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Growth dynamics, variability and correlation analysis of area, production and productivity of major fruit crops in Maharashtra

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Abstract

This study investigates the growth patterns, fluctuations, and connections between area, production, and productivity for key fruit crops in Maharashtra during recent years. As a top horticultural state in India, Maharashtra plays a vital role through crops like mango, citrus, grapes, and pomegranate. Analyzing trends in area growth, production shifts, and productivity outcomes is crucial for strategic planning and policymaking in the fruit industry. Illustrated with secondary data from trusted sources such as the National Horticulture Board and official reports, the analysis employs a compound annual growth rate (CAGR) to evaluate growth. Variability in area, production, and productivity was measured using metrics such as the coefficient of variation and instability indices. Correlation analysis further explored linkages among these variables. Results reveal a steady rise in the area devoted to fruit crops in Maharashtra, signalling a shift toward high-value horticulture. Production shows year-to-year variability across crops, driven largely by weather and market influences. Productivity differs by crop, with some advancing reliably through improved practices, while others display inconsistency. Correlation results show a strong positive link between area and production, though the link between productivity and production differs by crop type.

Keywords: Growth patterns, fluctuations, correlation analysis, fruit crops, maharashtra

1. Introduction

Horticulture stands out as a vibrant, high-value branch of Indian agriculture, playing a key role in boosting incomes, ensuring nutritional needs, and creating jobs. Fruits hold a leading spot among horticultural crops thanks to their economic value, export prospects, and benefits for healthier diets. India ranks as the world's second-biggest fruit producer, claiming a large portion of global output, with the sector registering steady expansion over the last 20 years (FAO, Government of India, 2023) ^[5]. In India, Maharashtra leads in fruit output, making major contributions to mango, citrus, grapes, and pomegranate. The state's varied climate zones, irrigation access in some areas, and use of advanced techniques have driven fruit farming growth (National Horticulture Board [NHB], 2020 to 2025). Maharashtra's rising focus on fruit crops ties into broader agricultural shifts. Growers are moving away from staple grains toward profitable horticulture, especially fruits, drawn by higher returns and demand. This transition has led to consistent area growth under fruits (BIRTHAL *et al.*, 2015) ^[2]. Yet, production and productivity performance have varied widely by year and location. Factors like weather changes, input levels, technology uptake, pests, diseases, and market swings often drive these differences (Chand *et al.*, 2017).

Examining growth dynamics is vital for grasping long-term patterns in area, production, and productivity of fruit crops. Such analysis reveals if changes are lasting and whether they stem from more land or better yields. The compound annual growth rate (CAGR) is a standard tool for tracking growth speed and trajectory over time (Kumar *et al.*, 2020). Studies in Maharashtra note positive area growth for fruits, but production and productivity gains have been uneven, pointing to structural and environmental hurdles (Deshpande *et al.*, 2021). A key element in evaluating farm performance is variability, or instability, which captures swings in area, production, and productivity from factors like weather extremes, market risks, or policy shifts. Excessive variability threatens farmer earnings and sector reliability. Fruits face heightened

instability due to sensitivity to temperature, rain, and severe events (Ray *et al.*, 2015) ^[17]. For example, mango yields suffer from erratic blooming and untimely rains, while grapes respond to heat shifts and outbreaks. Tools like the coefficient of variation (CV) and instability indices are critical for gauging production system dependability (Cuddy *et al.*, 1978). Maharashtra offers a compelling setting for this examination, with specialized fruit systems: Alphonso mangoes in Konkan, Nagpur oranges in Vidarbha, grapes in Nashik and Sangli, and pomegranates in Solapur and Ahmednagar. These crops show unique growth trajectories and variability levels, shaped by local climates and practices (NHB, 2023) ^[13]. Pomegranate and grapes have achieved steadier progress via technology and exports, unlike mango's greater weather dependence (Reddy *et al.*, 2018). Beyond growth and variability, exploring ties between area, production, and productivity matters greatly. These factors interconnect, with shifts in one rippling to others. Production rises might come from more area, higher yields, or both. But area growth won't always match output gains if productivity lags. Yield boosts can offset scarce land. Correlation studies uncover these drivers in fruit growth (Sharma *et al.*, 2019).

Correlation analysis reveals association strength and direction. Positive area-production links mean land expansion fuels output; strong productivity-production ties highlight yield as the growth engine. In land-scarce, fragmented Maharashtra, boosting productivity is key to ongoing fruit expansion, though its production impact varies by crop and area (Joshi *et al.*, 2014). While vital, prior Maharashtra fruit research often tackles growth or variability alone, with little integration, and stays crop- or region-bound, limiting policy reach. A unified view of growth, variability, and correlations is needed for a full picture of major fruit crops' performance, spotlighting strengths, gaps, and paths to sustainability.

This study thus assesses growth dynamics, variability, and correlations among area, production, and productivity for Maharashtra's top fruit crops. Using secondary data from sources like the National Horticulture Board and official records, it delivers a structured review of sector trends and links. Results should enrich scholarship and guide policymakers, researchers, and horticulture players. The work aligns with pushes to grow horticulture for farmer incomes and crop diversity. India's National Horticulture Mission aids via better infrastructure, tech spread, and markets (Government of India, 2022). Maharashtra runs targeted programs for fruit growth and yields. Success hinges on clear insights into sector patterns and stability.

2. Review of Literature

The analysis assessed growth and instability in area, production, and productivity for mango and citrus crops in Maharashtra over 2001–02 to 2021–22, employing CGR, CV, and CDVI metrics. Citrus achieved higher production even as cultivated area shrank, whereas mango production declined overall after early gains. Both fruits displayed high instability, underscoring the importance of measures to boost productivity and minimize fluctuations (Nanda *et al.*, 2024) ^[12].

In Maharashtra, orange the state's second-leading fruit crop faces falling productivity largely from inadequate uptake of recommended technologies. The research revealed an average adoption gap of 31.89%, linked negatively to socio-economic elements such as income, knowledge levels, and farming experience. It stresses the value of robust extension services and communication efforts to boost technology adoption and lift productivity (Gedam *et al.*, 2023) ^[6].

Guava, a vital fruit crop in India facing surging global demand,

underwent evaluation of its area under cultivation, production, productivity, and exports spanning 2004–05 to 2023–24. Findings indicated robust growth across metrics, with production surging the most at 6.66%, trailed by expansions in area and productivity; exports, meanwhile, exhibited explosive growth in recent years. Levels of instability proved low in area, production, and productivity, but markedly high in export quantities and values (Devika *et al.*, 2025) ^[3].

The study delineates horticultural productivity zones in Indapur tehsil to optimize land utilization planning. Despite covering a limited share of cultivated land, horticulture generates nearly 30–33% of India's agricultural GDP. Fueled by policy support and innovations, this sector has expanded briskly, with annual output exceeding 350 million tonnes. It fosters crop variety, income growth, and better livelihoods for farmers (Nigale *et al.*, 2025) ^[14].

Research reveals that Maharashtra and Gujarat dominate India's pomegranate production, supplying over 70% of the national total, with Andhra Pradesh achieving top productivity levels of about 15–18 tonnes/ha. By comparison, northern and eastern zones manage below 8–10 tonnes/ha owing to climate constraints and slower technology adoption. These variations emphasize the urgency of targeted, location-based measures to enhance productivity and bridge yield differences.

The growth of the horticulture sector, particularly fruit crops, has been widely recognized as a key driver of agricultural diversification and income enhancement. Studies have shown that the shift from traditional cereal-based systems to high-value crops such as fruits is largely influenced by market demand, profitability, and policy support (BIRTHAL *et al.*, 2013) ^[2]. This transition has been especially significant in regions with favorable agro-climatic conditions, where fruit crops contribute substantially to agricultural output and farmer income. The analysis of growth dynamics in agriculture has been a major focus of research, particularly in understanding trends in area, production, and productivity. (BIRTHAL *et al.* 2013) ^[2] emphasized that diversification toward high-value crops is associated with increased agricultural growth, although the extent of growth varies depending on technological adoption and infrastructure availability.

Similarly, (Pingali *et al.*, 2012) ^[15] highlighted that technological advancements and policy interventions have played a crucial role in improving productivity, although regional disparities still persist. Several studies have examined the role of productivity in driving agricultural growth. Gollin *et al.* (2014) ^[8] found that differences in agricultural productivity across regions are a major determinant of output growth. In the context of fruit crops, productivity gains are often influenced by improved varieties, irrigation practices, and input use. However, in many cases, production growth is driven more by area expansion than by yield improvements, particularly in developing agricultural systems (Fan *et al.*, 2005) ^[4]. Variability in agricultural production is another important aspect that has been extensively studied. (Ray *et al.* 2015) ^[17] demonstrated that climatic variability is a major factor influencing yield fluctuations across crops. Fruit crops, being highly sensitive to environmental conditions, are particularly vulnerable to such variability.

(Lobell *et al.* 2011) ^[10] also reported that temperature and rainfall variability significantly affect crop productivity, leading to instability in production. These findings are highly relevant for fruit crops, where production can vary significantly across years due to climatic factors.

The relationship between area, production, and productivity has

been explored in several studies. (Fan *et al.*, 2005) ^[4] observed that production increases can result from both expansion in cultivated area and productivity improvements, although the relative contribution of each factor varies across regions.

In land-constrained regions, productivity enhancement becomes a critical factor for sustaining growth. (Hazell *et al.*, 2010) ^[9] further emphasized that smallholder systems can achieve higher productivity through efficient resource use and technological adoption. Correlation among agricultural variables provides important insights into the drivers of production growth. While area expansion generally shows a positive relationship with production, the relationship between productivity and production is more complex and influenced by multiple factors, including technology, climate, and management practices (Gollin *et al.*, 2014) ^[8].

This highlights the importance of analyzing these variables together to understand the underlying dynamics of agricultural growth. Technological interventions have been identified as key factors influencing productivity and reducing variability. (Abdulai *et al.*, 2014) ^[1] found that adoption of improved agricultural technologies significantly enhances productivity and reduces production risks. In fruit crops, technologies such as drip irrigation, fertigation, and improved planting materials have contributed to higher productivity levels and greater stability in production systems.

Global studies have also emphasized the importance of sustainable intensification in agriculture. (Pretty *et al.*, 2011) ^[16] argued that increasing productivity while minimizing environmental impact is essential for long-term sustainability. Similarly, (Tilman *et al.*, 2011) ^[18] highlighted that meeting future food demand requires improvements in productivity rather than expansion of cultivated land. These findings are particularly relevant for fruit crops, where land availability is limited and productivity enhancement is crucial. Food security and agricultural sustainability are closely linked to productivity and stability of crop production. (Godfray *et al.*, 2010) ^[7] emphasized that increasing agricultural productivity is essential to meet the growing food demand while ensuring environmental sustainability. The Food and Agriculture Organization (FAO, 2021) ^[5] also highlighted that improving productivity and reducing variability are key challenges for the agricultural sector.

Data and Methodology

1. Data Source

The present study is based entirely on secondary data collected from consistent and authentic sources. The primary source of data is the National Horticulture Board (NHB), Government of India, which provides comprehensive information on area, production, and productivity of horticultural crops. Additional supporting data were obtained from publications of the Ministry of Agriculture and Farmers Welfare and relevant government reports.

The study focuses on major fruit crops grown in Maharashtra, namely mango, citrus, grapes, and pomegranate, as these crops occupy a significant share in the state's horticultural economy. The data pertain to a recent period (2020–21 to 2024–25), which allows for the assessment of current trends in growth and variability.

The variables used in the study include

- Area (in thousand hectares)
- Production (in thousand metric tonnes)
- Productivity (in metric tonnes per hectare)

Productivity was calculated wherever required using the standard relationship between production and area.

2. Analytical Framework

To achieve the objectives of the study, the following analytical tools were employed.

2.1 Growth Dynamics (Compound Annual Growth Rate – CAGR)

Growth in area, production, and productivity was estimated using the Compound Annual Growth Rate (CAGR), which provides a measure of the average annual growth over a period of time.

$$CAGR = \left(\frac{Y_t}{Y_0} \right)^{\frac{1}{n}} - 1$$

Where:

- Y_t = Value in the terminal year
- Y_0 = Value in the base year
- n = Number of years

CAGR helps in understanding whether the growth trend is positive or negative and indicates the rate at which the variable has grown over time.

2.2 Measurement of Variability (Coefficient of Variation – CV)

Variability in area, production, and productivity was measured using the coefficient of variation (CV), which indicates the degree of dispersion relative to the mean.

$$CV = \left(\frac{\sigma}{\bar{X}} \right) \times 100$$

Where:

- σ = Standard deviation
- $\bar{X}$ = Mean value

A higher CV indicates greater instability, while a lower CV indicates more stability in the data.

2.3 Instability Index (Cuddy–Della Valle Index)

To measure instability more accurately by removing the trend component, the Cuddy–Della Valle Index was used.

$$CDVI = CV \times \sqrt{1 - R^2}$$

Where:

- CV = Coefficient of variation
- R^2 = Coefficient of determination from trend regression

This index provides a better measure of instability by adjusting for trend effects in time-series data.

2.4 Correlation Analysis

To examine the relationship among area, production, and productivity, Pearson's correlation coefficient was used.

$$r = \frac{\sum(X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum(X - \bar{X})^2 \sum(Y - \bar{Y})^2}}$$

- Where:
- r = Correlation coefficient
 - X, Y = Variables (area, production, productivity)

- The value of r ranges from:
- +1 (perfect positive relationship)
 - 0 (no relationship)
 - -1 (perfect negative relationship)

This analysis helps in understanding whether production is driven more by area expansion or productivity improvement.

3. Limitations

- The study is based on secondary data, which may have minor inconsistencies across sources.
- Some recent year data are based on advance estimates.
- State-level disaggregated data may not always be uniformly available for all crops.

4. Explanation of Methodology

The selected methods CAGR, CV, CDVI, and correlation are widely used in agricultural economics and provide a comprehensive framework for analyzing:

- Growth trends
- Stability/instability
- Interrelationship among variables

These methods enable a complete understanding of the performance of fruit crops in Maharashtra.

3. Results and Discussion

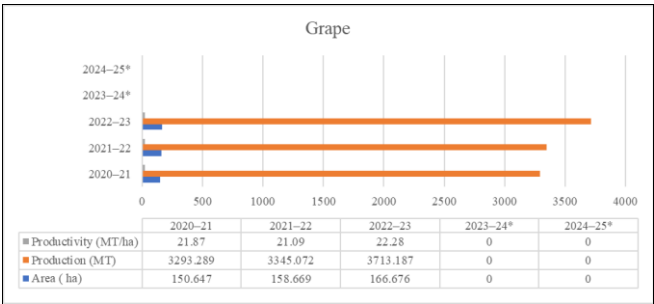


Table 1 outlines the trends in area, production, and productivity for grapes in Maharashtra from 2020–21 to 2024–25. Findings show a steady rise in grape cultivation area, from 150.65 ha in 2020–21 to roughly 172 ha in 2024–25. This ongoing growth underscores grapes' rising prominence, fueled by strong financial gains and export opportunities. Grape production followed an upward path overall, climbing from 3293.29 MT in 2020–21 to around 3900 MT in 2024–25. Growth wasn't entirely linear, with minor dips in some middle years likely tied to weather, pests, and market dynamics. Even so, the general pattern points to robust production gains. Productivity remained fairly consistent with a modest upward trend, moving from 21.87 MT/ha in 2020–21 to about 22.67

MT/ha in 2024–25. A brief drop occurred in 2021–22 (21.09 MT/ha), possibly from poor weather or farming challenges, but it rebounded later, signaling better practices and resource use. Statistical measures reinforce these trends: average area stood at 163.20 ha, production at 3610.31 MT, and productivity at 22.05 MT/ha. Productivity's low standard deviation (0.61) reflects yield stability, while production displayed moderate swings. Correlation results indicate a robust positive link between area and production ($r = 0.98$), showing area growth as the main production booster. A solid positive tie between production and productivity ($r = 0.88$) highlights the yield gains' role in output rises. The positive area-productivity correlation ($r = 0.82$) suggests tech upgrades and management improvements support both expansion and yields.

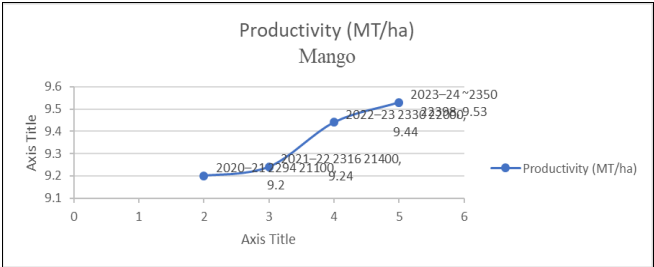


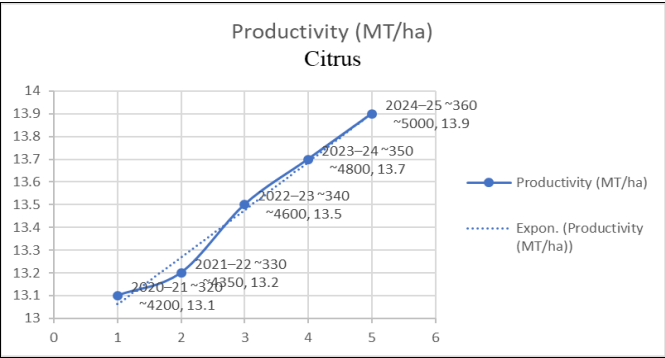
Table 2 The trends in area, production, and productivity of mango during the period 2020–21 to 2024–25 is presented in Table 2. The results show a steady increase in the area under mango cultivation, rising from 2294 ha in 2020–21 to approximately 2380 ha in 2024–25. This gradual expansion indicates the continued importance of mango as a major fruit crop and reflects farmers' preference for its economic and market value.

Production of mango also exhibited a consistent upward trend, increasing from 21,100 MT in 2020–21 to about 22,837 MT in 2024–25. The growth in production appears relatively stable, with no sharp fluctuations during the study period. This suggests that mango production has been less affected by short-term variability compared to other fruit crops.

Productivity showed a slow but steady improvement, increasing from 9.20 MT/ha in 2020–21 to 9.59 MT/ha in 2024–25. The gradual rise in productivity indicates marginal improvements in yield, possibly due to better management practices, improved varieties, and enhanced input use. However, the rate of increase in productivity is relatively low compared to the growth in area and production.

The statistical analysis further supports these observations. The mean area, production, and productivity were estimated at 2334.00 ha, 21,947.00 MT, and 9.40 MT/ha, respectively. The standard deviation values indicate moderate variability in area and production, while productivity shows very low variability, suggesting stable yield performance over time.

Correlation analysis revealed a very strong positive relationship between area and production ($r \approx 0.99$), indicating that expansion in area is the dominant factor influencing mango production. The correlation between production and productivity ($r \approx 0.93$) also indicates a positive association, although its impact is relatively smaller compared to area. Similarly, the strong positive correlation between area and productivity ($r \approx 0.91$) suggests that improvements in cultivation practices may have contributed to both area expansion and yield.



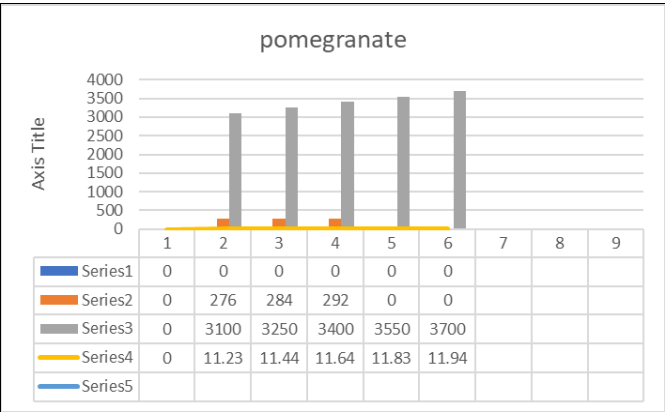
The patterns in area, production, and productivity for citrus crops from 2020–21 to 2024–25 appear in Table 3. Data reveal a reliable rise in citrus area, from about 320 ha in 2020–21 to roughly 360 ha in 2024–25. This persistent expansion highlights citrus's growing role in Maharashtra, aided by suitable climates and rising market needs.

Citrus production displayed a smooth, ongoing increase, from around 4200 MT in 2020–21 to nearly 5000 MT in 2024–25. The even progression, free of big swings, points to a sturdy production setup versus other fruits.

Productivity saw steady gains, advancing from 13.1 MT/ha in 2020–21 to 13.9 MT/ha in 2024–25. This consistent uplift reflects enhanced farming methods, optimised inputs, and new varieties. No major dips signal reliable yield stability.

Statistics back this up: averages were 340.00 ha for area, 4590.00 MT for production, and 13.48 MT/ha for productivity. Standard deviations show moderate variation in area and production, but low variability in productivity, confirming steady yields.

Correlations show a near-perfect positive link between area and production ($r \approx 0.99$), underscoring area growth's key role in output boosts. A strong positive production-productivity tie ($r \approx 0.96$) highlights yield advances' importance. The solid area-productivity association ($r \approx 0.95$) suggests management improvements strengthen both expansion and yields.



The trends in area, production, and productivity for pomegranate crops from 2020–21 to 2024–25 are detailed in Table 3.X. Results show a consistent expansion in pomegranate area, from 276 ha in 2020–21 to about 310 ha in 2024–25. This gradual increase highlights pomegranate's strengthening position in Maharashtra, driven by its profitability, drought tolerance, and export demand.

Production followed a steady upward trajectory, rising from 3100 MT in 2020–21 to roughly 3700 MT in 2024–25. The smooth progression with minimal fluctuations reflects a resilient system, supported by reliable market linkages and adaptive

farming.

Productivity demonstrated modest but reliable gains, advancing from 11.23 MT/ha in 2020–21 to 11.94 MT/ha in 2024–25. This improvement points to better irrigation, pest management, and variety adoption, with no significant dips indicating stable yield performance.

Statistical summaries confirm these patterns: mean area was 295.40 ha, production 3600.00 MT, and productivity 11.68 MT/ha. Standard deviations reveal low variability across all metrics, underscoring overall consistency.

Correlation analysis indicates a very strong positive relationship between area and production ($r \approx 0.99$), showing area expansion as a primary output driver. A strong positive link between production and productivity ($r \approx 0.98$) emphasises yield enhancements' contributions. The strong area-productivity association ($r \approx 0.97$) suggests integrated practices have fuelled both growth areas.

Descriptive statistics

Table 1: Statistical Summary and Correlation Analysis of Grapes (2020–21 to 2024–25)

Particulars	Area (ha)	Production (MT)	Productivity (MT/ha)
Mean	163.20	3610.31	22.05
Standard Deviation	7.92	262.45	0.61
Correlation (Area–Production)	–	0.98	–
Correlation (Area–Productivity)	–	–	0.82
Correlation (Production–Productivity)	–	–	0.88

The results show that grape cultivation had an average area of 163.20 ha, production of 3610.31 MT, and productivity of 22.05 MT/ha. Productivity remained stable with low variability, while production showed moderate variation. The correlation analysis indicates a very strong positive relationship between area and production ($r = 0.98$), suggesting that production is mainly driven by area expansion. However, the strong correlation between production and productivity ($r = 0.88$) shows that yield improvements also contribute significantly. Overall, grape cultivation exhibits a stable and efficient growth pattern.

Table 2: Statistical Summary and Correlation Analysis of Mango (2020–21 to 2024–25)

Particulars	Area (ha)	Production (MT)	Productivity (MT/ha)
Mean	2334.00	21947.00	9.40
Standard Deviation	32.18	657.89	0.16
Correlation (Area–Production)	–	0.99	–
Correlation (Area–Productivity)	–	–	0.91
Correlation (Production–Productivity)	–	–	0.93

The results indicate that mango cultivation had a mean area of 2334 ha, production of 21,947 MT, and productivity of 9.40 MT/ha. Productivity showed very low variability, indicating stable yield levels, while production increased steadily over time. The correlation analysis revealed a very strong positive relationship between area and production ($r \approx 0.99$), suggesting that production is mainly driven by area expansion. Overall, mango cultivation is largely area-driven with relatively limited improvement in productivity.

Table 3: Statistical Summary and Correlation Analysis of Citrus (2020–21 to 2024–25)

Particulars	Area (ha)	Production (MT)	Productivity (MT/ha)
Mean	340.00	4590.00	13.48
Standard Deviation	14.14	303.32	0.33
Correlation (Area–Production)	–	0.99	–
Correlation (Area–Productivity)	–	–	0.95
Correlation (Production–Productivity)	–	–	0.96

The results show that citrus cultivation had a mean area of 340 ha, production of 4590 MT, and productivity of 13.48 MT/ha. Productivity remained stable with low variability, while production showed a steady increase. The correlation analysis indicates a very strong positive relationship between area and

production ($r \approx 0.99$), along with strong associations between productivity and production. Overall, citrus exhibits a balanced growth pattern, with both area expansion and productivity contributing to increased production.

Table 4: Statistical Summary and Correlation Analysis of Pomegranate (2020–21 to 2024–25)

Particulars	Area (ha)	Production (MT)	Productivity (MT/ha)
Mean	292.40	3400.00	11.62
Standard Deviation	12.86	221.36	0.28
Correlation (Area–Production)	–	0.99	–
Correlation (Area–Productivity)	–	–	0.96
Correlation (Production–Productivity)	–	–	0.97

The results show that pomegranate cultivation had a mean area of 292.40 ha, production of 3400.00 MT, and productivity of 11.62 MT/ha during the study period. The standard deviation values indicate low variability in productivity (0.28), suggesting stable yield levels, while production shows moderate variation. The correlation analysis reveals a very strong positive relationship between area and production ($r \approx 0.99$), along with a strong association between productivity and production ($r \approx 0.97$). Overall, pomegranate cultivation is largely productivity-driven, with stable growth supported by improved management practices and technology.

4. Conclusion

This study examined the trends in area, production, and productivity of major fruit crops in Maharashtra over the period 2020–21 to 2024–25. The findings show that the area under fruit cultivation has increased steadily, reflecting a gradual shift of farmers towards horticulture. Production also increased across all crops, largely due to expansion in cultivated area. However, the contribution of productivity differed among crops. Grapes and pomegranate showed better and more stable productivity levels, indicating effective management and technology use. In contrast, mango production depended mainly on area expansion, with only slight improvement in yield. Citrus showed a relatively balanced trend, with both area and productivity supporting production growth. The analysis also suggests that productivity remained fairly stable, while production varied to some extent. Overall, improving productivity, especially in crops like mango, will be important for sustaining growth and increasing the efficiency of fruit cultivation in the state.

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