

## Growth Performance of Cotton in India - Insights from Major Cotton Producing States

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### Abstract

The study revealed that there was significant growth in area, production, and productivity of cotton in period II (2004-05 to 2017-18) and the overall period (1995-96 to 2017-18) in major cotton-producing states of India which mainly attributed to the introduction of Bt cotton. The decomposition of cotton production in area, yield, and interaction effect showed that the yield effect in the case of Maharashtra, Andhra Pradesh, and Haryana was more while the interaction effect was found more pronounced in the case of Gujarat, and Rajasthan states. The area under cotton was found more stable than production and yield during different periods and overall periods in India. Therefore, policies should be framed to reduce the risks in production as cotton crop is highly prone to pests and diseases. To check the perennial pest infestation of cotton, effective disease and pest control measures need be developed.

**Keywords:** Cotton, Decomposition, Growth, Instability, Production

### Introduction

COTTON is a commercial crop that provides livelihood security to farm families in India and several countries. Cotton has been cultivated and used to make fabrics for at least 7,000 years. It may have existed in Egypt as early as 12,000 B.C. Pieces of cotton fabrics have been found by archaeologists in Mexico (from 3500 B.C.), in India (3000 B.C.), in Peru (2500 B.C.), and in the southwestern (500 B.C.) United States (Anonymous, 2017). India occupies 37.56 percent of the world cotton area and produces 24.26 percent of world cotton production and stands tall followed by China in the global scenario in 2019-20. The major cotton-producing countries are India, China, the United States, Brazil, and Pakistan accounting for 73 percent of the cotton area and 78 percent of total cotton production in the world (Pehsin *et al*, 2021). Asian countries harvest about 21.2 million ha and contribute 62.5 percent to world cotton production and 82.4 percent to total world consumption.

In the domestic scenario, it contributes around 65 percent of the raw material to the textile industry and provides employment to 60 million people (Anonymous, 2015). Furthermore, empirical studies in India have shown that increased cotton production

resulted in increased women's labor opportunities thereby contributing to poverty reduction (Subramanian, 2011).

India has the unique distinction of being the only country in the world to cultivate all four cultivable cotton species viz., *Gossypium arboreum* and *G. herbaceum* (Asian cotton), *G. barbadense* (Egyptian cotton) and *G. hirsutum* (American upland cotton) besides hybrid cotton on a commercial scale (Anonymous, 2017). India harvested a record production of 36.07 million bales from an area of 13.48 million hectares with a productivity of 455 kg/ha in 2019-20 (Anonymous, 2021). Though the productivity of cotton has increased over the years in India (Malik and Devi, 2020) it is still very low in comparison (decadal-2009-19, average 506.79 kg lint ha<sup>-1</sup>) to other cotton-growing countries like China (1794 kg lint ha<sup>-1</sup>), Brazil (1673 kg lint ha<sup>-1</sup>) and USA (968 kg lint ha<sup>-1</sup>). The area under Bt cotton increased from 6.3 million ha in 2007-08 to over 10.22 million ha during 2017-18. Of the total agricultural area, the area under the cotton crop accounts for approximately nine percent. Till the 1970s, the country used to import massive quantities of cotton in the range of eight to nine lakh bales per annum. However, after

Government launched special schemes like intensive cotton production programs through successive five-year plans, cotton production received the necessary impetus through an increase in area and the sowing of hybrid varieties around the mid70s. Since then the country has become self-sufficient in cotton production barring a few years in the late 90s and early 20s when large quantities of cotton had to be imported due to lower crop production and increasing cotton requirements of the domestic textile industry. Since the launch of the Technology Mission on Cotton by the Government of India in February 2000 significant achievements have been made in increasing yield and production through the development of high-yielding varieties, appropriate transfer of technology, better farm management practices, increased area under cultivation of Bt cotton hybrids etc. The quality profile of Indian cotton changed significantly. Long staple cotton which constituted 20 percent in 2000, increased to more than 88 percent of the total cotton produced in 2014 because of the Bt cotton hybrids, most of which are of the long staple category. Cotton is grown in the country's distinct agroecological zones (North, Central, and South). About 65 percent of India's cotton is raised in dry land and 35 percent on irrigated lands. These findings were in consonance with those obtained in a study conducted by Samuel *et al.*, (2015). The northern zone is virtually irrigated, whereas the percentage of irrigated area is much lower in the southern zone (40%) and the lowest in the central zone (23%) is almost 60 percent of the cotton area of our country. Cotton is cultivated throughout the country but the major cotton-growing states divided into three distinct regions are the northern part of Punjab, Haryana, and Rajasthan; the central part of Gujarat, Maharashtra, and Madhya Pradesh; and the southern part of Andhra Pradesh, Karnataka and Tamil Nadu (Sabesh *et al.*, 2014). Cotton crop has a prominent position among the commercial crops in these states. The growth of area, production, and productivity of cotton has not been equal across the different states of India. In the backdrop of this, the present study was undertaken to

- i) To examine the production performance of cotton in major cotton-producing states of India,
- ii) To analyze the growth, instability, and sources of growth of cotton in major cotton-producing states of India.

### Methodology

The study is based on secondary data compiled from the official websites of various Departments. The

data pertaining to the area, production, and productivity of cotton were collected from [www.dacnet.nic.in](http://www.dacnet.nic.in) of the Directorate of Economics and Statistics (DES),

Ministry of Agriculture, [www.cotcorp.gov.in](http://www.cotcorp.gov.in) of Cotton Corporation of India Ltd., Ministry of Textiles, etc. The data of the time series nature from the year 1995-96 to 2017-18 were collected and analyzed between three periods viz. Period I (1995-96 to 2003-04) before the introduction of Bt cotton, Period II (2004-05 to 2017-18) after the introduction of Bt cotton, and Overall period (1995-96 to 2017-18) for states and for the country as a whole. Triennium averages were worked out to even out the inter-year fluctuations in the data. The data were analyzed using the Compound Annual Growth rate (CAGR), Instability Index, and Decomposition model.

Compound Annual Growth rates (CAGR)

The annual compound growth rate (CAGR) for the cotton area, production, and yield of cotton were calculated as under:

$$Y_t = ab^t e^u$$

Log transformation of the above function is

$$\ln Y_t = \ln a + t (\ln b) + u$$

$$\ln b = \ln (1+r)$$

$$b = 1+r$$

$$r = b - 1$$

$$r = [\text{Antilog} (\ln b) - 1]$$

The compound growth rates were estimated as

$$\text{CGR} (\%) = r \times 100$$

Where,

$Y_t$  = area/production/yield/export of cotton for the year 't'

t = Time variable

a = Constant

ln b = Regression coefficient of time

u = Error term

r = CGR

The significance of these compound growth rates (CAGR) was tested at one percent, five percent, and ten percent levels of significance by using a student's t-test.

*Instability Analysis*

The present study used the Cuddy-Della Valle index owing to its usage in recent years by many researchers to estimate variability in time series data.

$$\text{Instability Index (II)} = \text{CV} \times (1 - R^2)^{0.5}$$

$$\text{CV} = (\text{Standard deviation} / \text{Mean}) \times 100$$

Where,

CV = Coefficient of Variation

$R^2$  = Co-efficient of multiple determination adjusted

from trend value

#### *Decomposition Analysis*

To measure the comparative contribution of area, and yield to the total change in cotton crop production, decomposition analysis was used (Minhas and Vaidyanathan, 1965). The method states that if  $A_0$ ,  $P_0$ , and  $Y_0$ , respectively are area, production, and productivity in the base year and  $A_n$ ,  $P_n$ , and  $Y_n$  are the values of the said variables in the element of the  $n$ th year.

$$P_0 = A_0 \times Y_0 \text{ and} \\ P_n = A_n \times Y_n \text{ ————— (1)}$$

Where  $A_0$  and  $A_n$  represent the area and  $Y_0$  and  $Y_n$  represent the yield in the base year and  $n$ th year respectively

$$P_n - P_0 = \Delta P,$$

$$A_n - A_0 = \Delta A$$

$$Y_n - Y_0 = \Delta Y \text{ ————— (2)}$$

From equations (1) and (2) we can write

$$P_0 + \Delta P = (A_0 + \Delta A)(Y_0 + \Delta Y)$$

$$\text{Hence, } \Delta P = A_0 * \Delta Y + Y_0 * \Delta A + \Delta A * \Delta Y$$

Production = Yield effect + area effect + interaction effect

As a result, the total production change can be decomposed into three components viz. yield effect, area effect, and interaction effect due to yield and area change.

### **Results and Discussion**

#### *Cotton Production Scenario in India and Major Cotton Producing States*

The details of the area, production, and yield of cotton in India and major cotton-producing states during TE 1995-96 To TE 2017-18 are presented in Table 1. The area under cotton in the country increased from 8075.70 thousand hectares in TE 1995-96 to TE 11901.47 thousand hectares in 2017-18.

After the introduction of Bt technology, the area under the cotton crop was found to increase. The highest area under cotton in India was recorded in the year 2015-16 at 12357.00 thousand hectares. The area under cotton receded drastically to 11979.13 thousand hectares in TE 2016-17 and then to 11901.47 in TE 2017-18 due to fear of infestation of whitefly in the north zone, infestation of pink bollworms in central and south zones including the decision of Andhra Pradesh and Telangana states for diversion of cotton area to

pulses and oilseeds.

A perusal of Table 1 reveals that the production of cotton in India has increased from 11830.00 thousand bales in TE 1995-96 to 31795.80 thousand bales in TE 2017-18. The progress of cotton production in the country remained impressive from the TE 2003-04 to 2015-16 due to the adoption of Bt hybrids by the farmers in the country and the adoption of modern technologies. Bt cotton has played a catalytic role in enhancing cotton production in India.

The yield of cotton in India increased from 249.33 kg/ha in TE 1995-96 to 456.67 kg/ha in TE 2017-18. Cotton yield in India has witnessed a substantial increase over the years. The yield of cotton started increasing from 189 kg/ha in TE 2002-03 to 463.0 kg/ha in 2016-17 which might be attributed to the widespread adoption of Bt cotton during the period. In TE 2017-18, there was a slight decrease in the productivity of cotton to 456.67 kg/ha.

Cotton is grown in different states of India, but the major cotton-producing states of India viz. Maharashtra, Gujarat, Andhra Pradesh (Telangana), Haryana, and Rajasthan contributed 29.52, 25.38, 5.80, 4.88, and 4.72 percent respectively in total production of cotton in the country in TE 2017-18. These states covered about 70 percent of the production of cotton in the country. Based on the production Gujarat ranked at the top with a share of 29.52 percent. In terms of area under cotton Maharashtra occupied the top position with a share of 34.61 percent in the 11901.47 thousand hectares of area under cotton cultivated in the country. However, the average yield of cotton was one of the lowest in Maharashtra at 338.67 kg/ha as against 456.67 kg/ha for the country as a whole in TE 2017-18. A perusal of Table 1 showed that the area under cotton in Gujarat has increased from 1247.00 (thousand hectares) in TE 1995-96 to 2576.00 thousand hectares in TE 2017-18. After the introduction of Bt technology, the area under the cotton crop was found to increase thereafter. The highest area under cotton was recorded in the TE 2015-16 at 2671.33 thousand hectares. The production of cotton in Gujarat increased from 2031.33 thousand bales (of 170 Kg each) in TE 1995-96 to 9387.3 thousand bales (of 170 Kg each) in TE 2017-18. The highest production of cotton was recorded in the TE 2015-16 (10016.67 thousand bales). The yield of cotton in Gujarat increased from 276.67 kg/ha in TE 1995-96 to 619.67 kg/ha in TE 2017-18. There was more increase in yield from TE 2005-06 which

Table 1. Area, Production, and Productivity of Cotton in Major Cotton Producing States of India, (TE 1995-96 to TE 2017-18)  
Area ' 000 Hectares, Production ' 000 Bales of 170 kg, Yield Kg/ha

States		1995-96	2000-01	2005-06	2010-11	2015-16	2016-17	2017-18
Gujarat	A	1247.00	1604.53	1817.77	2483.53	2671.33	2625.67	2576.00
	P	2031.33	2383.33	5174.57	8466.70	10016.67	9491.67	9387.33
	Y	276.67	250.67	480.67	576.33	638.67	614.33	619.67
Maharashtra	A	2768.0	3176.6	2825.7	3527.7	4196.3	4065.8	4119.5
	P	2640.3	2505.8	3059.7	6370.4	7778.0	8372.9	8070.9
	Y	163.0	133.3	184.3	303.0	315.0	354.0	338.7
Andhra Pradesh	A	877.33	1113.90	1016.00	1089.70	721.13	653.00	594.67
	P	1461.67	1593.23	2062.67	4032.00	2046.70	2097.67	1846.33
	Y	286.67	246.67	349.00	429.33	475.00	544.33	531.33
Haryana	A	588.67	560.33	576.67	484.67	599.67	611.00	616.67
	P	1260.00	1186.67	1659.67	1844.67	1865.00	1778.00	1553.67
	Y	365.33	362.33	486.33	648.33	535.67	495.33	433.00
Rajasthan	A	536.7	579.4	417.6	360.6	442.7	468.7	501.0
	P	1017.3	887.2	784.7	842.9	1342.7	1381.0	1503.0
	Y	318.7	261.7	321.7	403.3	517.0	500.0	506.0
India	A	8075.70	8861.97	8353.87	10257.80	12357.00	11979.13	11901.47
	P	11830.00	11112.33	16218.87	26432.67	33570.67	32462.47	31795.80
	Y	249.30	179.67	329.00	435.00	462.33	463.00	456.67

might be attributed to the widespread adoption of BT cotton during this period. The highest yield of cotton was recorded in the state in TE 2015-16 at 638.67 kg/ha.

Maharashtra accounted for the largest area (34.46%) under cotton in the country. The state produced 25.38 percent of cotton production in the country in 2017-18. The area, production, and yield of cotton in Maharashtra from TE 1995-96 to TE 2017-18 are presented in Table 1. The area under cotton increased from 2768.00 thousand hectares in 1995-96 to 4119.5 thousand hectares in 2017-18. With the introduction of Bt technology, the area under the cotton crop was found to increase thereafter. The highest area under cotton was recorded in the TE 2015-16 at 4196.3 thousand hectares. The production of cotton in Maharashtra state increased from 2640.3 thousand bales (of 170 Kg each) in TE 1995-96 to 8070.9 thousand bales (of 170 Kg each) in TE 2017-18. There was an increase in production of cotton onwards 2005-06 and reached the maximum, at 8372.9 thousand bales in 2016-17. In the year 2017-18, there was a slight decline in cotton production due to a decline in the yield of cotton. Over time the yield of cotton in Maharashtra state increased from 163.0 kg/ha in TE 1995-96 to 338.7 kg/ha in TE 2017-18. There was more increase in yield from 2004-05 which might be attributed to the widespread adoption of BT cotton

during this period. The highest yield of cotton was recorded in TE 2016-17 at 354.0 kg/ha.

Andhra Pradesh accounted for 4.99 percent of the total area under cotton cultivation and contributed nearly 5.80 percent of cotton production in the country. The area, production, and yield of cotton in Andhra Pradesh from TE 1995-96 to TE 2017-18 are presented in Table 1. The area under cotton has increased from 877.33 thousand hectares in 1995-96 to 1113.90 thousand hectares in TE 2000-01 and declined to 1016.00 thousand hectares in 2005-06. But in TE 2010-11 again surge in the area under cotton was observed to 1089.70 thousand hectares. The highest area under cotton was recorded in the TE 2009-10 at 1333.3 thousand hectares. The production of cotton in India has increased from 1461.67 thousand bales (of 170 Kg each) in TE 1995-96 to 1846.33 thousand bales in TE 2017-18. With the introduction of Bt technology, the production of cotton crops was found to increase. The highest production of cotton was recorded in the year 2010-11 at 4032.00 thousand bales. After the formation of Telangana, the production of cotton in the state declined along with a decline in the area under the cotton crop. But the yield of cotton increased in the state increased from 286.67 kg/ha in TE 1995-96 to 531.33 kg/ha in TE 2017-18.

In Haryana, the area, production, and yield of cotton during TE 1995-96 to TE 2017-18 presented in

Table 2: Growth of Cotton in Major Cotton Producing States of India (%)

Periods/Particulars	States					India
	Gujarat	Maharashtra	Andhra Pradesh	Haryana	Rajasthan	
<b>Period I (1995-96 to 2003-04)</b>						
Area	3.12*** (0.00)	0.39NS (0.56)	0.59NS (0.59)	-1.33** (0.031)	-3.52** (0.05)	-0.21NS (0.73)
Production	-3.13NS (0.37)	-0.55NS (0.48)	0.61NS (0.37)	-2.98*** (0.00)	12.17*** (0.00)	-3.05* (0.00)
Yield	-6.00* (0.08)	-0.94NS (0.47)	-0.11NS (0.91)	-1.36NS (0.11)	-8.50*** (0.00)	-3.63* (0.06)
<b>Period II (2004-05 to 2017-18)</b>						
Area	3.01*** (0.00)	3.69*** (0.00)	-5.18*** (0.00)	1.07* (0.06)	1.67*** (0.00)	3.61*** (0.00)
Production	6.09*** (0.00)	8.60*** (0.00)	-1.06NS (0.58)	1.3NS (0.21)	7.08*** (0.00)	6.97*** (0.00)
Yield	3.06*** (0.00)	4.83*** (0.00)	3.85*** (0.00)	0.31NS (0.78)	5.21*** (0.00)	3.32*** (0.00)
<b>Overall period (1995-96 to 2017-18)</b>						
Area	3.64*** (0.00)	1.81*** (0.00)	-2.32*** (0.00)	-0.10NS (0.45)	-1.62*** (0.00)	1.93*** (0.00)
Production	9.30*** (0.00)	7.20*** (0.00)	2.44*** (0.00)	3.09*** (0.00)	2.12** (0.05)	6.64*** (0.00)
Yield	5.47*** (0.00)	5.31*** (0.00)	4.03*** (0.00)	3.28*** (0.00)	3.81*** (0.00)	4.94*** (0.00)

Note: Figures in parentheses indicate P- value

\*, \*\*, and \*\*\* indicate significance at 10 percent, 5 percent, and 1 percent levels, respectively

Table 1 reveals that the area under cotton increased from 588.67 thousand hectares in TE 1995-96 to 616.67 thousand hectares in 2017-18. Production and yield of the cotton crop increased considerably till TE 2015-16 but trends reversed then till 2004-05. The highest yield of cotton was observed in the TE 2010-11 with 648.33kg/ha. The productivity of cotton declined thereafter from 648.33kg/ha in TE 2014-15 then to 433.00 kg/ha in 2017-18 but higher production was attained due to increased area under cotton crop in the state.

The trends in the area, production, and yield of cotton in Rajasthan are presented in Table 1. In TE 1995-96 the area under cotton crop was 536.67 thousand hectares, further decreased to 360.6 thousand hectares in TE 2010-11 and in TE 2017-18 it reached 501.0 thousand hectares while the production was maintained at 1503.00 thousand bales with productivity level of 506 kg/ hectares.

#### *Growth of Cotton in Major Cotton Producing States of India*

The CAGR of area, production, and yield of cotton in major cotton-producing states and for the country as a whole is presented in Table 2. The decrease in the area was observed (-0.21%) in period I which then grew at the rate of 3.61 percent in period II. But in period I, the decrease in area was not significant while in period II the increase in area was found significant at a one percent level. A growth rate of 1.93 percent in the area was observed in an overall

period which was significant at a one percent level. The performance of production was not impressive in period I as there was a significant decline in the production of cotton at the rate of 3.05 percent which might be due to a decrease in the area during the said period. Period II witnessed a higher growth rate in production which was 6.97 percent significant at a one percent level of significance. It was noticed that during the overall period, the production of cotton increased significantly at the rate of 6.64 percent. The productivity growth during period I in the country was negative significantly (-3.63%) while it showed positive growth in period II and the overall period at the rates of 3.32 percent and 4.94 percent respectively. It can be revealed that there was significant growth in area production and productivity of cotton in period II and the overall period mainly attributed to the introduction of Bt cotton.

The compound annual growth rate (CAGR) of the area, production, and yield of cotton in Gujarat is presented in Table 2. The CAGR of the area under cotton was positive (3.12%) and significant at 1 percent level during period I while during period II and overall period, corresponding figures were noticed to be positive and significant with a magnitude of 3.01 percent and 3.64 percent respectively. It is apparent from the table that the CAGR for cotton production showed a negative growth rate during period I but growth was non-significant (-3.13%). The growth trends in production in period II (6.09%) and the overall

Table 3: Instability of Cotton in Major Cotton Producing States of India (%)

Periods/Particulars	States					India
	Gujarat	Maharashtra	Andhra Pradesh	Haryana	Rajasthan	
Period I (1995-96 to 2003-04)						
Area (%)	4.01	5.02	8.01	3.89	11.34	4.61
Production (%)	24.55	5.83	5.47	5.25	16.03	6.44
Yield (%)	21.48	9.93	9.23	6.06	10.03	12.81
Period II (2004-05 to 2017-18)						
Area (%)	7.45	5.00	21.94	7.55	7.90	4.68
Production (%)	15.52	12.68	30.26	15.17	9.19	12.39
Yield (%)	10.73	10.76	27.03	16.60	7.86	9.41
Overall period (1995-96 to 2017-18)						
Area (%)	6.84	8.82	19.19	7.7	15.98	8.43
Production (%)	27.17	17.5	29.38	17.49	29.36	19.4
Yield (%)	24.08	14.85	10.23	19.42	22.05	18.31

Table 4: Per cent Contribution of Area, Yield, and their Interaction towards Production of Cotton in Major Cotton Producing States of India, 1995-96 to 2017-18

Periods/Particulars	States					India
	Gujarat	Maharashtra	Andhra Pradesh	Haryana	Rajasthan	
Period I(1995-96 to 2003-04)						
Area effect	152.47	77.52	46.50	36.23	41.68	-8.99
Yield effect	-39.06	21.74	51.22	67.27	75.75	108.23
Interaction effect	-13.41	0.94	2.28	-3.50	-17.43	0.76
Period II(2004-05 to 2017-18)						
Area effect	28.28	25.42	-431.97	188.50	18.27	32.46
Yield effect	48.08	50.69	840	-79.66	63.45	45.5
Interaction effect	23.64	23.87	-308.41	-8.84	18.28	22.04
Overall period(1995-96 to 2017-18)						
Area effect	29.38	23.33	-125.70	19.69	29.38	27.87
Yield effect	34.19	51.51	333.00	76.66	34.18	48.95
Interaction effect	36.43	25.15	-107.30	3.65	36.44	23.18

period (9.30%) were found positive and significant at a one percent level. The CAGR for a yield of cotton in Gujarat was negative (-6.00%) and significant at a ten percent level during period I. However it is worth mentioning that it was found positive and significant during period II (3.06%) and overall period (5.47%). In the case of the overall period, area and yield contributed jointly to the significant increase in cotton production. The single most important factor of the widespread adoption of Bt cotton resulted in growth in area and productivity which resulted in production growth of 9.30 percent during the period 1995-96 to 2017-18

During the period I (1995-96 to 2003-04) the CAGR of area, production, and yield of cotton in Maharashtra was 0.39, -0.55, and -0.94 percent which were non-significant. The compound growth rates of area and production of cotton were highest during period II (2004-05 to 2017-18) at 3.69, and 8.60 percent respectively which was significant at a one percent level. The CAGR of area, production, and yield of cotton in Maharashtra state in the overall period (1995-96 to 2017-18) at 1.81 percent, 7.20 percent, and 5.31 percent respectively were positive and significant. The introduction of Bt cotton significantly increased production from all the sources of growth.

In Andhra Pradesh during period I, the CAGR of the area under cotton was positive at 0.59 percent but non-significant (Table 2). The area under cotton during period II decreased significantly at the rate of -5.18 percent. In the overall period, the decrease in the area was at the rate of -2.32 percent which was significant at a one percent level of significance. The non-significant decrease in the production of cotton was observed at the rate of -1.06 percent during period II. There was a significant increase in the production of cotton in the state at the rate of 2.44 percent. The highest increase in yield of cotton in Andhra Pradesh was noticed in the overall period to the tune of 4.03 percent per annum followed by period II (3.85%). During the period I there was a decrease in yield at the rate of -0.11 percent but found non-significant. It can be inferred that in the overall period due to an increase in the productivity of cotton, production of cotton in the state increased significantly.

In Haryana, during the period I, the compound annual growth rate of the area under cotton was positive and significant at 1.33 percent which showed growth in the area under cotton during this period. But production decreased significantly at the rate of -2.98 percent. These findings were similar and consistent with the findings of Suresh *et al.* (2013) as it was reported that the decline in the performance of cotton attributed due to the infestation of cotton plant with mealy bug and American bollworm causing serious damage to cotton in Haryana. The decline in yield at the rate of -1.36 percent was noticed but was non-significant. The area during period II increased significantly at the rate of 1.07 percent whereas an increase in production and yield was noticed at the rate of 1.3 percent and 0.31 percent respectively but the increase was non-significant. In the overall period, production increased significantly at the rate of 3.09 percent due to significantly increased yield at the rate of 3.28 percent per annum (Table 1).

The growth in area, production, and yield of cotton in Rajasthan (Table 2) reveals that the area under cotton decreased significantly during the period I with a CAGR of -3.52 percent but during period II area grew significantly at the rate of 1.67 percent. However, the CAGR of the area under cotton was founded significantly declined (-1.62%) during the overall period. The CAGR in production in the period I was -12.17 percent showing a significant decline in production during the period. But during period II and

the overall period the growth in production of cotton was positive and significant at 7.08 percent and 2.12 percent respectively. The yield of cotton in the state found declined significantly at the rate of -8.50 percent per annum during the period I. But thereafter growth in yield was observed during period II and the overall period at the CAGR of 5.21 percent and 3.81 percent respectively which were found significant at a one percent level of significance.

#### *Instability of Cotton in Major Cotton Producing States of India*

The instability indices of area, production, and yield were estimated and are presented in Table 3. The area under cotton in India indicated instability of 4.61 percent, 4.68 percent, and 8.43 percent during the period I (1995-96 to 2003-04), period II (2004-05 to 2017-18), and overall period (1995-96 to 2017-18) respectively. Similarly, the production showed variability of 6.44 percent, 12.39 percent, and 19.4 percent respectively during periods I, II, and the overall period. The variability in yield was 12.81 percent in period I 9.41 percent in period II and 18.31 percent in the overall period.

The area in Gujarat was found more stable during period I while the production of cotton (15.52 %) and yield of cotton (10.73%) were more stable in period II in the state. In the overall period, the production of cotton and yield recorded the highest variation i.e. 24.17 percent and 24.55 percent respectively. The variation in area production and yield due to uncontrollable factors like climatic conditions could cause upward bias in the instability index.

Maharashtra was having highest variability in the area (8.82%) production (17.54) and yield (14.85 percent) of cotton during the overall period. The state showed the lowest variability in the area during period II while instability in production (5.83%) and yield (9.93%) was found lowest during the period I. The stability of production and yield was found highest in period I as compared to period II and the overall period. In Andhra Pradesh, the variability of area, production, and yield was highest in period II with the percentage of 21.94 percent, 30.26 percent, and 27.03 percent respectively. In the overall period, the variability of area, production, and yield was 19.19 percent, 29.38 percent, and 10.23 percent respectively. During the period I area, production, and yield were found more stable.

Instability in the area under cotton in Haryana state was 7.70 percent during the overall period while

the instability of production and yield was 17.49 percent and 19.42 percent respectively during this period. The Instability of area, production, and yield of cotton in Haryana in period II was 7.55, percent, 15.17 percent, and 16.60 percent respectively. During the period I the instability in the area, production and yield of cotton in Haryana in the period I (1995-96 to 2017-18) was found lowest i.e. 3.89 percent, 5.25 percent, and 6.06 percent respectively. The highest instability in yield was recorded in an overall period of 19.42 followed by 16.60 percent and 15.17 percent in period II 2004-05 to 2017-18 and period I respectively.

Rajasthan experienced high variability in the area (15.98%) and production (29.36%) due to yield variation (22.05%) during the overall period. The variability in area, production, and yield of cotton during the period I was 11.34 % 16.03 %, and 10.03 % respectively. But in the period II area, production and yield were found more stable in period II with 7.9 percent, 9.19 percent, and 7.86 percent respectively.

#### *Sources of Growth of Cotton Production*

The decomposition of cotton production in area, yield, and interaction effect are presented in Table 4 and the results demonstrate the percent contribution of area, yield, and their interaction for increasing of production of cotton in India. In period I, the results clearly indicated that the yield effect of 108.23 percent was more responsible for increasing the production of cotton in India with area effect and interaction effect of -8.99 percent and 0.76 percent respectively. It is revealed that the production of cotton in India in this period was increased due to an increase in yield not due to increased area as the area effect was negative for cotton during the period I. In period II also yield effect had got domination over the area and interaction effect. In period II, the production of cotton increased due to both area and yield. The area effect was found 32.46 percent whereas the yield effect was 45.50 percent and the interaction effect was 22.04 percent respectively.

During the overall period, the yield effect had recorded domination over the area and interaction effect. The area, yield, and interaction effect were 27.87 percent, 48.95 percent, and 23.18 percent respectively. So it is concluded that in this period, the yield effect was responsible for increasing for production of cotton in India.

The decomposition of cotton production in area, yield, and interaction effect for Gujarat state brought

out that in period I the area effect of 152.47 percent was more pronounced for increasing the production of cotton in Gujarat state with yield effect of -39.06 percent and interaction effect of -13.41 percent. In period II, the yield effect was found more pronounced at 48.08 percent than that of the area effect (23.64%) which indicated that the production of cotton in Gujarat state in period II increased more due to an increase in yield. In the overall period, the interaction effect was responsible for the production of cotton in Gujarat.

In Maharashtra, in period I the results clearly indicated that the area effect of 77.32 percent was more responsible for increasing the production of cotton in India with an interaction effect of 21.74 percent and yield effect of 0.94 percent. The results were inconformity with the findings of Patel *et al* (2016) which showed increase in area under cotton due to adoption of Bt cotton. It is revealed that the production of cotton in the state was increased due to an increase in area not due to increased yield as the area effect was more for cotton during period I. In period II also yield effect had got domination over the area and interaction effect, thus, the production of cotton increased due to the yield effect.

In Andhra Pradesh in period I the yield effect (51.22%) was more pronounced for increasing the production of cotton. The area effect was in correspondence to the compound annual growth in the area and stability in the area during the period. The area effect and interaction effect for increasing the production of cotton were 46.50 percent and 2.28 percent respectively. In period II yield effect at 840.38 percent was more pronounced while the area effect was found negative (- 431.97 percent). In the overall period, the yield effect was observed to be positive i.e. 333.00 percent while the area effect and interaction effect were found negative with -125.70 percent and -107.30 percent respectively.

The results demonstrate the percent contribution of area, yield, and their interaction for increasing the production of cotton in Haryana. In the period I the results clearly indicated that the yield effect of 67.27 percent was more responsible for increasing the production of cotton in Haryana with an area effect of 36.23 percent and an interaction effect of -3.50 percent. It is revealed that the production of cotton in India was increased due to an increase in yield not only due to increased area as the yield effect was more for cotton during period I. In period II area effect



Table 5: Area of Bt Cotton, Non-Bt Cotton and Total Cotton in Major States of India, 2005-06 to 2017-18 (Area: In Lakh Hectares)

Year	Gujarat		Maharashtra		Andhra Pradesh		Haryana		Rajasthan		India							
	Bt	Non-Bt	Total	Bt	Non-Bt	Total	Bt	Non-Bt	Total	Bt	Non-Bt	Total						
2005-06	1.06	17.12	18.18	1.79	19.79	21.58	0.58	8.67	9.25	0.04	6.05	6.08	0.01	4.17	4.18	5.32	78.22	83.23
2006-07	2.27	18.40	20.67	7.29	21.86	29.15	2.73	7.88	10.61	0.18	5.60	5.78	0.02	4.17	4.20	16.55	72.15	88.70
2007-08	6.19	16.21	22.39	15.75	14.84	30.59	5.82	4.64	10.46	1.11	4.21	5.32	0.15	3.82	3.84	36.29	54.49	90.78
2008-09	10.52	13.36	23.89	22.63	8.86	31.49	9.33	2.35	11.68	2.22	2.67	4.89	1.37	2.74	3.50	55.64	37.58	93.22
2009-10	14.30	9.84	24.13	27.27	5.51	32.79	11.32	2.01	13.33	3.72	1.10	4.82	2.29	2.14	3.81	70.87	25.64	96.51
2010-11	16.92	7.91	24.84	30.54	4.73	35.28	13.66	2.16	15.82	4.18	0.67	4.85	3.03	1.29	3.83	81.35	21.24	102.58

had got domination over the yield and interaction effect. In period II, the production of cotton increased due to the area under cotton in Haryana. The area effect was found 188.50 percent whereas the yield effect and interaction effect were -79.66 percent was -8.85 percent respectively. During the overall period, the yield effect (76.66%) recorded domination over area and interaction effect which were 19.69 percent and 3.65 percent respectively so it is concluded that in this period, the yield effect was responsible for increasing for production of cotton in Haryana.

In Rajasthan state in period I the increase in output of cotton was mainly due to an increase in yield with the contribution towards yield for this crop of 75.75 percent in the state. Therefore, the yield effect was more responsible for cotton production followed by the area effect which came out to be 41.68 percent. The interaction effect was -17.43 percent. In period II output expansion of cotton was influenced more by expansion of yield (63.45%) followed by expansion of area (18.28%). In the overall period, the production of cotton was influenced by more yield (34.18 %) followed by interaction effect (36.44%) and area effect (29.38%).

#### Adoption of Bt Cotton Hybrids in India

Bt cotton, which confers resistance to important insect pests of cotton, was first adopted in India as a hybrid in 2002. The early adopters of Bt cotton were Gujarat and Maharashtra followed by Andhra Pradesh and Karnataka. The area under Bt cotton in Gujarat was 1.06 lakh hectares which jumped to 22.69 lakh hectares while that of non-Bt cotton which was grown in 17.12 lakh hectares in the state declined to 2.84 lakh hectares. Similar was the situation with other states i.e. Maharashtra, Andhra Pradesh, Haryana, and Rajasthan, where the area under Bt cotton increased to 34.87, 11.89, 5.04 3.80 lakh hectares respectively in the year 2017-18. In India, the area under Bt cotton increased from 5.32 lakh hectares in 2005-06 to 102.27 lakh hectares in 2017-18 and that of the non-Bt cotton area declined from 78.22 lakh hectares to 16.24 lakh hectares during the said period (Table 5).

#### Growth in Area Under Bt and Non-Bt Cotton in Major States of India

Growth in the area of Bt, Non-Bt, and Total cotton of major producing states i.e. Gujarat, Maharashtra, Andhra Pradesh, Haryana, and Rajasthan is presented in Table 6. The significant positive growth rate of area under BT cotton in Rajasthan was observed from 2005 to 2018 (54.03%) followed by Haryana (36.29 %), Gujarat (24.39 %), Andhra Pradesh (19.80%) Maharashtra (19.03%). The growth of area under non-bt cotton in Rajasthan, Haryana, Gujarat Andhra Pradesh Maharashtra declined at the rate of -11.44 percent-16.62 percent, -19.74 percent, -20.96 percent-12.43 percent from 2005 to 2018. The area under cotton in major cotton-producing states was stagnant or declining before the introduction of Bt in 2002-03 showing a significant increase in area under cotton in most of the states. Adoption of Bt cotton

Table 6: Compound Growth Rate in Area under Bt Cotton &amp; Non Bt Cotton in Major States of India, 2005-06 To 2017-18

States	Variable	Bt cotton	Non-Bt cotton	Total cotton
Gujarat	Area	24.39***	-19.74	-12.43***
Maharashtra	Area	19.03***	-12.43***	3.84*
Andhra Pradesh	Area	19.80***	-20.96***	3.84*
Haryana	Area	36.29***	-16.62***	1.11*
Rajasthan	Area	54.03***	-11.44***	1.82***
India	Area	20.90***	-14.36***	3.49***

(Note: \*, \*\*, and \*\*\* indicate significance at 10 percent level, 5 percent level, and 1 percent level, respectively.)

benefitted the farmers through higher profitability mainly due to reduced pest control costs and higher yields.

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