Varietal Transformation in Sugarcane: Economic Implications of CoM 265 in Maharashtra

Pradipkumar Adhale[1] and Vasant Pokharkar[2]

[1]Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, Punjab
[2]Department of Agricultural Economics, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra

Abstract

This paper aims to estimate the economic impact of the sugarcane variety CoM 265 on the farm economy of Maharashtra.The study employed compound growth rates, Cuddy-Della Valle instability index, and Markov chain analysis to assess long-term trends, variability, and varietal shifts in sugarcane cultivation in Maharashtra. Partial budgeting and upscaling techniques were used to evaluate the economic impact of university-released sugarcane variety CoM 265. The expansion of the sugarcane area significantly contributed to increased sugarcane production. However, the productivity of sugarcane remained stagnant during the study period.The CoM 86032 was identified as Maharashtra's most stable sugarcane variety, followed by CoM 265 and CoC 671. In 2007, Mahatma Phule Krishi Vidyapeeth Rahuri released CoM 265, a promising sugarcane variety. By 2023-24, CoM 265 covered nearly 24.65per cent of the total sugarcane cultivation area and retained 77.80per cent of its previous year's area. The total economic impact of the sugarcane variety CoM 265 on the farming community in Maharashtra over sixteen years was Rs. 2,223.09 Crore. The cultivation of sugarcane variety CoM 265 was profitable than the other varities. Therefore this study suggests that giverment may increase investments in sugarcane research to develop improved varieties.

Keywords: CoM 265, Economic impact, Partial budgeting, Farm economy

JEL Classification: Q10, Q19, Q16

Introduction

Sugarcane is originated in New Guinea and cultivated in tropical and subtropical areas (Chhabra, 2016). It is widespread and most important commercial crop, accounting for over 2.57per cent of the total cropped area and primarily used as raw material in sugar manufacturing factories (Zhao and Li, 2015). India is the second largest producer of sugarcane after Brazil, accounting for approximately 25per cent of global production (Upreti and Singh, 2017). It directly or indirectly provides jobs for more than a million people (Solomon, 2016).The sugar industry is the second largest after the textile agro-industry, contributing to India's employment and economyic development (Solomon and Swapna, 2022). Approximately 7.5 per cent of the Indian rural population is engaged in sugarcane farming and contributed 6 per cent of agricultural GDP in 2010-11 (Solomon, 2016). Maharashtra is India's second-largest sugarcane-growing state. Over the years, there has been steady growth in area and sugar cane production. However, the decline in sugarcane productivity over the last few decades is of great concern. In the last few decades, Sugarcane farmers have suffered many threats, such as increased input costs, decreasing profit margins, and unsystematic and insufficient institutional and infrastructural facilities.

Agricultural growth necessitates the continuous improvement of crop production technology at the farm level, and a partial budget's objective is to recommend distinct technologies that are economically superior and socially acceptable to farmers (Soha, 2014). Sugarcane farmers constantly adjust their farms to ensure smooth operation and profitability.Many of these decisions are made to improve the profits of the farm business. In contrast, others are made out of necessity to mitigate the effects of unfavourable conditions or natural calamities, such as drought, floods, or market fluctuations. Alternative options within a single enterprise can have different impacts on farm profitability. As a result, making the best decision could mean the difference between profit and loss in the farm business. In such cases, partial budgeting is remarkably beneficial in making such changes on a farm (Swinton and Lowenberg, 1998).On the other hand, the findings of a partial budget analysis are highly dependent on the quality of the data used in the analysis

Corresponding author email: pradipkumar@pau.edu

(Tigner, 2018). Sugarcane cultivation remained in the centre of attention of the politicians, policy makers, and academics in Maharashtra (Immanuelraj and Atteri, 2013). There are few varities commonaly cultivated in the Maharashtra and the CoM 265 is one of the promisimg variety that covered apprxomatly 25 per cent area under sugarcane cultivation. In this regard it is important to asses the monetary impact of the variety in the region. Partial budget analysis helps to set priorities over competing initiatives and policy decisions on effective resource allocation. In this context the economic impact of sugarcane variety CoM 265 on the farm economy of Maharashtra examined the current study.

Data Sources and Methodology

The secondary data on sugarcane area, production, and productivity were obtained from the official publication *Epitome of Agriculture*, Pune. Data on sugarcane costs and returns for 2023-24 was compiled using quick estimate reports from the Cost of Cultivation Scheme, Department of Agricultural Economics, Mahatma Phule Krishi Vidyapeeth, Rahuri. Additionally, data on the area under different sugarcane varieties and details regarding research investments were obtained from the official records of the Central Sugarcane Research Station (CSRS), Padegaon.

Growth and Instability Analysis

The compound growth rates were computed based on time series data on area, production, and productivity of sugarcane for Maharashtra as a whole for 64 years of the study period, from 1960-61 to 2023-24. The Cuddy-Della Valle index, which detrends the series and shows the exact direction of the instability, is a better tool for estimating instability. As a result, instability in the sugarcane area, production, and productivity was investigated using instability measures such as the Cuddy-Della Valle Instability Index (Cuddy and Valle, 1978).

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

CV is the coefficient of variation in per cent, and R^2 is the coefficient of determination.

The extent of the area shifts of sugarcane varieties

The Markov chain analysis was used to study shifts in the shares of various sugarcane varieties to understand the dynamics of varietal changes. P_{ij} is central to Markov chain analysis when estimating the transitional probability matrix. The element P_{ij} of the matrix P denotes the Probability that the area will shift from the ith to the jth variety over time (Dent, 1967; Lee *et al*, 1970; and Gillet, 1976). The diagonal elements of the matrix represent the probability that the area of variety will be retained. As a result, examining the diagonal elements reveals that farmers prefer variety in sugarcane cultivation.

The present study treated structural changes as a random process with selected sugarcane varieties. The average area under any particular variety was considered a random variable that depends primarily on the previous area of the variety, which can be denoted algebraically.

$$E_{jt} = \sum_{i=1}^{r} E_{it-1} \cdot P_{ij} + e_{jt}$$

Where,

E_{jt} = Area shift from variety to j^{th} variety during the year t.

E_{it-1} = Area shift from variety to i^{th} variety during the period t-1.

P_{ij} = Probability that the area shift will shift from i^{th} variety to j^{th} variety.

e_{jt} = The error term, which is statistically independent of E_{it-1}.

t = Number of years considered for the analysis.

r = Number of sugarcane varieties.

The transitional probabilities P_{ij} which can be arranged in a (c x r) matrix have the following properties.

$0 \le P_{ij} \le 1$

$\sum_{j=1}^{r} P_{ij} = 1$ for all i

Thus, the expected area of each variety during the period 't' was calculated by multiplying the area of these varieties in the previous period (t-1) by the transitional probability matrix.

Partial Budgeting Approach

A partial budgeting approach was employed to estimate the impact of research outcomes on farm income generation. The primary objective of this method is to evaluate the change in farm profit or loss resulting from a specific alteration in the farm plan (Boehlje and Eidman, 1984). Partial budgeting is useful for assessing the economic viability of incremental changes within a farming system such as adopting a new variety, technology, innovation, practice, equipment, or service. It helps in evaluating the additional costs and benefits associated with a specific change in the operation of an individual enterprise (Horton, 1982).

Credit or Return side

Reduced costs (or savings) due to CoM 265 cultivation includes cost savings on human labour, machine labour, seed, manure, and irrigation. Additional returns in main produce and by produce in both quantity and monetary terms. The partial budgeting technique was used to estimate the economic viability of university-released varieties. It represents the economic impact of the university-released variety over other competing varieties in Maharashtra. Figure. 1 depicts an illustration of a partial budget.

Debit or Cost Side

Additional expenditures incurred due to CoM 265

cultivation include additional cost accounting, human labour, machine labour, seed, manure, irrigation, management, risk premium, research and extension, and so on, as well as reduced returns in quantity and monetary terms, if any.

Upscaling the economic impact

Partial budgeting is applicable for assessing the economic impact of the university-released sugarcane variety over a broader cultivation area. However, straight forward linear extrapolation of benefits per hectare is not justifiable due to the influence of the Law of Diminishing Marginal Returns (LDMR) in agriculture. To account for this, three critical parameters are integrated into the extrapolation process: (i) performance of the variety, (ii) adoption rate of the sugarcane variety, and (iii) depreciation or decline in effectiveness over time. These parameters effectively capture the implications of LDMR, recognizing that real-world field conditions differ from controlled research settings and that farmers may not achieve the same outcomes as researchers. The upscaling technique is a process in which data or findings from a lower spatial scale (such as individual farms or experimental plots) are translated into insights applicable at a larger spatial scale (such as regions or states). In this technique, the economic viability of university-released varieties is estimated by multiplying the estimated returns with factors reflecting depreciation, the adoption rate, and the probability of achieving actual field-level yield. After upscaling economic worthiness was deflated with consumer price index to obtained the per hectare net gain.This approach provides a more realistic estimation of net returns attributable to specific sugarcane varieties under practical farming conditions.

Results and Discussion

Growth and instability of area, production, and yield of sugarcane

Table 1 highlights the growth and instability trends in Maharashtra's sugarcane area, production and productivity. The area under sugarcane cultivation in Maharashtra showed a consistent and significant increase across all periods, with growth rates of 2.19 per cent, 6.86 per cent, 4.75 per cent, 1.38 per cent, 4.33 per cent, and 3.63 per cent, respectively. Sugarcane production also recorded significant growth during most periods, except for 1994-04. However, the growth in sugarcane productivity was negative and statistically non-significant. The rise in sugarcane production in Maharashtra from 1961 to 2024 was mainly driven by the expansion in cultivated areas rather than productivity improvements. Similar findings were reported by Adhale *et al,* 2019a, Upreti and Singh, 2017, and Adhale *et al,* 2019b.

The area under sugarcane cultivation in Maharashtra remained stable (instability index below 15) and exhibited consistent growth across all periods. Similarly, sugarcane yield remained stable throughout the entire period from 1961 to 2024. In contrast, sugarcane production showed moderate instability (instability index between 15 and 30). While both the area and production of sugarcane have increased over time primarily due to area expansion (area effect), the productivity or yield effect has not shown any significant improvement.Compared to other crops, sugarcane cultivation in Maharashtra is more attractive to farmers due to policy incentives such as Fair and Remunerative Prices (FRP) and assured procurement. These factors encourage farmers to favor sugarcane cultivation, continuously expanding the area under the crop (Gupta, 2021).

Varietal spread in Maharashtra

The area under various sugarcane varieties in Maharashtra is depicted in Annexure I. Co 86032 has consistently dominated sugarcane cultivation in Maharashtra, having a share of 48.07 per cent (2023-24).CoC 671, once the second most cultivated variety at 31.34 per cent in 2008-09, has sharply declined, falling below 1 per cent after 2020-21. CoM 265 variety was released in 2007 and has grown steadily, becoming the second most significant variety with 24.65 per cent area share in 2023-24.Co 86032 and CoM 265, these two varieties, competed with each other but replaced other sugarcane varieties instead of covering more areas themselves. The total area under sugarcane cultivation has

Table 1: Growth and instability of area, production, and yield of sugarcane in Maharashtra

Year	Compound Annual Growth Rates (%)			Cuddy-Della Valle Index (%)		
	Area	Production	Yield	Area	Production	Yield
1961-71	2.19 **	3.96 ***	1.73 NS	8.75	12.09	11.16
1972-82	6.86 ***	6.49 ***	-0.34 NS	16.05	14.13	10.63
1983-93	4.75 ***	3.34 **	-1.35 **	10.49	13.83	4.67
1994-04	1.38 NS	-0.69 NS	-2.04 *	15.91	21.55	8.95
2005-14	4.33 *	5.41 *	1.03 **	24.04	25.80	5.06
2015-24	9.24 **	11.2 **	1.8 ***	20.99	21.71	3.84
1961-24	3.66 ***	3.71 ***	0.06 NS	19.41	23.52	10.88

*Source: Epitome of Agriculture, Pune Note: ***, ** and * significant 1, 5, and 10 per cent, respectively, NS: Non-significant*
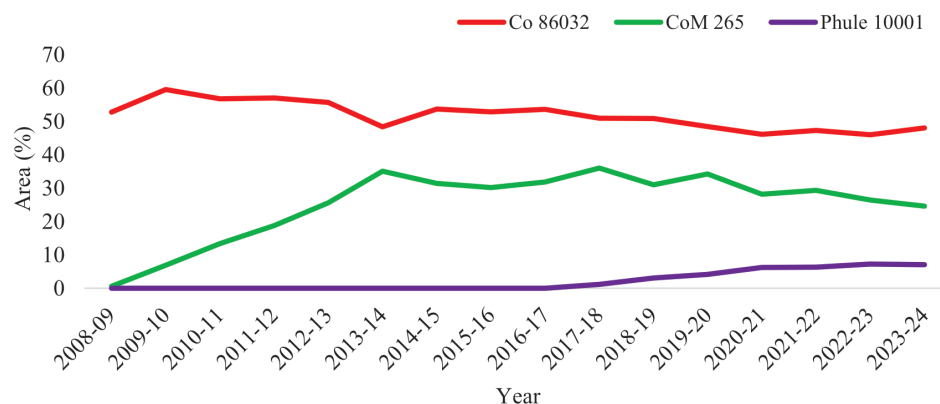
Figure 1. Spread of major sugarcane varities in Maharashtra

fluctuated over the years, reaching 13.07 lakh ha in 2022-23, with some recovery after lower levels in 2019-20 and 2020-21. In Maharashtra, CoM 86032 (48.07%) and CoM 265 (24.65%) covered about 72.72% of the total sugarcane area in 2023-24. CoM 0265 has emerged as a pillar variety in Maharashtra's sugarcane sector demonstrating how timely varietal innovation and extension support can transform the varietal landscape. The increasing diversification in sugarcane varieties in recent years suggests farmers are shifting toward risk mitigation and varietal replacement strategies.

Change in area under various sugarcane varieties in Maharashtra

The shift in area under different sugarcane varieties in Maharashtra was analyzed using Markov chain analysis to estimate the Transitional Probability Matrix (TPM), as shown in Table 2. Eight major sugarcane varieties were considered: CoM 86032, CoM 265, Co 671, Co 94012, Co 8014, Co 92005, Co 740, and Co 7219. The diagonal elements of the TPM indicate the probability of a variety retaining its area from the previous year. In contrast, the row elements reflect the Probability of losing area to competing varieties. Conversely, the column elements represent the probability of gaining area from other varieties. Among the varieties, CoM 86032 retained 81.7 per cent of its previous year's area,

losing about 12.6 per cent to CoM 265 and 5 per cent to Co 92005. CoM 265 retained 77.8 per cent of its area, with losses of 11.2 per cent to Co 92005, 10.8 per cent to CoM 86032, and 0.008 per cent to Co 740. On the other hand, CoM 265 gained 25.6 per cent area from Co 92005 and 12.6 per cent from CoM 86032.

Sugarcane variety CoC 671 retained 71.1 per cent of its previous year's area, gained the entire area previously under Co 8014, and received 56.4 per cent of the area from Co 94012 while losing 27.7 per cent of its area to CoM 86032. The CoM 86032 was Maharashtra's most stable sugarcane variety, followed by CoM 265 and CoC 671. Co 740 also showed stability, retaining 70 per cent of its previous year's area. In contrast, sugarcane varieties Co 8014, Co 92005, and Co 7219 did not retain any cultivation areas from the previous year.

Economic viability of sugarcane variety CoM 265

The partial budgeting technique is used to evaluate the profitability or loss resulting from changes in the farm plan (Boehlje and Eidman, 1984). In this study, it was applied to assess the economic viability of cultivating the sugarcane variety CoM 265 replaced other existing varieties. Partial budgeting consists of four main components and additional

Table 2: Transitional probability matrix of major sugarcane varieties

Variety	Co 86032	CoC 671	Co 94012	Co 8014	CoM 265	Co 92005	Co 740	Co 7219
CoM 86032	**0.817**	0.000	0.003	0.006	0.126	0.051	0.000	0.000
CoC 671	0.277	**0.711**	0.010	0.000	0.000	0.000	0.000	0.000
Co 94012	0.000	0.564	**0.403**	0.0315	0.000	0.000	0.000	0.000
Co 8014	0.000	1.000	0.000	**0**	0.000	0.000	0.000	0.000
CoM 265	0.108	0.000	0.000	0.000	**0.778**	0.112	0.008	0.000
Co 92005	0.743	0.000	0.000	0.000	0.256	**0**	0.000	0.000
Co 740	0.267	0.000	0.000	0.000	0.000	0.006	**0.700**	0.000
Co 7219	0.000	0.000	0.000	1.000	0.000	0.000	0.000	**0**

Table 3: Economic worthiness of sugarcane variety CoM 265

Debit		Credit	
A. Added cost	Cost (Rs. /ha)	**C. Reduced costs (Savings)**	Cost (Rs. /ha)
1. Human labour	8429.15	1. Seed	3986.4
2. Chemical fertilizers	349.12	2. Biofertilizers	267.39
3. Irrigation	3340.15	3. Bullock labour	1741.44
4. Weedicide	487.51		
5. Micro-nutrients	1176.11		
6. Growth regulator	28.61		
7. Manure cost	850.67		
8. Machinelabour	876.27		
Added cost	15537.59	C. Reduced cost	5995.23
1. Opportunity cost of capital @ 6per cent	932.25		
2. Management cost @ 5per cent	776.87		
3. Risk premium @ 5per cent	776.87		
4. Research cost/ha	169.53		
5. Extension cost/ha	95.11		
B. **Total added cost**	2750.63	D. Total added returns	42770.8
Total debit side	18288.24	Total credit side	48766.03
The economic worthiness of the sugarcane variety CoM 265 = Rs. 30477.79			

costs are incurred from cultivating CoM 265 compared to the counterfactual variety, Co 92005. These may include costs related to inputs specific to the new variety. Reduced returns refer to any decrease in income that may occur due to the change in variety. Reduced costs include savings in certain expenses such as seed cost, bio-fertilizers, and bullock labour, which may be lower with the CoM 265 variety. Additional income represents the extra income generated from cultivating CoM 265 due to its higher yield than other varieties. The study estimates the net economic benefit or loss from cultivating the CoM 265 by analyzing these components.

The final step in the partial budgeting process involves estimating the net difference between the credit and debit sides. Table 6 presents the credit and debit components of the partial budget. As shown in Table 3, totat debit side includes additional cost for direct expenses Rs. 15537.59 and cost for indirect expenses including research cost was Rs. 2750.63. On the other hand, the savings in costs and increased income from cultivating CoM 265 amounted to Rs. 48,766.03 per hectare. Therefore, the net economic benefitor the total economic worthiness of the university-released sugarcane variety CoM 265 over competing varieties in Maharashtra was Rs. 30,477.79 per hectare. These findings align with earlier studies by Gulave *et al*, 2020.

Upscaling the economic impact

The results of the partial budgeting analysis can be extended to a larger area under sugarcane; however, a simple linear extrapolation of the benefit of Rs. 30,477.79 per hectare would be unrealistic due to the application of the law of diminishing marginal returns (LDMR) in agriculture (World Bank, 2003 and Suresh, 2022) Three key parameters were considered in the extrapolation process: the probability of performance technology (CoM 265), the adoption rate of the sugarcane variety, and the depreciation or decline in varietal performance over time (Table 4). After applying these parameters, the adjusted economic impact per hectare was estimated at Rs. 15,351.66. Given that the area under CoM 265 in 2023-24 was 307632 hectares, the total economic impact for that year was estimated at Rs. 1617.35 crore highlighting the significant contribution of CoM 265 to the sugarcane economy in Maharashtra, even after adjusting for real-world conditions like adoption variability and performance probability.

Total economic impact

Table 5 illustrates the total economic impact of the sugarcane variety CoM 265 over the sixteen years (2008-09 to 2022-24). The per hectare net gain for 2023-24 has been adjusted for inflation and deflated from 2013-24 to 2008-09. It helps compare the economic impact over time by accounting for the effects of inflation, ensuring that the net gain in real

Table 4: Upscaling the economic impact

Particulars	Cost (Rs.)
Probability performance of sugarcane variety	0.69
Rate of adoption of sugarcane variety	0.25
Depreciation of technology (if 1, no depreciation)	1
Economic worthiness of university released variety /ha	Rs. 30,477.79
The economic impact of university-released variety /ha	Rs. 5,257.42
The area under sugarcane variety com 265 in 2023-24 (ha)	307632
Economic impact for the year 2023-24	Rs. 1,617.35 crore

Table 5: Total economic impact of sugarcane variety CoM 265

Year	Net gain (Rs. /ha)	Area (ha)	Economic impact (Rs. in Crore)
2008-09	1799.21	4620	0.83
2009-10	2018.86	52164	10.53
2010-11	2293.90	128790	29.54
2011-12	2518.27	192034	48.36
2012-13	2782.01	204960	57.02
2013-14	3091.81	369638	114.28
2014-15	3312.77	331798	109.92
2015-16	3483.82	2520030	877.93
2016-17	3665.25	201737	73.94
2017-18	3791.51	298606	113.22
2018-19	3947.02	388496	153.34
2019-20	4099.95	197449	80.95
2020-21	4390.61	181568	79.72
2021-22	4628.03	302702	140.09
2022-23	4960.37	346094	171.68
2023-24	5257.42	307632	161.74
Total		6028316	2223.09

terms is consistent across the years. From 2008-09 to 2023-24, the net gain per hectare increased steadily, starting at Rs. 1799.21 in 2008-09 and rising to Rs. 5257.42 in 2023-24. The area under cultivation also grew significantly, from 4,620 hectares in 2008-09 to 3,07,632 hectares in 2023-24, reflecting farmers' expanding adoption of CoM 265. As a result, the total area under CoM 265 was 6028316 hectares over the entire period, contributing a total economic impact of Rs. 2223.09 crore. These findings demonstrate the monetary benefit for farmers and the significant contribution of CoM 265 to the sugarcane economy in Maharashtra.Comparable results were observed by Niranjan *et al* (2024) and Gulave *et al* (2020).

Conclusions and Policy Implications

The study reveals that the increase in sugarcane area and production in Maharashtra was primarily attributed to the area effect, exhibiting steady growth over time. However, productivity remained statistically insignificant and moderately unstable, indicating limited yield improvements during the study period. In 2023-24, the sugarcane variety CoM 265 occupied approximately 24.65per cent of Maharashtra's total cultivation area, retaining 77.80 per cent of its area compared to the previous year. In Maharashtra, the economic viability of the university-released sugarcane variety CoM 265, compared to competing sugarcane varieties, was estimated at Rs. 30,477.79 per hectare. The total economic impact of the sugarcane variety CoM 265 on the farming community in Maharashtra over sixteen years was estimated at Rs. 2,223.09 Crore. This study found the monetary returns from cultivating the university-released sugarcane variety CoM 265 profitable. Therefore, it is

recommended that future research investments in sugarcane research be enhanced to develop more improved varieties.

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Appendix I

The area under different sugarcane varieties in Maharashtra (%)

Year	Co 86032	CoC 671	Co 94012	Co 8014	VSI 434	CoM 265	Co VSI 9805	Co 92005	Co 740	Phule 10001	Others	Total area (Lakh ha)
2008-09	52.77	31.34	5.04	1.16	0.27	**0.60**	0.00	0	0.72	0.00	8.1	**7.70**
2009-10	59.56	24.21	2.61	0.47	0.19	**6.90**	0.10	0.00	0.16	0.00	5.80	**7.56**
2010-11	56.75	19.81	2.07	0.72	0.28	**13.36**	0.44	4.21	0.08	0.00	2.28	**9.64**
2011-12	57.05	16.44	1.09	0.08	0.25	**18.79**	0.54	4.09	0.02	0.00	1.65	**10.22**
2012-13	55.74	9.92	0.82	0.04	0.46	**25.62**	0.96	5.00	0.01	0.00	1.43	**8.00**
2013-14	48.38	6.81	0.59	0.03	0.24	**35.07**	1.04	5.69	0.03	0.00	2.12	**10.54**
2014-15	53.72	4.84	0.44	0.03	0.14	**31.45**	1.10	5.37	0.01	0.00	2.90	**10.55**
2015-16	52.87	4.70	0.48	0.14	0.46	**30.18**	0.88	6.26	4.03	0.00	0.00	**8.35**
2016-17	53.62	2.27	0.00	0.00	0.40	**31.87**	0.64	7.62	2.95	0.00	0.63	7.01
2017-18	50.99	1.40	0.00	0.00	0.33	**36.02**	0.23	5.24	0.00	1.20	4.59	**8.29**
2018-19	50.91	1.45	0.00	0.00	0.57	**31.03**	0.29	4.99	0.00	3.07	7.69	**12.52**
2019-20	48.49	1.44	0.00	0.00	0.57	**34.22**	0.29	3.67	0.00	4.17	7.15	**5.77**
2020-21	46.17	0.65	0.10	0.01	0.16	**28.15**	1.12	4.86	0.00	6.22	12.56	**6.45**
2021-22	47.27	0.69	0.14	0.01	0.32	**29.36**	0.23	2.16	0.00	6.28	13.54	**10.31**
2022-23	46.01	0.50	0.12	0.02	0.46	**26.48**	0.16	4.76	0.00	7.26	14.23	**13.07**
2023-24	48.07	0.43	0.08	0.01	0.22	**24.65**	0.23	3.66	0.00	7.04	15.61	**12.48**

Sources: 1) Central Sugarcane Research Station (CSRS), Padegaon, Mahatma Phule Krishi Vidyapeeth, Rahuri, and 2) Vasant Dada Sugar Institute (VSI), Pune.