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Growth dynamics of citrus fruits in India: A decomposition analysis with seasonal indicators

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ABSTRACT

This study focused on the dynamics of citrus production in India and Himachal Pradesh over a 48 year period (1975–2022), emphasising regional differences and underlying development drivers. Compound annual growth rate (CAGR) and decomposition analysis were employed to examine the contributions of acreage, yield, and their interaction to production growth. Citrus production in India was primarily area-driven, with acreage growing by 12.96% during the period, while yield gains were minor (-0.26%). In Himachal Pradesh, however, output growth was driven by yields, with an 8.11% increase contributing considerably to the overall 10.45% growth. Seasonal indices of lemon prices and arrivals in four main northern Indian markets i.e. Ambala, Jassur, Azadpur, and Dehradun showed that prices peaked in April and May, with arrivals following similar seasonal trends. Notably, Azadpur had the highest price trend value of 7.73 in December, demonstrating the impact of large-scale production and effective supply chains. It underscored the relevance of contemporary farming techniques, resource management, and climate-friendly solutions for increasing productivity. Furthermore, insights about lemon market trends provided actionable guidance for optimising supply chains and eliminating market anomalies, particularly in volatile places such as Ambala and Dehradun. By combining data analysis with policy recommendations, this research provides a comprehensive framework for enhancing citrus production and market efficiency in India.

Keywords: Growth rate, Lemon, Productivity, Time series, Trends

Citrus fruits like oranges, lemons and limes play a crucial role in India's agriculture and economy. These colourful fruits are not just a popular choice on our plates, they also drive agricultural productivity and bring significant export revenue. India is one of the world's top producers of citrus fruits with oranges, lemons, and limes being the most grown varieties. According to the Agricultural and Processed Food Products Export Development Authority (APEDA 2022), India's citrus production in 2021–22 was estimated at 9.8 million tonnes, with oranges contributing the largest share. The states of Maharashtra, Andhra Pradesh, Karnataka, and Gujarat are major contributors to citrus production in India, owing to their favourable agro-climatic conditions, i.e. moderate temperatures and adequate rainfall. The northern regions of India, especially Himachal Pradesh, also have a unique edge when it comes to citrus fruits. The state's temperate climate with its distinct seasons, creates ideal conditions for growing oranges, mandarins, and other citrus varieties. Over the years, Himachal Pradesh has become a key player in citrus production, taking advantage of its hilly terrain, abundant water sources, and suitable weather. For example, the Kangra valley is famous for producing oranges known for their exceptional sweetness and flavour.

Citrus farming brings more than just fresh fruit to the market, it provides jobs and supports livelihoods, especially in rural areas. From sowing and harvesting to processing and selling, the citrus industry touches many lives. It also boosts local economies, whether through the sale of fresh fruit or processed products like juices and jams. Sustaining the growth of the citrus industry requires a clear understanding of its underlying drivers and the identification of areas for potential improvement. Tools like decomposition analysis and compound annual growth rate (CAGR) can help. These methods offer insights into production trends, highlight challenges, and help stakeholders make viable informed decisions. With this knowledge, policymakers, researchers and industry leaders can develop strategies to improve productivity, enhance quality, and make India's citrus industry more competitive on a global scale. Similar studies on growth trends and forecasting in agricultural production have been carried out using advanced time series techniques (Sahu *et al.* 2023, Kumar *et al.* 2024a, Kumar *et al.* 2024b).

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MATERIALS AND METHODS

The study was based on secondary data collected from various sources including the Ministry of Agriculture and the Directorate of Economics and Statistics, AGMARK and HP Horticulture Department. For the proposed study, time series data for area, production, and yield of 48 years, from 1975 to 2022 (HP Horticulture Department 2024, MOA 2021) were employed for India and Himachal Pradesh. The entire study period was further divided into three periods, namely Period I (1975–90), Period II (1991–2006) and Period III (2006–2022) with Overall period (1975–2022). Appropriate tools like Multiplicative decomposition (Minhas decomposition) was applied for the decomposition model. The study was constrained to the three main citrus crops, i.e. oranges, lemons and lime. Lemons' monthly pricing and arrival data covered a 11-year period due to their year-round availability. Unlike seasonal crops with distinct harvest seasons, lemons are grown and picked all round the year in various parts of India. This regular supply provides a continual market presence while price changes occur due to factors such as production cycles, demand patterns, and weather conditions. Monthly data analysis provided a detailed view of these processes, allowing for a thorough understanding of price trends, seasonal changes, and potential market disruptions. To further analyse these patterns and isolate the underlying components of the time series, multiplicative decomposition was applied to data from four major north Indian markets Ambala (Haryana), Jassur (Himachal Pradesh), Azadpur (Delhi) and Dehradun (Uttarakhand). This method allowed the division of the time series into its individual components: trend, seasonal, cyclical, and irregular.

Compound growth rate: The annual compound growth rate was estimated to know the acreage, output, and yield of the crops over the study period and was calculated by using the exponential trend model ($Y = ab^t$) (Balai *et al.* 2021). Using the logarithmic version of the equation, compound growth rate was computed as follows:

$$\text{Log } Y = \log a + t \log b,$$

Where Y, Acreage/output/yield; a, Intercept; b, Regression coefficient/(1+r); t, Year.

$$r = \text{Compound growth rate/Antilog } b - 1.$$

The per cent compound growth rate (CGR) will be as:

$$CGR = [(\text{Anti log of } b) - 1] \times 100$$

Decomposition analysis: To estimate the relative contribution of acreage, yield, and the interaction of acreage and yield towards increasing cereal output in India, the following decomposition analysis model was used (Minhas and Vaidyanthan 1965):

$$\Delta P = AB \times \Delta Y + YB \times \Delta A + \Delta A \times \Delta Y = (\text{Yield effect}) + (\text{Acreage effect}) + (\text{Interaction effect})$$

Where $\Delta A = AC - AB$; $\Delta P = PC - PB$; $\Delta Y = YC - YB$; AB, PB, and YB are the acreage, output, and yield of cereals for the base year, respectively (1975, 1991 and 2007); AC, PC and YC are the acreage, output, and yield for the current year, respectively (1990, 2006 and 2022); ΔA, Change in acreage; ΔP, Change in production; ΔY, Change in yield.

As a result, the overall change in output can be divided into three components: yield effect, acreage effect, and interaction effect due to changes in yield and acreage.

Multiplicative decomposition: In multiplicative decomposition analysis, a time series is expressed as the product of its components, namely trend, seasonality, and irregularity. The general form of the multiplicative model (Montgomery *et al.* 2015, Hyndman and Athanasopoulos 2021) is as follows:

$$Y(t) = T(t) \times S(t) \times I(t)$$

Where Y(t), Observed value at time t; T(t), Trend component at time t; S(t), Seasonal component at time t; I(t), Irregular (or residual) component at time t.

RESULTS AND DISCUSSION

The compound growth rate analysis (Table 1) showed significant regional differences between India and Himachal Pradesh in citrus production drivers. In India, citrus acerage has mostly grown because more land is being used for farming (12.96%), but improvements in yield have been almost negligible (-0.26%). This issue was especially clear during Period II (1991–2006) when a significant increase in farmland (18.50%) could not make up for a drop in productivity (-5.34%). The main reasons for this were limited use of modern farming techniques and poor farm management practices (Moore 2001, Sharma *et al.* 2007, Bhat *et al.* 2011, Kadu *et al.* 2021).

Himachal Pradesh showed a different pattern. The state recorded a 10.45% increase in citrus production, primarily

Table 1 Compound growth rate of citrus in India

Period	India			Himachal Pradesh		
	Acreage (%)	Production (%)	Yield (%)	Acreage (%)	Production (%)	Yield (%)
I (1975–90)	5.00	7.00	1.90	28.90	13.27	13.27
II (1991–2006)	18.50	12.17	-5.34	-11.18	24.30	39.94
III (2007–22)	4.66	12.53	7.52	3.32	4.25	0.90
Overall (1975–2022)	12.96	12.67	-0.26	2.17	10.45	8.11

driven by a substantial improvement in yield (8.11%), indicating a shift towards productivity-led growth. During Period II (1991–2006), the adoption of improved cultivation practices, including high-yielding varieties, better orchard management, and efficient resource utilisation, contributed significantly to this growth (Sharma *et al.* 2007, Kadu *et al.* 2021). These findings are consistent with recent studies highlighting the importance of technological interventions and improved management practices in enhancing productivity and export performance of citrus crops (Vaza *et al.* 2025). However, during Period III (2007–2022), the growth rate exhibited a slowdown, which can be attributed to constraints such as limited land availability, declining marginal productivity, and increasing climatic variability. Recent evidence suggests that fluctuations in temperature, irregular rainfall patterns, and environmental stress have adversely affected the stability of fruit crop production, particularly in hilly regions like Himachal Pradesh (Kumar *et al.* 2024b, Singh 2024).

At the national level, improving citrus production requires a strategic focus on yield enhancement through the adoption of advanced technologies, efficient input management, and sustainable farming practices. In Himachal Pradesh, sustaining productivity growth will depend on the promotion of precision agriculture, climate-resilient farming techniques, and strengthened extension services to mitigate environmental risks and improve long-term agricultural sustainability (FAO 2019).

The decomposition analysis (Table 2) highlighted the differences in the dynamics of citrus production between India as a whole and the specific case of Himachal Pradesh.

Period I (1975–1990): In the first period, both the acreage effect (34.04) and yield effect (53.35) contributed positively to citrus production, while the interaction effect (12.61) further reinforced these gains. This indicated a simultaneous increase in both the area cultivated and productivity, marking a developmental phase for citrus production in India. The positive outcomes can be attributed to the expansion of land under citrus cultivation and the gradual adoption of improved farming techniques, as noted by Kumar *et al.* (2024a). In contrast, a markedly different scenario was observed in Himachal Pradesh. While the acreage effect was significantly positive (425.39), the yield effect was notably negative (-15,191.73), indicating a steep decline in productivity. The interaction effect (1,602.73) reflected an imbalance where area expansion failed to translate into improved yields. This decline can be linked to factors such as poor crop management, pest and disease infestations, or suboptimal growing conditions during this phase, as discussed by Moore (2001) and Bhat *et al.* (2011).

Table 2 Decomposition analysis of area, production and yield of citrus in India

Period	Acreage effect	Yield effect	Interaction effect
India			
I (1975–90)	34.04	53.35	12.61
II (1991–2006)	-34.89	226.23	-91.34
III (2007–22)	47.27	34.49	18.23
Overall (1975–2022)	2.86	79.44	17.69
Himachal Pradesh			
I (1975–90)	425.39	-15,191.74	1,602.73
II (1991–2006)	291.96	-67.16	-124.80
III (2007–22)	16.73	79.36	3.91
Overall (1975–2022)	-39.99	239.65	-99.65

Period II (1991–2006): During Period II, citrus production experienced significant changes, with the acreage effect declining to -34.89, indicating reduced cultivated area, while the yield effect surged to 226.23, becoming the main driver of growth in the country. However, the interaction effect was negative at -91.34, revealing inefficiencies in balancing area reduction with yield gains. This rise in yield can be attributed to advancements in agricultural technology, such as high-yielding varieties and better irrigation (FAO 2019), but the decrease in area reflects competing land uses or shifting priorities.

In Himachal Pradesh, despite an overall acreage increase (291.95), productivity remained slightly negative (-67.15), suggesting limited improvements. Stagnant yields indicated challenges like inadequate adoption of modern practices and poor input management (Sharma *et al.* 2007, Kadu *et al.* 2021).

Period III (2007–2022): In India, both the acreage effect (47.27) and yield effect (34.50) positively contributed to citrus production, complemented by a favourable interaction effect (18.23), indicating coordinated growth in both area and productivity. This phase represents a balanced period where both land expansion and productivity gains fuelled citrus production growth, driven by supportive government policies, technological advancements, and infrastructure improvements (Kumar and Sharma 2019). In Himachal Pradesh the acreage effect remained modestly positive (16.72), while the yield effect saw a significant increase (79.36), reflecting improvements in productivity. The positive interaction effect (3.91) further suggests better alignment between area expansion and yield enhancement. The positive yield effect indicated enhancements in crop management practices and resource utilisation, due to government initiatives promoting citrus cultivation in hilly regions (Sharma *et al.* 2007, Kadu *et al.* 2021).

Overall analysis (1975–2022): Throughout the entire period, the acreage effect was slightly positive (2.86), indicating marginal net growth in the cultivated area in the country. However, the yield effect (79.44) emerged as the dominant factor driving production, with the interaction effect (17.69) reinforced these gains.

In Himachal Pradesh, although the acreage effect later turned negative (-39.99), signalling a net reduction in cultivated area, the yield effect remained significantly

Table 3 Multiplicative decomposition of monthly prices and arrivals of lemon

Months	Ambala (Haryana)		Jassur (Himachal Pradesh)		Azadpur (Delhi)		Dehradun (Uttarakhand)	
	Prices	Arrivals	Prices	Arrivals	Prices	Arrivals	Prices	Arrivals
January	0.67	0.94	0.61	0.73	0.65	0.64	0.78	0.69
February	0.75	1.07	0.74	0.79	0.93	0.72	0.88	0.73
March	1.09	1.25	1.35	0.86	1.51	0.82	1.04	0.79
April	1.08	1.08	1.61	0.94	1.69	1.26	1.63	1.01
May	1.79	1.46	1.36	0.99	1.17	1.63	1.18	1.40
June	1.00	1.17	1.09	1.29	0.90	1.84	1.17	1.47
July	1.02	1.06	1.07	1.08	0.78	1.32	0.99	1.06
August	0.96	1.16	1.09	0.83	0.85	0.99	1.05	1.05
September	0.94	0.98	1.07	1.06	1.20	0.79	0.86	1.63
October	0.98	1.02	0.87	0.82	1.00	0.70	0.81	0.61
November	0.94	1.02	0.66	1.16	0.75	0.68	0.81	0.86
December	0.78	1.00	0.49	1.45	0.57	0.62	0.80	0.72

positive at 239.64, underscoring that productivity improvements were crucial. The negative interaction effect (-99.65) pointed to inefficiencies in aligning changes in area with yield gains (Rani and Kaur 2021, Thakur and Chauhan 2024). In Himachal Pradesh, despite overall substantial productivity gains, the negative acreage effect indicated constraints on land availability due to urbanisation, diversification into other crops, or topographical challenges. Additionally, the negative interaction effect highlighted inefficiencies in resource optimisation that require targeted policy interventions (Kavita *et al.* 2015, Kashish and Dhawan 2017, Kaur *et al.* 2023).

Multiplicative decomposition: The Table 3 presents the seasonal indices of lemon prices and arrivals in four key markets of north India: Ambala, Jassur, Azadpur and Dehradun across different months. The seasonal index provided insight into the fluctuations in prices and arrivals of lemons throughout the year, highlighting the seasonal trends in lemon production and marketing across various regions. In Ambala, peak in lemon prices in April (1.08) and May (1.79), indicated higher demand coupled with lower arrivals during these months, which corresponds to the seasonal peak for lemons. Arrivals peaked in April (1.08) and May (1.46), suggesting a delayed supply response due to production cycles. In Jassur, prices peak in April (1.61), while arrivals reached their highest in May (1.46),

Table 4 Decomposition of prices of lemon

Months	Ambala (Haryana)			Jassur (Himachal Pradesh)			Azadpur (Delhi)			Dehradun (Uttarakhand)		
	Trend	Season-ality	Irregu-larity	Trend	Season-ality	Irregu-larity	Trend	Season-ality	Irregu-larity	Trend	Season-ality	Irregu-larity
January	2,809.92	0.94	0.94	5,533.06	1.02	0.56	3,554.06	1.13	0.53	2,498.52	1.00	0.68
February	2,814.67	1.07	0.92	5,532.77	1.04	0.67	3,553.86	1.08	0.79	2,498.10	1.10	0.69
March	2,819.41	1.25	1.14	5,532.49	1.11	1.14	3,553.65	1.04	1.33	2,497.68	1.12	0.81
April	2,824.15	1.08	1.30	5,532.21	1.05	1.43	3,553.45	1.12	1.38	2,497.26	1.76	0.81
May	2,828.90	1.46	1.61	5,531.92	1.07	1.19	3,553.25	1.34	0.80	2,496.84	1.22	0.84
June	2,833.64	1.17	1.12	5,531.64	1.08	0.95	3,553.05	1.13	0.74	2,496.42	1.23	0.83
July	2,838.39	1.06	1.26	5,531.36	1.14	0.88	3,552.85	1.23	0.58	2,496.00	1.08	0.80
August	2,843.13	1.16	1.07	5,531.07	1.21	0.84	3,552.65	1.15	0.68	2,495.58	1.13	0.82
September	2,847.87	0.98	1.24	5,530.79	1.21	0.83	3,552.44	1.13	0.98	2,495.16	1.01	0.74
October	2,852.62	1.02	1.25	5,530.50	0.98	0.83	3,552.24	1.11	0.83	2,494.74	0.98	0.72
November	2,857.36	1.02	1.18	5,530.22	0.98	0.64	3,552.04	1.07	0.64	2,494.32	0.96	0.74
December	2,862.10	1.00	1.00	5,529.94	1.00	0.46	3,551.84	1.11	0.47	2,493.90	1.02	0.69

reflecting a delayed harvest influenced by favourable climatic conditions that extend the growing season. Azadpur showed a significant price peak in April (1.69) while arrivals peaked in June (1.84), indicating strong market demand and limited supply during this time. In Dehradun, peak in prices in April (1.63), reflected increased summer demand, while arrivals peak in September (1.63) suggested that lemons are harvested earlier here. Overall, these seasonal indices illustrated how geographical and climatic factors impact lemon production and marketing, revealing how variations in harvest cycles affect both prices and supply in northern Indian markets.

Decomposition analysis of prices and arrivals of lemon: The multiplicative decomposition analysis separated the monthly series of lemon prices and arrivals into three components, namely trend, seasonality and irregularity, providing a detailed understanding of the temporal behaviour of the selected markets (Tables 4 and 5). The decomposition facilitates the identification of long-term movements, recurring seasonal patterns and random fluctuations affecting market prices and arrivals (Montgomery *et al*. 2015, Hyndman and Athanasopoulos 2021).

The trend component indicated relatively stable long-term movements in lemon prices across the selected markets. Ambala exhibited a gradual increase in the price trend from 2,809.92 in January–2,862.10 in December, whereas Jassur showed a marginal decline from 5,533.06–5,529.94 during the study period. Similarly, the trend values in Azadpur declined slightly from 3,554.06–3,551.84, while Dehradun recorded a small decline from 2,498.52–2,493.90. These results suggest that long-term price movements remained relatively stable throughout the year. In contrast, the trend component of arrivals showed a gradual increase across all markets, rising from 0.73–0.86 in Ambala, 0.08–0.09 in Jassur, 6.28–7.73 in Azadpur and 1.97–2.13 in Dehradun, indicating a steady increase in market arrivals over time. The comparatively higher arrival trend observed in Azadpur reflects its role as one of the largest wholesale markets with continuous inflow of produce from different producing regions (APEDA 2022).

The seasonal component revealed distinct monthly variations in lemon prices and arrivals across the selected markets. For prices, Ambala recorded the highest seasonal index in March (1.25), Jassur in August and September (1.21 each), Azadpur in May (1.34) and Dehradun in April (1.76). These seasonal peaks indicate the influence of regional harvesting periods, climatic conditions and variations in consumer demand. Seasonal patterns in arrivals also differed among markets. Ambala exhibited the highest seasonal arrival index in October (1.51), Jassur in December (1.81), Azadpur in April (1.11) and Dehradun in November (2.97). These variations reflect differences in harvesting schedules, market arrivals and regional supply conditions across the selected markets (APEDA 2022).

The irregular component captured short-term fluctuations in lemon prices and arrivals that were not explained by trend or seasonal effects. The irregular indices for prices remained close to unity in most markets, indicating comparatively stable price behaviour with only minor deviations caused by temporary market conditions. In contrast, the irregular component for arrivals exhibited greater variability, particularly in Azadpur, indicating considerable short-term fluctuations in market arrivals. Ambala and Dehradun also showed moderate irregular variations, whereas Jassur exhibited comparatively lower fluctuations during most months. These irregular movements may be attributed to temporary weather disturbances, transportation constraints, variations in gradual increase across all markets, rising from 0.73 to 0.86 in Ambala, 0.08 to 0.09 in Jassur, 6.28 to 7.73 in Azadpur and 1.97 to

Table 5 Decomposition of arrivals of lemon

Months	Ambala (Haryana)			Jassur (Himachal Pradesh)			Azadpur (Delhi)			Dehradun (Uttarakhand)		
	Trend	Season-ality	Irregu-larity	Trend	Season-ality	Irregu-larity	Trend	Season-ality	Irregu-larity	Trend	Season-ality	Irregu-larity
January	0.73	1.22	0.71	0.08	1.13	5.37	6.28	1.03	19.60	1.97	1.73	1.11
February	0.74	3.99	0.28	0.08	1.20	5.42	6.41	1.05	21.12	1.99	1.42	1.43
March	0.75	2.99	0.21	0.08	1.25	5.58	6.54	1.02	24.40	2.00	1.83	1.19
April	0.76	1.39	1.58	0.08	1.32	5.68	6.67	1.11	33.57	2.01	1.64	1.70
May	0.78	1.43	2.27	0.08	1.54	5.10	6.81	1.07	44.29	2.03	1.35	2.83
June	0.79	1.46	3.02	0.08	1.53	6.58	6.94	1.04	50.71	2.04	1.15	3.44
July	0.80	1.09	2.00	0.08	1.32	6.37	7.07	1.02	36.25	2.06	1.91	1.49
August	0.81	1.49	1.59	0.08	1.07	5.90	7.20	1.02	26.62	2.07	1.73	1.62
September	0.82	1.02	1.66	0.09	1.23	6.56	7.34	1.07	19.97	2.08	2.77	1.56
October	0.83	1.51	1.09	0.09	1.08	5.75	7.47	1.03	17.96	2.10	2.26	0.71
November	0.84	1.06	1.18	0.09	1.31	6.58	7.60	1.05	16.84	2.11	2.97	0.76
December	0.86	1.12	0.53	0.09	1.81	5.88	7.73	1.05	15.03	2.13	1.25	1.49

2.13 in Dehradun, indicating a steady increase in market arrivals over time. The comparatively higher arrival trend observed in Azadpur reflects its role as one of the largest wholesale markets with continuous inflow of produce from different producing regions (APEDA 2022).

The findings of this study showed that citrus production in India has mainly grown due to an increase in cultivated area, while Himachal Pradesh has achieved better growth through improvements in yield. Period II (1991–2006) marked rapid area expansion nationally but yield stagnation, whereas, Himachal Pradesh achieved productivity-led gains. The decomposition analysis highlights that yield plays a key role in sustaining production growth, and the seasonal analysis reflects clear differences in market behaviour across regions.

Lemon price decomposition revealed clear seasonal peaks (April–May) and regional contrasts, with Azadpur showing highest price trends due to efficient supply chains. Strengthening yield improvement strategies, infrastructure, and climate-smart practices will be essential to sustain citrus growth and market stability across regions.

The decomposition of lemon prices and arrivals over the past 11 years revealed significant patterns affecting northern Indian markets. Price trends showed a steady upward trajectory, influenced by inflation, rising production costs, and increasing consumer demand, with notable seasonal peaks in April and May, particularly in Azadpur due to its extensive supply chains. In contrast, Dehradun exhibited more stable price trends, impacted by regional production constraints. Arrival trends indicated consistent growth driven by improved infrastructure and production capabilities, with peaks during April and May in Jassur and Ambala, attributed to favourable climatic conditions. Dehradun experiences moderate arrival trends due to supply chain limitations. These insights are crucial for stakeholders aiming to optimise production processes, address irregularities, and enhance overall market efficiency.

Going forward, improving citrus productivity will require greater attention to yield enhancement through better farming practices, improved varieties, and efficient use of resources. The use of modern approaches such as precision agriculture and climate-smart techniques can help farmers deal with changing weather conditions and resource limitations. At the same time, improving market infrastructure and supply chains will be important to reduce price fluctuations and ensure better returns to farmers. Future research can focus on using advanced statistical and forecasting methods to better understand production and price trends. More region-specific studies that consider climatic and economic factors will also help in designing effective policies. Overall, a combined focus on technology, sustainability, and market efficiency will be essential for the long-term development of the citrus sector in India.

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