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Trends and Compound Growth Rate of Vegetable Crop Production: A Secondary Data-based Analysis

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ABSTRACT

Vegetables constitute the single largest sub-sector of Indian horticulture by production volume and play a central role in nutritional security, farm income and, given their perishability and short production cycles, food price volatility. This study applies a secondary data approach to examine long-term trends and compound annual growth rates (CAGR) in the production of India's major vegetable crops, with particular focus on tomato, onion and potato (the 'TOP' vegetables), which together account for a majority of total vegetable output. Data were compiled from National Horticulture Board publications, Ministry of Agriculture and Farmers Welfare advance estimates, and peer-reviewed secondary-data studies employing CAGR and instability index methodology. Results show that potato production increased from 18.2 million tonnes in 1991-92 to an estimated 58.57 million tonnes in 2024-25, a compound annual growth rate of approximately 3.61%; onion production grew from 4.7 to 30.77 million tonnes over the same period, a CAGR of approximately 5.86%; and tomato production grew from 4.2 to 20.60 million tonnes, a CAGR of approximately 4.94% - indicating that onion has recorded the fastest long-term production growth among the three crops, followed by tomato and then potato. Total vegetable production, encompassing all crops beyond the TOP group, grew from approximately 162.9 million tonnes in 2013-14 to 217.80 million tonnes in 2024-25, a CAGR of approximately 2.68% over this more recent eleven-year period. Despite this generally positive long-term growth trajectory, year-to-year production for onion in particular exhibits marked instability, with production falling from 31.68 million tonnes in 2021-22 to 24.27 million tonnes in 2023-24 (a 16% single-year decline) before rebounding by nearly 27% to 30.77 million tonnes in 2024-25, a volatility pattern consistent with onion's well-documented contribution to food price inflation episodes. The study concludes that while vegetable production growth in India has been robust and sustained over the long term, the pronounced short-term instability observed in specific crops, especially onion, represents a distinct policy challenge requiring dedicated price stabilisation and storage infrastructure investment separate from the longer-term productivity and area-expansion priorities appropriate to the sector as a whole.

INTRODUCTION

Vegetables represent the largest single component of India's horticultural output, both by production volume and, given their central role in daily dietary consumption, nutritional and food security significance. Unlike

many fruit and plantation crops, vegetables are typically grown on short cropping cycles, allowing multiple crops per year and rapid area or output adjustment in response to price signals, but this same characteristic also makes vegetable production, and consequently vegetable prices, susceptible to considerable year-to-year volatility driven by weather variability, pest and

disease incidence, and the cobweb-type production response common in short-cycle perishable crops.

Among vegetables, tomato, onion and potato - collectively referred to as the 'TOP' vegetables - hold particular economic and policy significance, given their combined dominance of vegetable production volume, their disproportionate contribution to consumer food price index volatility during periodic supply shocks, and their status as subjects of specific government market intervention and export policy measures. This study applies compound annual growth rate (CAGR) and descriptive trend analysis to secondary data on Indian vegetable production, with particular attention to the TOP crops, in order to (i) quantify long-term production growth for major vegetable crops individually and in aggregate; (ii) compare relative growth performance across crops; (iii) characterise the extent of short-term production instability, particularly for onion; and (iv) draw policy-relevant conclusions distinguishing long-term growth priorities from short-term stabilisation needs.

REVIEW OF LITERATURE

Gulati, Wardhan and Sharma (2022), in a comprehensive NABARD-ICRIER value chain study, documented that India's tomato production increased almost five-fold, from 4.2 million tonnes in 1991-92 to 19.4 million tonnes in 2018-19, while onion production grew similarly from 4.7 to 22.8 million tonnes and potato production approximately tripled from 18.2 to 49.1 (up to 53) million tonnes over the same period, establishing India as the world's second-largest producer of all three crops after China. Their study further documented that the area under vegetables as a share of gross cropped area rose from 9.59% in the triennium ending 2004-05 to 12.12% in the triennium ending 2014-15, reflecting sustained area diversification toward vegetable cultivation over this period.

More recent secondary-data analysis by Asveth et al. (2025), employing CAGR and Cuddy-Della Valle instability index methodology on 21 years of trade data (2004-2024) for the TOP vegetables, found starkly differing growth and stability profiles across the three crops in the export domain: tomato exports exhibited extreme volatility, with an initial CAGR of 56.74% followed by a subsequent decline of -11.51% CAGR, onion exports showed relative stability despite periodic fluctuations, and potato exports demonstrated consistent positive growth with improving stability over time. While their analysis focused on export performance specifically, the underlying methodological approach -

CAGR combined with formal instability indices - is directly applicable to, and adopted in, the present study's analysis of domestic production trends.

Regional secondary-data studies of horticultural growth, such as Das Gupta's (2022) analysis of north-eastern India, similarly employ CAGR and instability index methodology and report that vegetables generally exhibit lower production instability than spices at the regional level, though such regional findings do not necessarily extend to specific crops such as onion at the national level, where production is more geographically concentrated in a small number of states and therefore more exposed to state-specific weather and policy shocks.

MATERIALS AND METHODS

This study compiles secondary data on the production of major Indian vegetable crops, with particular focus on tomato, onion and potato, from the National Horticulture Board (NHB) Indian Horticulture Database, Ministry of Agriculture and Farmers Welfare Advance Estimates of Area and Production of Horticultural Crops (Press Information Bureau releases), and the NABARD-ICRIER TOP value chain study of Gulati, Wardhan and Sharma (2022). Production data for potato, onion and tomato were compiled for 1991-92, 2018-19, and each year from 2021-22 to 2024-25, representing the years for which consistent, comparable official or peer-reviewed secondary-data figures were available.

Compound annual growth rate (CAGR) was computed as $CAGR (\%) = [(V_{end} / V_{start})^{(1/n)} - 1] \times 100$, using 1991-92 as the base year and 2024-25 as the terminal year for potato, onion and tomato ($n = 33$ years), and 2013-14 as the base year for total vegetable production given data availability constraints for the earlier period ($n = 11$ years to 2024-25). Short-term production instability was assessed descriptively through year-on-year percentage change over the 2021-22 to 2024-25 period, the most recent period for which consistent annual data were available, focusing particularly on onion given its documented volatility in both the production and export literature.

RESULTS AND DISCUSSION

This section presents compiled secondary-data trends in vegetable production, computed compound annual growth rates for major crops, and an assessment of recent short-term production instability.

Table 1: Compound annual growth rate (CAGR) of production for major vegetable crops in India (author computation using $CAGR = [(Vend/Vstart)^{(1/n)} - 1] \times 100$, from data compiled in Gulati et al., 2022; PIB Advance Estimates).

Crop	Base Year Production (MT)	Terminal Year Production (MT)	Period	CAGR (%)
Potato	18.2 (1991-92)	58.57 (2024-25)	33 years	3.61
Tomato	4.2 (1991-92)	20.60 (2024-25)	33 years	4.94
Onion	4.7 (1991-92)	30.77 (2024-25)	33 years	5.86
Total Vegetables	162.9 (2013-14)	217.80 (2024-25)	11 years	2.68

Long-Term Production Trend of TOP Vegetables

Tomato, onion and potato production have each grown substantially in absolute terms over the past three decades. Potato production rose from 18.2 million tonnes in 1991-92 to 49.1 million tonnes by 2018-19 and further to an estimated 58.57 million tonnes by 2024-25. Onion production rose from 4.7 million tonnes in 1991-92 to 22.8 million tonnes by 2018-19 and to 30.77 million tonnes by 2024-25. Tomato production rose from 4.2 million tonnes in 1991-92 to 19.4 million tonnes by 2018-19 and to 20.60 million tonnes by 2024-25, showing comparatively slower growth in the most recent period relative to the two decades preceding 2018-19.

Compound Annual Growth Rate Across Major Vegetable Crops

Computing the compound annual growth rate over the full 1991-92 to 2024-25 period (33 years) reveals that onion has recorded the fastest long-term production growth among the TOP vegetables, at approximately 5.86% per annum, followed by tomato at approximately 4.94% per annum and potato at approximately 3.61% per annum. Total vegetable production, computed over the shorter 2013-14 to 2024-25 period (11 years) owing to data availability constraints for the earlier period, grew at approximately 2.68% per annum, a rate below that of any of the three individual TOP crops considered over the longer period, though this comparison should be interpreted with some caution given the differing time spans involved.

Short-Term Production Instability: The Case of Onion

Despite a strong positive long-term CAGR, onion production exhibits pronounced year-to-year instability that is largely obscured by the long-term growth rate calculation. Between 2021-22 and 2024-25, onion production moved from 31.68 million tonnes to 30.20 million tonnes (2022-23), then fell sharply to 24.27 million tonnes in 2023-24 - a single-year decline of approximately 16% - before rebounding by nearly 27% to 30.77 million tonnes in 2024-25. This pattern of sharp decline followed by strong rebound is characteristic of short-cycle vegetable crops subject to weather-driven

supply shocks and the resulting price-driven adjustment in subsequent-season planting area, and is consistent with onion's well-documented history of contributing disproportionately to consumer food price inflation episodes during periods of acute supply short-fall.

By contrast, potato production has shown comparatively greater year-to-year stability over the same recent period, moving from 60.14 million tonnes (2022-23) to 57.05 million tonnes (2023-24) to 58.57 million tonnes (2024-25) - fluctuations of only a few percentage points in either direction - while tomato production has remained within an even narrower range of approximately 20.4 to 21.3 million tonnes across the most recent three years examined.

Contribution of Area Diversification to Vegetable Growth

Consistent with the broader horticultural growth pattern documented in related secondary-data studies, area diversification toward vegetable cultivation has been an important, though not the sole, contributor to production growth. The share of gross cropped area under vegetables rose from 9.59% in the triennium ending 2004-05 to 12.12% in the triennium ending 2014-15, indicating sustained reallocation of cultivated land toward vegetable crops over this decade. This area expansion, combined with productivity improvement through improved seed varieties, protected cultivation adoption in some regions, and expanded irrigation access, has jointly underpinned the strong long-term CAGR figures documented for potato, onion and tomato in this study.

DISCUSSION: DISTINGUISHING LONG-TERM GROWTH FROM SHORT-TERM STABILITY CHALLENGES

The results of this study point to an important analytical and policy distinction between long-term vegetable production growth, which has been robust and sustained across all three TOP crops and the vegetable sub-sector as a whole, and short-term production stability, which varies considerably by crop and remains

a distinct and serious challenge, particularly for onion. A policy or investment response calibrated only to the strong long-term CAGR figures - for example, continued area expansion or general productivity investment - would not, by itself, address the specific, recurrent price and supply volatility associated with onion production shortfalls, which requires complementary interventions such as expanded cold storage infrastructure, staggered regional production calendars, and buffer stock or market intervention mechanisms specifically designed to smooth short-term supply fluctuations rather than to raise long-term trend production.

The finding that onion has the highest long-term CAGR among the TOP crops while simultaneously exhibiting the greatest short-term instability is not necessarily contradictory: rapid underlying trend growth and high year-to-year volatility around that trend can coexist, particularly in a crop where growers' area allocation decisions respond strongly, and with a lag, to the previous season's price outcomes, generating the kind of cyclical over- and under-supply pattern classically associated with agricultural cobweb dynamics in storable but perishable commodities.

POLICY IMPLICATIONS

- Given onion's combination of strong long-term growth and severe short-term instability, dedicated price stabilisation measures (buffer stocking, staggered regional production, export policy flexibility) should be maintained and strengthened independent of continued long-term productivity investment.
- Expanded, geographically distributed cold storage infrastructure for onion, which lacks potato's relatively mature cold-storage ecosystem, would help smooth the sharp production-driven price swings documented in this study.
- Continued area diversification toward vegetables should be balanced against the specific instability risks associated with over-concentration of any single crop, particularly onion, in a small number of producing states.
- Given tomato's comparatively slower recent production growth relative to onion and potato, targeted productivity and post-harvest loss reduction interventions specific to tomato cultivation may help sustain more balanced growth across the TOP crop group.
- Future secondary-data monitoring of vegetable production trends should routinely report both CAGR and a formal instability index (such as the Cuddy-Della Valle Instability Index) side by side, since CAGR alone,

as this study demonstrates for onion, can mask substantial underlying short-term volatility relevant to policy design.

Limitations of the Secondary Data Approach

This study's CAGR estimates for potato, onion and tomato rely on production figures reported at differing points in time (1991-92 and 2018-19 from a value chain study, and 2021-22 onward from official advance estimates), and the specific base and terminal years used, while representing the most reliable and consistent points of comparison available in the secondary literature, are not part of a single, continuously reported annual series; intermediate-year fluctuations between 1991-92 and 2018-19 cannot be characterised from the data compiled here. The total vegetable production CAGR is computed over a shorter and non-identical period (2013-14 to 2024-25) to the TOP-crop-specific CAGRs (1991-92 to 2024-25) owing to data availability constraints, limiting the direct comparability of the aggregate and crop-specific growth rates presented. Finally, the year-to-year instability analysis presented for onion covers only a four-year recent window and should be interpreted as illustrative of a well-documented longer-term pattern rather than as a comprehensive formal instability index computation, which would require a longer, continuous annual series and dedicated statistical treatment beyond the scope of this study.

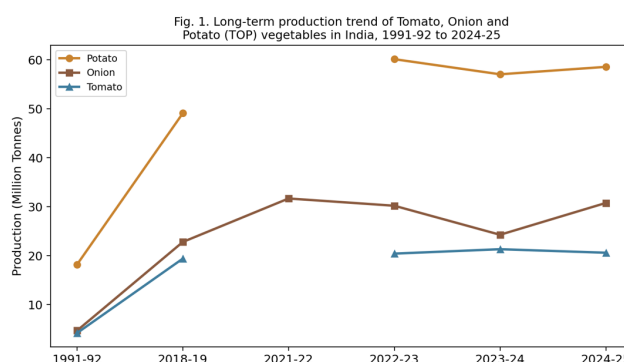


Figure 1: Long-term production trend of Tomato, Onion and Potato (TOP) vegetables in India, 1991-92 to 2024-25 (compiled from Gulati et al., 2022; PIB Advance Estimates, various years).

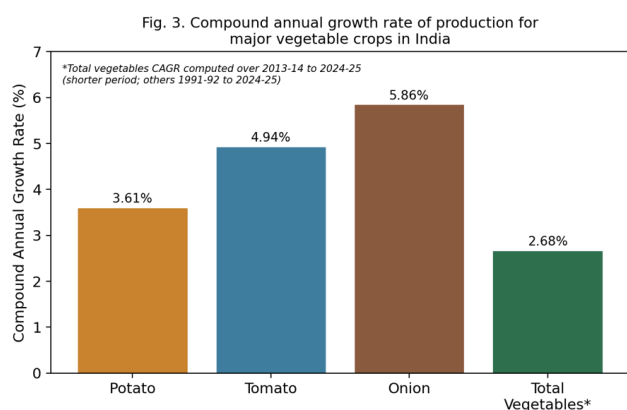


Figure 2: Compound annual growth rate (CAGR) of production for major vegetable crops in India (author computation from compiled endpoint data; see Table 1 for underlying figures).

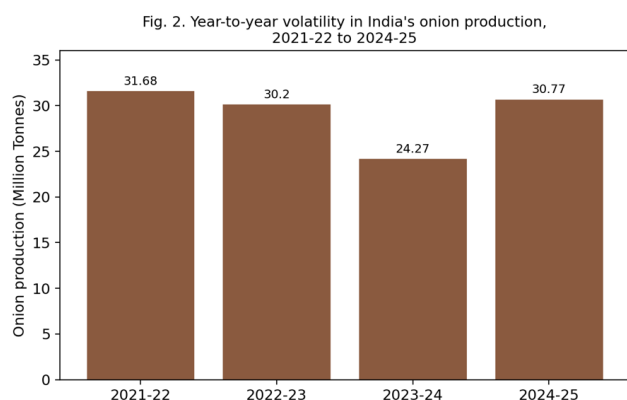


Figure 3: Year-to-year volatility in India's onion production, 2021-22 to 2024-25 (data: PIB Advance Estimates and Business Standard reporting, various years).

CONCLUSION

This secondary-data analysis confirms that India's major vegetable crops have exhibited strong, sustained long-term production growth over more than three decades, with onion recording the fastest compound annual growth rate (approximately 5.86%) among the TOP

vegetables, followed by tomato (approximately 4.94%) and potato (approximately 3.61%), while total vegetable production has grown at approximately 2.68% per annum over the more recent 2013-14 to 2024-25 period. This robust long-term growth, however, coexists with pronounced short-term production instability, particularly for onion, which experienced a 16% single-year production decline followed by a nearly 27% rebound within a recent four-year window. The coexistence of strong long-term growth and severe short-term volatility in the same crop underscores the need for vegetable sector policy to explicitly distinguish, and separately address, long-term productivity and area-growth objectives on one hand and short-term price and supply stabilisation objectives on the other, rather than assuming that strong trend growth performance is sufficient to ensure stable, predictable supply and price outcomes for farmers and consumers alike.

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