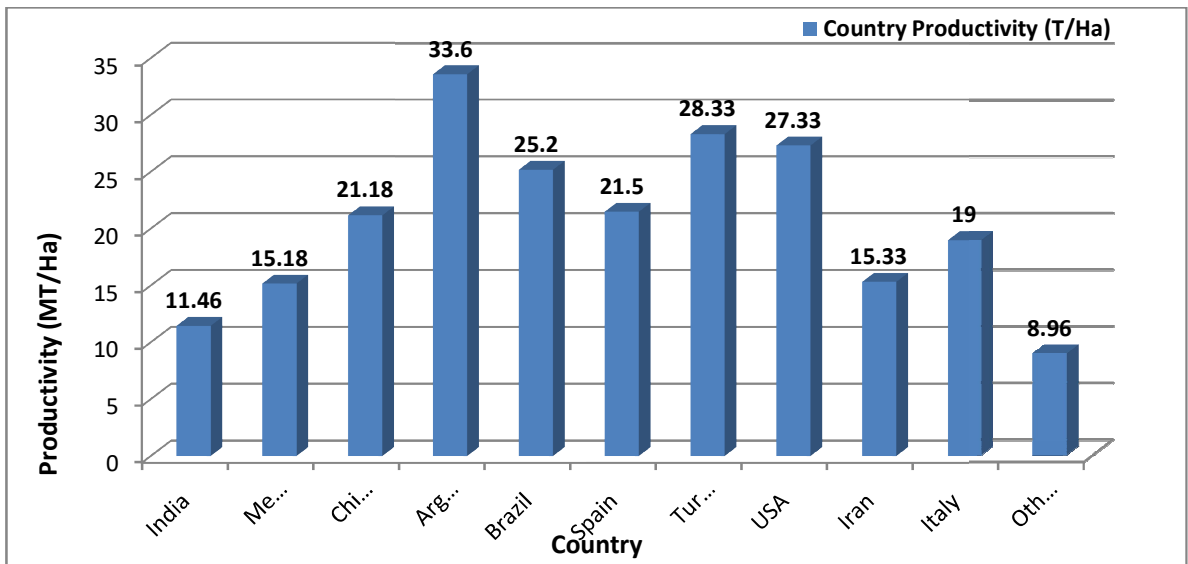
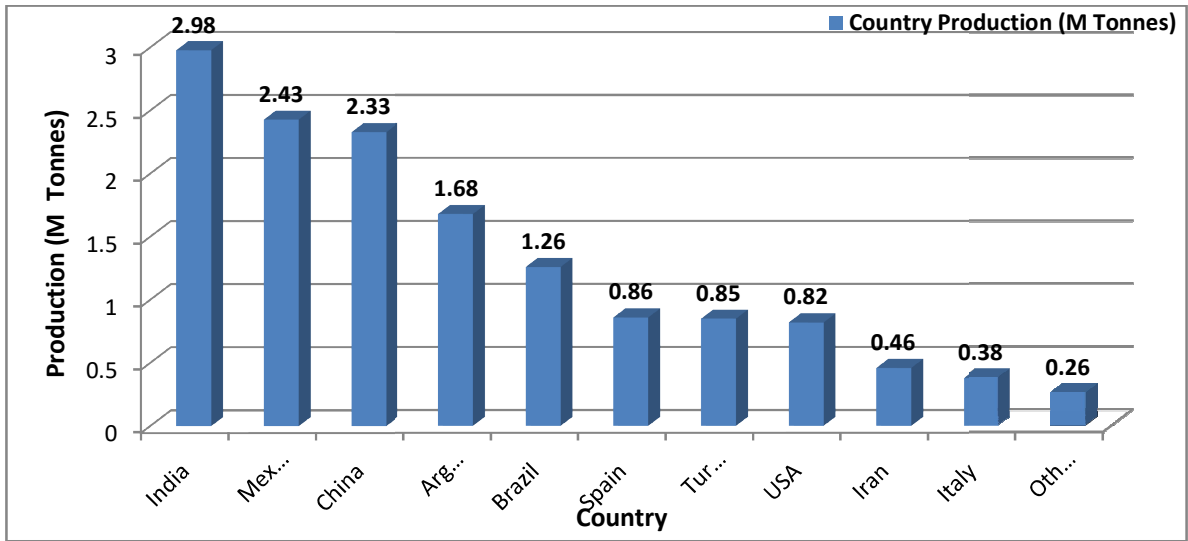
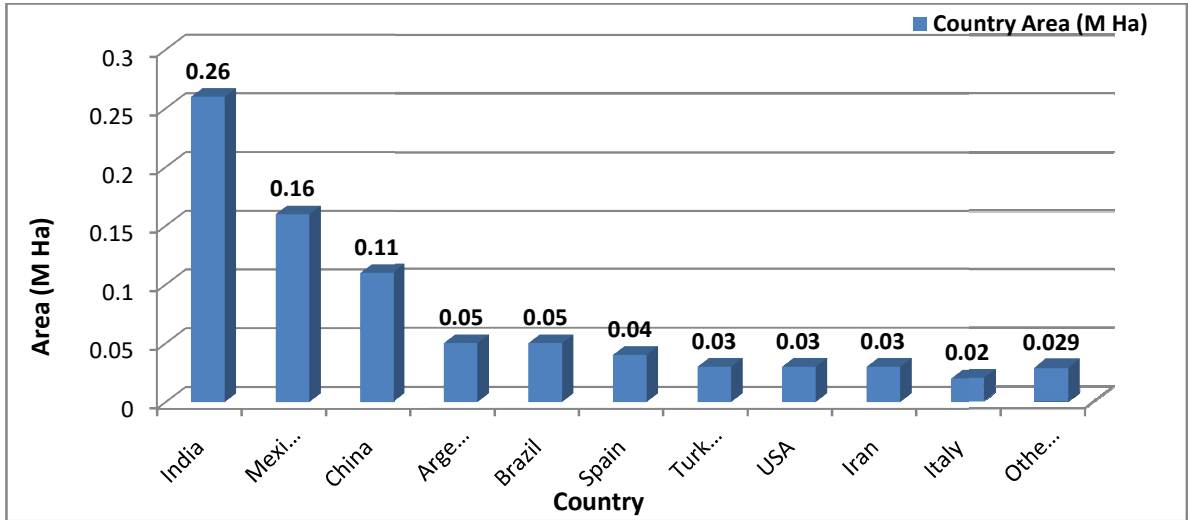


Fig 4.1: Major Acid Lime Producing Countries in the World (2016-17)

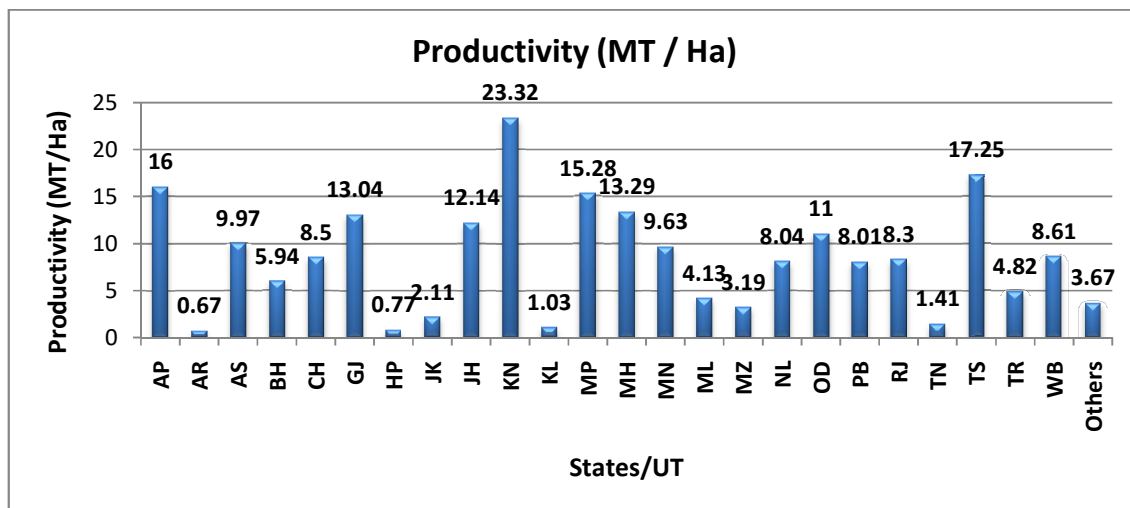
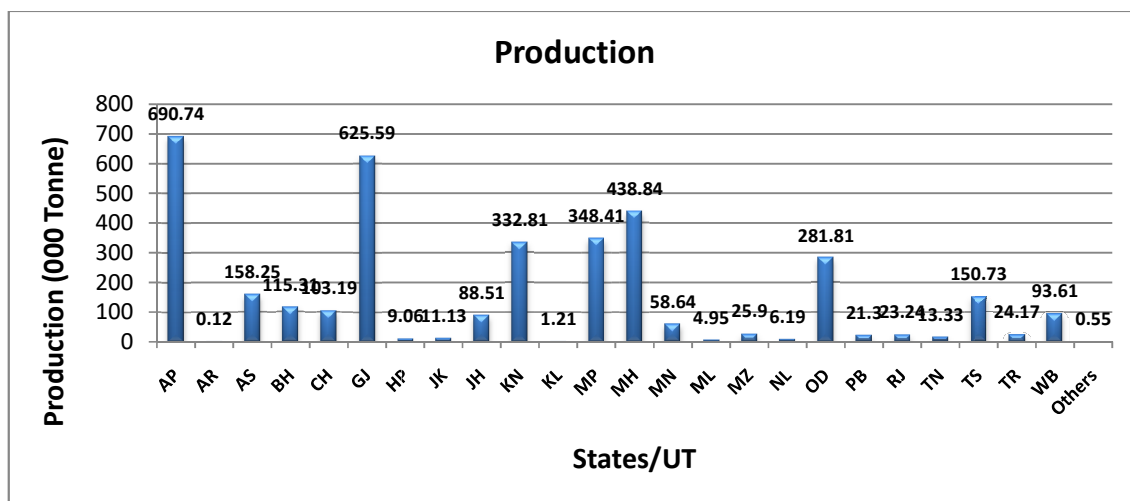
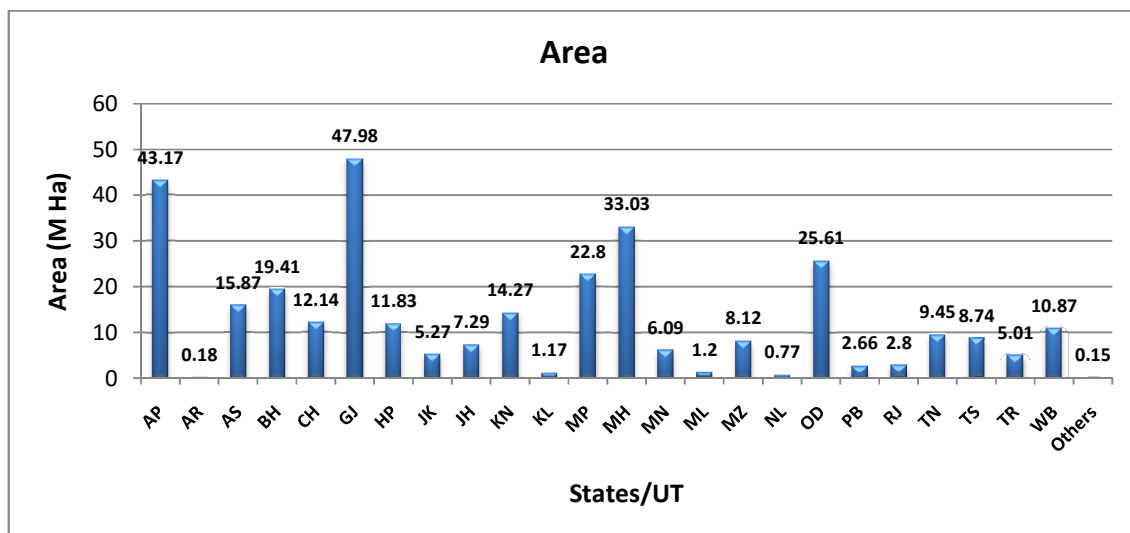


Fig 4.2: State wise Area, Production and Productivity of Acid Lime in India (2019-2020)

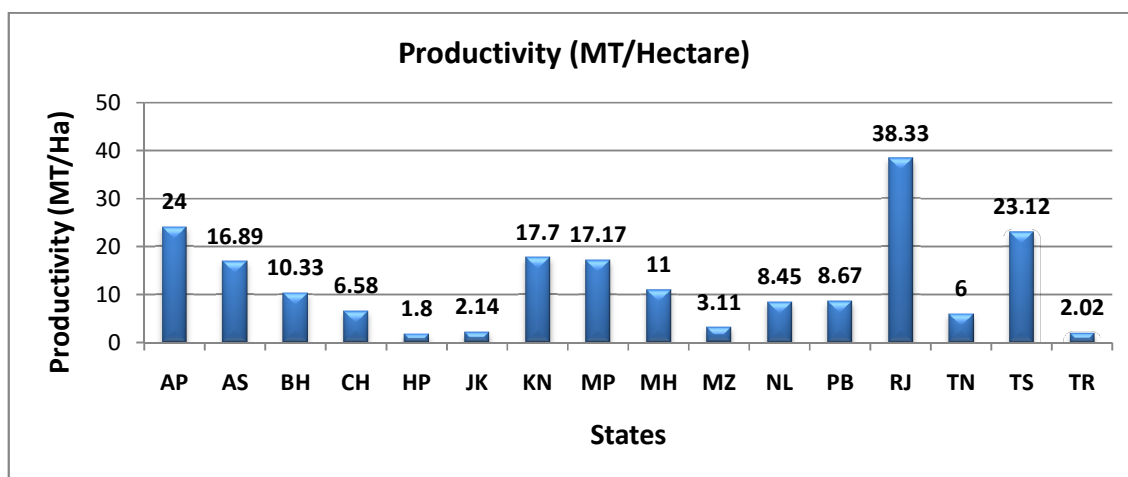
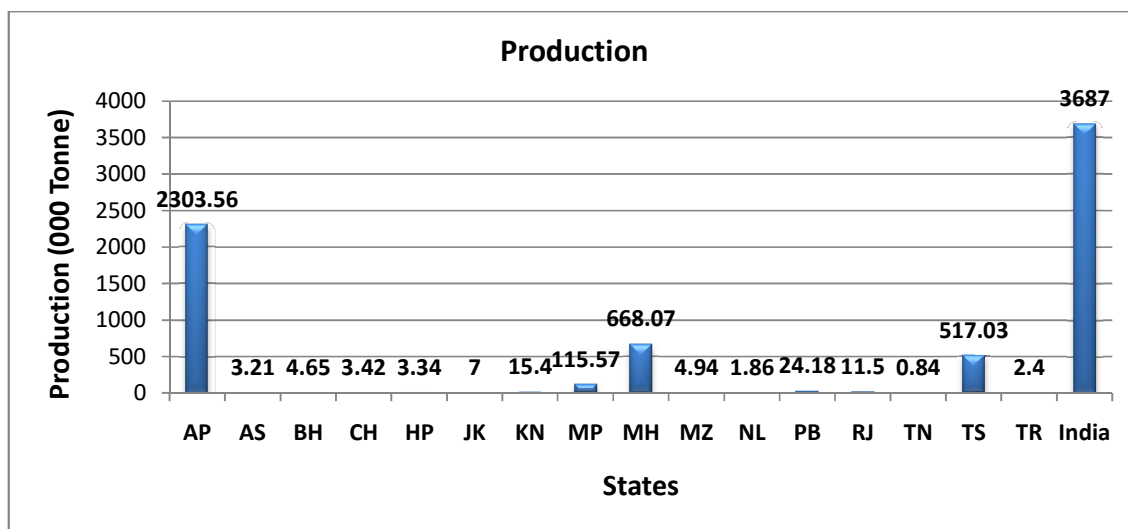
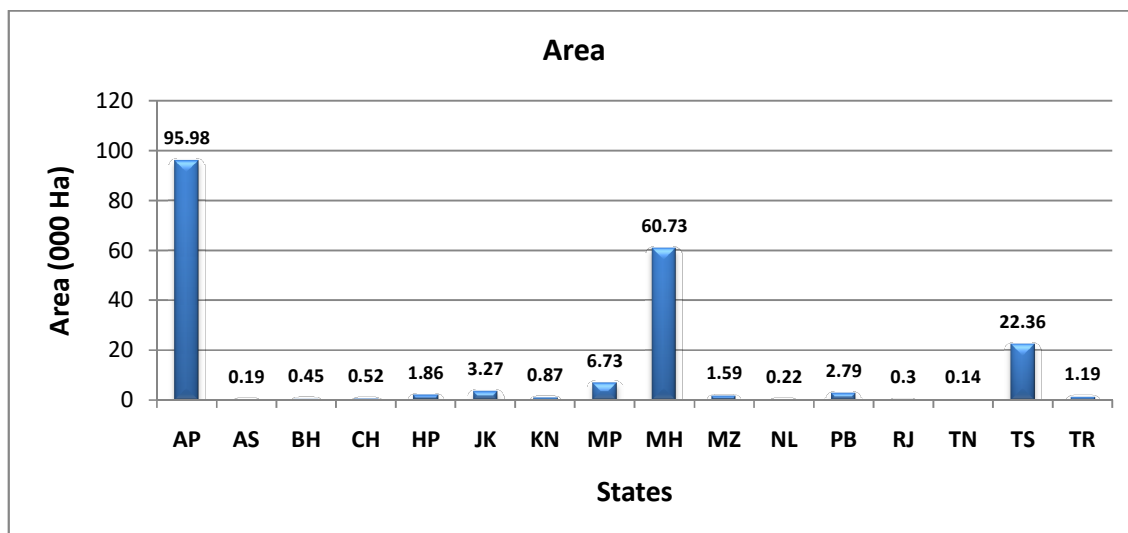


Fig 4.3: State wise Area, Production and Productivity of Sweet Orange in India (2019-2020)

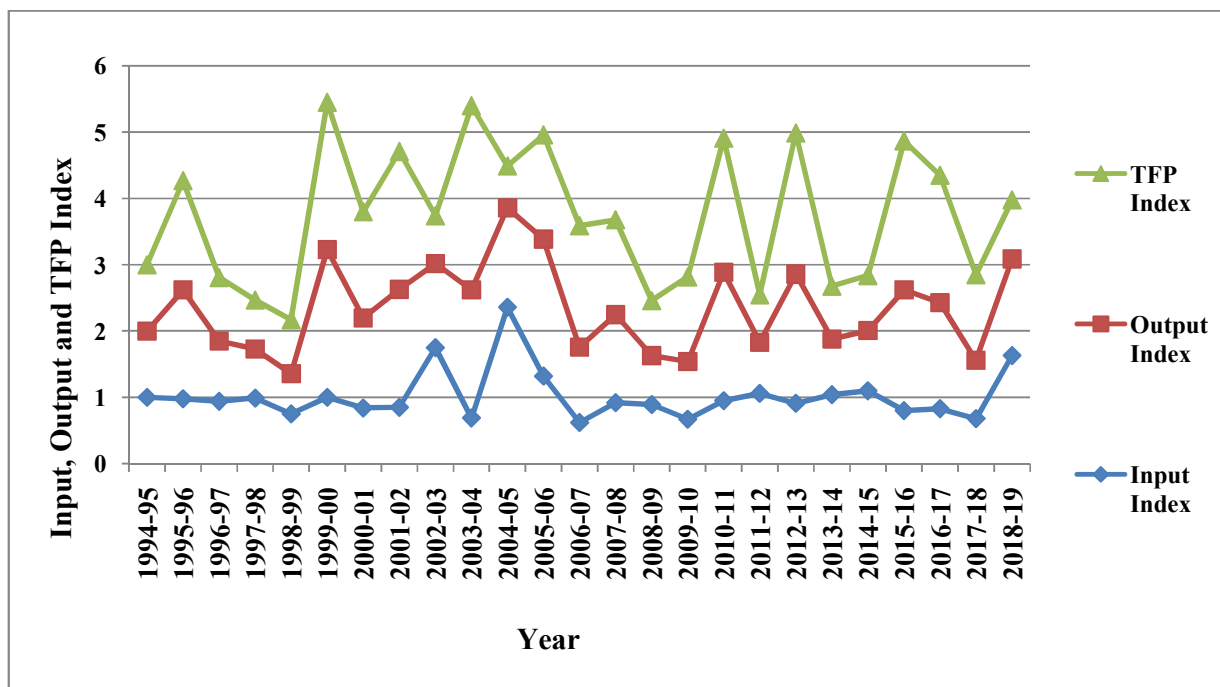


Fig 4.4: Input, Output and TFP Index of Acid Lime for the period 1994-95 to 2018-19

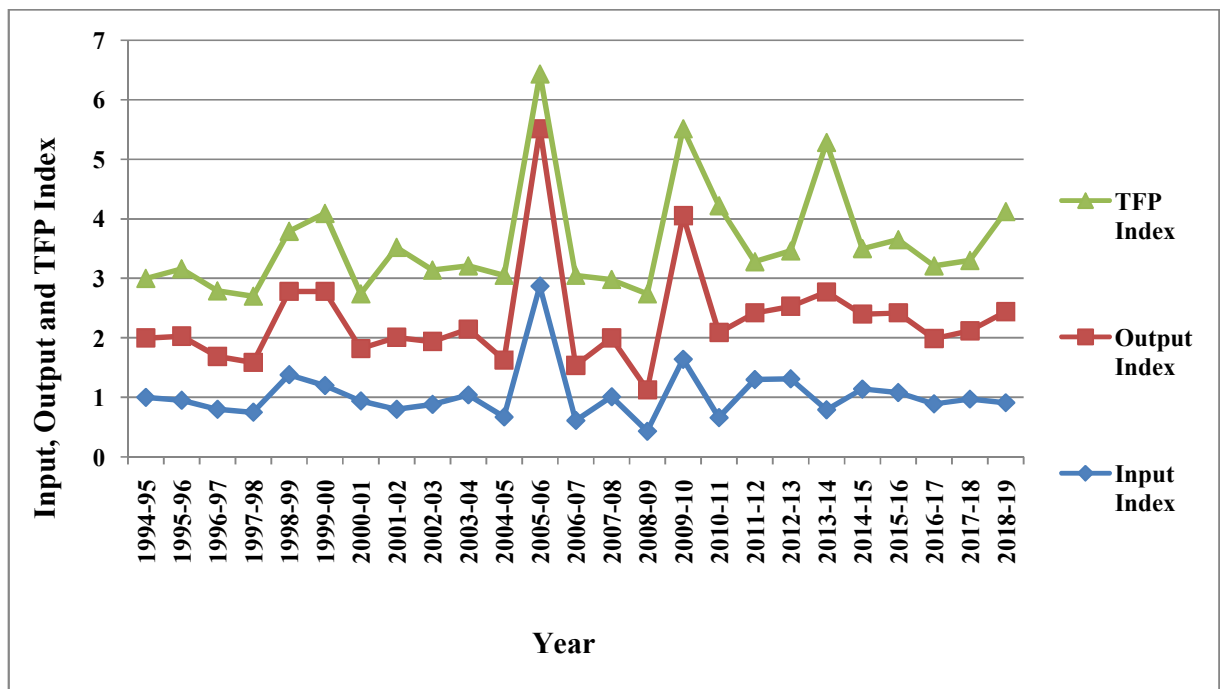


Fig 4.5: Input, Output and TFP Index of Sweet Orange for the period 1994-95 to 2018-19