Original Research Article

Soybean based Cropping Systems in Central India: Production Growth and Instability Analysis

Abstract

Aim: Soybean being one of most substantial contributor to the Indian edible oil pool and Madhya Pradesh being its dominant contributor necessities the study on growth and instability of soybean based cropping systems in Madhya Pradesh.

Study and Design: The estimates of compound growth rate and instability were worked out for the period of 32 years (1988-89 to 2019-20).

Place and Duration of study: The study was conducted in nine major soybean growing districts having more than 75 percent Kharif cropped area under soybean crop including Bhopal (84%), Sehore (82%), Rajgarh (82%), Indore (91%), Ujjain (98%), Mandsaur (78%), Ratlam (79%), Shajapur including Aagar Malwa (95%) and Harda (75%) were purposively selected for the present study of Madhya Pradesh state by taking wheat and gram as Rabi crop in the system.

Methodology: The exponential trend equation was used to estimate the compound growth rate. Using the Cuddy Della Valle Instability Index (CDVI) the risk was estimated of the soybean crop's area, production, and productivity.

Result: The results of study reveal that in the state of Madhya Pradesh positive and significant growth rate in area, production and productivity of soybean based cropping systems i.e. soybean, wheat after soybean and chickpea after soybean were observed. On the contrary growth in productivity of soybean was positive but it is insignificant. The most of the selected districts also lies in low instability zone for production components of soybean based cropping systems.

Conclusion: The 30 per cent of the soybean production in the state was in low range of production growth with low to medium instability.

Key words*: Soybean, Wheat, chickpea, Madhya Pradesh, Cropping Systems, Growth, Instability*

1. Introduction

Soybean (*Glycine max*) is a popular leguminous oilseed crop that provides a good source of protein and edible oil for human. After five decades of its commercial cultivation in India, soybean has established itself as a key oilseed crop (Sharma, 2016). It is one among the world's fastest growing oilseed crops and plays a vital part in the edible oil sector. India ranks fourth in area with 11.34 million hectares accounting for 9.41 per cent of the world area and fifth in production with 11.22 million tons in 2019-20 (Soybean Outlook, January, 2022). Soybean also makes a significant contribution to the Indian edible oil pool. Soybeans currently account for 43 per cent of overall oilseed production and 25 per cent of total oil production in the country (Evaluation of the PPPIAD, Project on soybean, FICCI). In India area under soybean (2021-22) was 121.76 lakh hectares. Among the states, Madhya Pradesh stood first with 55.84 lakh ha followed by Maharashtra (46.01 lakh ha), Rajasthan (10.62 lakh ha), Karnataka (3.82 lakh ha), Gujarat (2.24 lakh ha) and Telangana (1.51 lakh ha) as per Soybean Outlook, 2022. In Madhya Pradesh, soybean has long been a major crop of kharif season accounting for about 40 per cent of the kharif crop

area. In the rainfed agro-ecosystems of central and peninsular India, soybean has established itself as a key rainy season crop (Agarwal *et. al.*, 2013). Soybean-wheat cropping systems are common under irrigated conditions, whereas soybean-chickpea cropping systems are common in rainfed conditions in state of Madhya Pradesh (Gathiye and Kushwaha, 2019). Area under wheat was 102.17 lakh ha and that of chickpea was 19.26 lakh ha. These two crops together constitutes 91 per cent of total Rabi crop area in the state of Madhya Pradesh (2019-20). The objective of this paper is to examine instability and growth in production component of soybean based cropping systems including wheat and gram as dominating Rabi crops in the system. Evaluation of production performance i.e. growth and instability helps policy makers to frame research and development strategies for sustainable production (Deb and Pramanik, 2015). Because in the recent past the acreage of soybean is substituted by maize crop in many soybean growing districts of Madhya Pradesh on account of aberrant weather peril.

2. Research Methodology

Nine districts viz., Bhopal (84%), Sehore (82%), Rajgarh (82%), Indore (91%), Ujjain (98%), Mandsaur (78%), Ratlam (79%), Shajapur including Aagar Malwa (95%) (as Aagar Malwa is newly formed district) and Harda (75%) were purposively selected for the present study based on the maximum area under soybean crop (>75% of Kharif cropped area) from state of Madhya Pradesh. The corresponding area under wheat and chickpea were considered for collection of secondary data. The secondary data regarding area, production, productivity, were collected from the website of Ministry of Agriculture and Farmers Welfare and compiled data of Agro Economic Research Centre, JNKVV, Jabalpur. The secondary data were collected for the period of 32 years (1988-89 to 2019-20). To calculate the compound growth rate (CGR) in production component of soybean based cropping systems, the following exponential trend equation was used:

$$Y = ab^t$$

Where Y = The variable for which growth rate is calculated,
t = time variable taking the values 1, 2, 3,… n,
a = intercept,
b = the regression co-efficient of 'Y' on t.
CGR in per cent was expressed as:

$$\text{CGR (\%)} = (\text{Antilog } b - 1) \times 100$$

The CGR value was tested for its significance using t test. The range of CGR was distributed as:

- Low growth rate = less than 3
- Medium growth rate = 3 to 6
- High growth rate = 6 and above

The method suggested by Cuddy Della Valle (1978) was used to compute the instability index in production component. The Cuddy Della Valle Index (CDVI) was calculated as follows:

$$\text{CDVI} = \frac{\text{Standard Deviation } (\sigma)}{\text{Mean } (\bar{X})} * 100 * \sqrt{1 - \bar{R}}$$

Where, $\bar{R}$ is adjusted coefficient of determination and Instability index ranges from:

- Low instability = 0 to 15
- Medium instability >15 and < 30
- High instability > 30

Krishan and Chanchal (2014) and Vekariya *et. al.(*2020) employed Cuddy Della Valle Index to measure instability and considered coefficient of determination from a time-trend regression adjusted by the number of degrees of freedom.

3. Results & discussion

Farmers' response to adoption of crop mainly depends on profitability from the crop and adaptability in the agro-ecosystem. Soybean being lesser known crop till 1970 gradually becomes most important oilseed crop of Madhya Pradesh mainly because of its economic superiority over other crops (Sharma, 2016b). As presented in table 1 the compound growth rate of area of soybean (3.30%) in Kharif season and wheat (2.30%) and chickpea (1.10%) crops in Rabi season were found to be positive and significant in Madhya Pradesh for the period 1988-89 to 2018-19. Although, the growth in area of soybean was higher as compared to growth in area of wheat and chickpea. Similar results with positive and significant CGR were observed by Rajneet *et. al.* (2018) for area of soybean, wheat and chickpea in Madhya Pradesh.

In case of major soybean growing districts the rate of growth in area were highly significant for all the selected districts except for Harda District, where negative but insignificant growth in area of soybean is reported. The highest growth in area of soybean was observed for Rajghar district (5.40%) followed by Mandsaur (4.60%) and Ratlam (3.70%). For the Madhya Pradesh as a whole the growth in area of soybean was 3.30 per cent. This shows that even after more than five decades of introduction of soybean crop in the state of Madhya Pradesh its magnitude in terms of area coverage in major soybean growing districts is still increasing. The growth in production of soybean is also showing the similar trend and it was highest and highly significant in Rajghar district (6.90%) followed by Mandsaur (4.70%) and Ratlam (4.30%). It was negative in Harda District. For the state as a whole it was 3.60 per cent. But when we look at the growth rate of productivity of soybean surprisingly it is observed that the productivity is almost stagnant in major soybean growing districts except in Rajghar district where significant growth (1.40%) was observed. Thus growth in production of soybean during Kharif season in major soybean growing districts is only due to expansion in area and contribution of enhanced productivity was negligible. This is major concern of the policy makers and planners because even after development and introduction of improved varieties of soybean suited to different agro-climatic conditions the yield gap is not bridge as excepted.

In Rabi season mainly wheat and chickpea is grown by the soybean growers of the selected districts after harvest of soybean. Under assured irrigated condition soybean growers prefer to grow wheat. In case of wheat crop almost all the districts shows positive and significant growth in area of wheat. The highest growth in area of wheat was observed for Rajghar district (8.30%), followed by Shajapur (4.00%) and Ratlam districts (4.00%). For Madhya Pradesh as whole the growth in area of wheat was positive and highly significant (2.30%). The double digit growth in production of wheat was observed in Rajghar district (10.20%) and it was very high in Harda (8.50%) and Sehore (6.00%). These districts are famous for production of quality wheat. For the state as whole very high and significant growth (5.40%) in production of wheat was observed. Regarding the growth in productivity of wheat it was found to be positive and highly significant for all selected districts and state as a whole (3.00%). The highest growth in productivity of wheat was observed for Harda district (4.70%) followed by Bhopal (2.90%) and Sehore (2.70%). Thus, growth in production of wheat is mainly accounted for growth in productivity for the state as whole and for Bhopal and Harda districts because in this area the growth in productivity of wheat was higher than growth in area of wheat.

The chickpea is mainly grown by the soybean growers under semi-irrigated condition. The positive and significant growth in chickpea acreage was observed only for Rajgarh (3.40%) and Sehore districts (1.80%), rest of the districts shows positive growth in area of chickpea but it was insignificant and even in two districts (Bhopal and Mandsaur) significant and negative growth in area of chickpea was observed. For state as a whole growth rate of area of chickpea was 1.10 per cent. The growth in production of chickpea was highest for Rajgarh district (6.10%), followed by Harda (3.40%) and Sehore (3.20%) districts. In the state of Madhya Pradesh the growth in production of chickpea was 2.90 per cent and it was highly significant. The productivity of chickpea shows positive and significant growth for all the selected districts except for Shajapur district. It was highest for Rajgarh district (2.60%) followed by Indore and Harda districts (1.80% each). In Madhya Pradesh the growth in productivity of chickpea was 1.70 per cent.

Table 1: Growth in area, production and productivity of soybean, chickpea and wheat in Major soybean growing districts of Madhya Pradesh

(Percentage)

[#]Including Aagar Malwa
*** Significant at 1 per cent*
** Significant at 5 per cent*

Crops	Production Component	Bhopal	Sehore	Rajgarh	Mandsaur	Harda	Indore	Ujjain	Shajapur[#]	Ratlam	Madhya Pradesh
Soybean	Area	3.40**	2.30*	5.40**	4.60**	-0.10	1.40**	2.30**	2.60**	3.70**	3.30**
	Production	3.40**	2.30*	6.90**	4.70**	-1.40	2.10**	2.30**	2.90**	4.30**	3.60**
	Productivity	0.001	0.001	1.40*	0.10	-1.30	0.70	0.001	0.30	0.60	0.20
Wheat	Area	0.70*	3.20**	8.30**	2.30*	3.60**	3.20**	3.80**	4.00**	4.00**	2.30**
	Production	3.70**	6.00**	10.20**	4.00**	8.50**	4.80**	5.40**	5.50**	5.30**	5.40**
	Productivity	2.90**	2.70**	1.70**	1.70**	4.70**	1.50**	1.50**	1.40**	1.20**	3.00**
Chickpea	Area	-1.90*	1.80**	3.40**	-2.90**	1.60	1.60	1.60	1.10	0.80	1.10**
	Production	-0.50	3.20**	6.10**	-1.60	3.40**	3.10**	3.10**	1.90*	2.20	2.90**
	Productivity	1.40**	1.40**	2.60**	1.30*	1.80	1.80**	1.50**	0.80	1.40*	1.70**

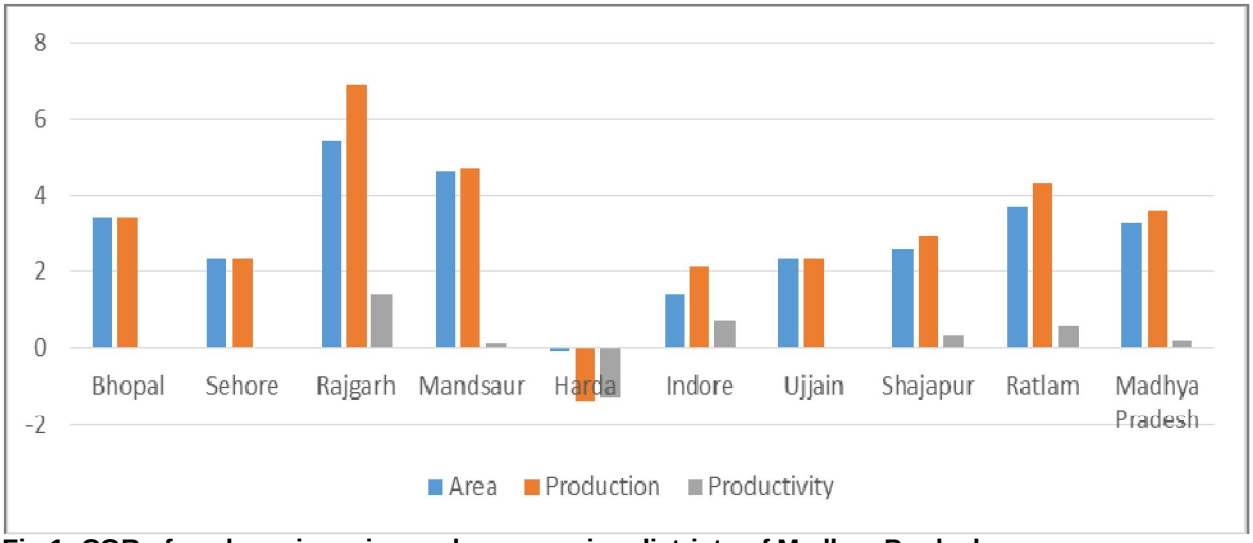

Fig 1: CGR of soybean in major soybean growing districts of Madhya Pradesh

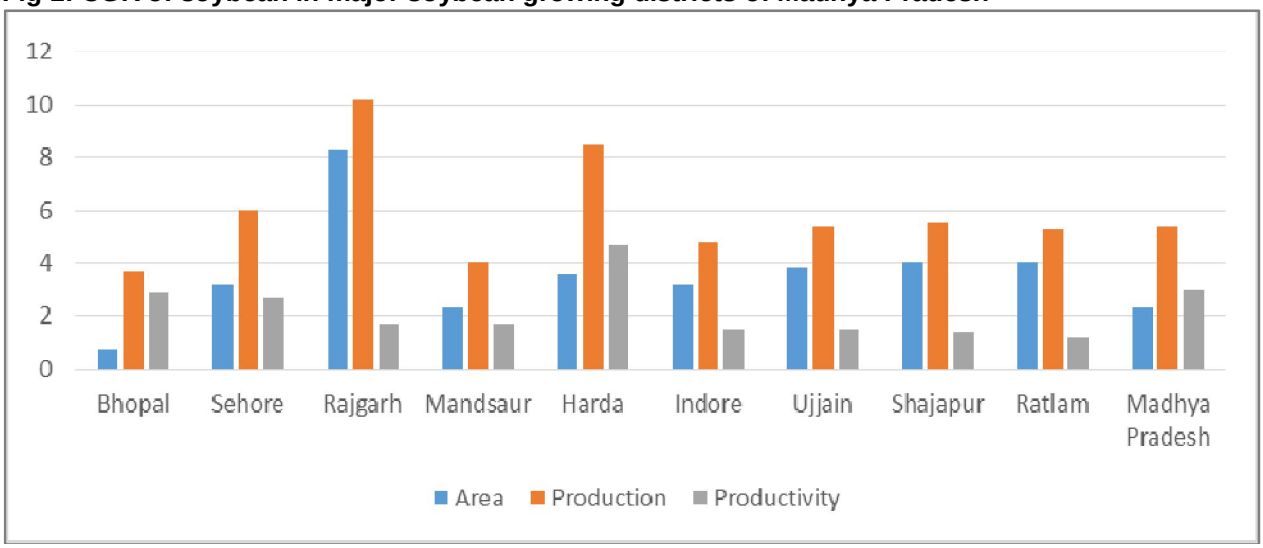

Fig 2: CGR of wheat in major soybean growing districts of Madhya Pradesh

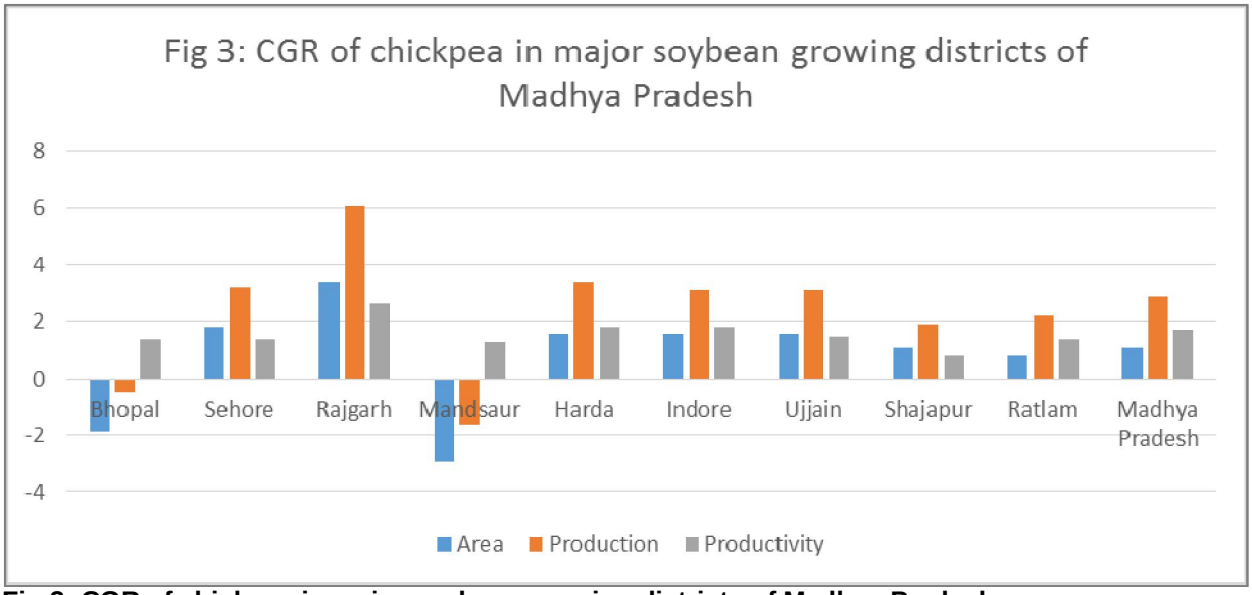

Fig 3: CGR of chickpea in major soybean growing districts of Madhya Pradesh

Extent of risk in production of any crops is generally associated with extent of instability in production of that crop and thus the analysis on extent of instability in production is measures and data on the same are presented in table 2. Method suggested by Cuddy Della Valle (1978) was used to calculate the extent of instability and as per this method instability index was categories as low (0 to 15 index), medium (15 to 30 index) and high (> 30 index).

In case of soybean crop the low instability was observed for selected districts. For the state of Madhya Pradesh area of soybean was found to be more stable (2.52%) during last 32 years. Among the districts area of soybean was found to be more stable in major soybean growing districts and instability index for these districts ranged between 2.43 per cent (Bhopal) to 7.84 per cent in Sehore district. Soybean production was found to be more instable as compared to area since instability were in the range of medium instability index for Sehore (15.46%), Mandsaur (20.98%), Harda (22.05%), and Ujjain (15.41%). For Madhya Pradesh state as a whole production of soybean was more stable (2.84%). The productivity of soybean was found to be more instable as compared to area of soybean for almost all the selected districts and at state level. Medium instability was observed for Rajgarh district (15.58%), Mandsaur district (17.83%), Harda district (19.86%) and Ratlam districts (15.01%).

Wheat being a major Rabi crop mainly produced under irrigated condition in Madhya Pradesh just after harvest of Soybean and other Kharif crops. Thus the acreage response to this crop depends on rainfall pattern and total rainfall during kharif season and therefore magnitude of instability in area of wheat was higher as compared to soybean in most of the soybean growing districts and for the state as a whole. High instability in production of wheat was noted for Mandsaur (34.75%) and Shajapur (35.49%) districts. It was moderated for Rajgarh (23.52%), Indore (15.63%), Ujjain (23.56%) and Ratlam (16.70%) districts. For rest of the districts it was low. Instability in productivity of wheat was low in major soybean growing districts of the state. Thus production of wheat in soybean growing districts is less risky.

Table 2: Instability Index of area, production and productivity of soybean, chickpea and wheat in Major soybean growing districts of Madhya Pradesh

(Percentage)

Crops	Production Component	Bhopal	Sehore	Rajgarh	Mandsaur	Harda	Indore	Ujjain	Shajapur #	Ratlam	Madhya Pradesh
Soybean	Area	02.43	07.84	04.32	07.19	06.25	2.74	3.36	03.01	03.71	02.52
	Production	11.67	15.46	12.82	20.98	22.05	9.48	15.41	11.56	12.44	02.84

	Productivity	10.6	14.75	15.58	17.83	19.86	09.9	14.93	13.01	15.01	07.85
Wheat	Area	08.69	05.06	16.52	22.41	03.65	10.61	13.71	16.15	14.18	06.74
	Production	11.04	10.6	23.52	34.75	06.33	15.63	23.56	35.49	16.70	09.15
	Productivity	07.56	08.33	10.08	06.49	03.88	08.17	09.74	08.77	05.71	04.15
Chickpea	Area	14.18	07.36	13.16	15.44	15.62	17.26	16.69	15.28	17.51	04.13
	Production	16.65	09.25	13.87	25.08	24.08	22.81	16.1	17.59	22.12	06.06
	Productivity	05.66	07.77	06.47	13.03	12.93	09.29	09.9	14.81	14.09	05.59

[#]*Including Aagar Malwa*
Low instability = 0 to 15, Medium instability >15 and < 30 and High instability > 30

Chickpea is mainly produced by those farmers who are not having assured irrigation sources or complete land holding is not under irrigation. Because chickpea crop require less irrigation as compared to wheat. Instability in area of chickpea was lower in Bhopal, Sehore and Rajgarh districts. For Madhya Pradesh state the instability in area was in the range of low instability. For rest of the districts it was moderate. The production instability of chickpea was low in Sehore (9.25%) and Rajgarh (13.87%) districts and for the state as a whole (6.06%). For rest of the major soybean growing districts instability in production was moderate. Productivity instability of chickpea was low in all the districts revealing that under semi-irrigated condition of Madhya Pradesh especially in soybean growing area producing chickpea after soybean was less risky.

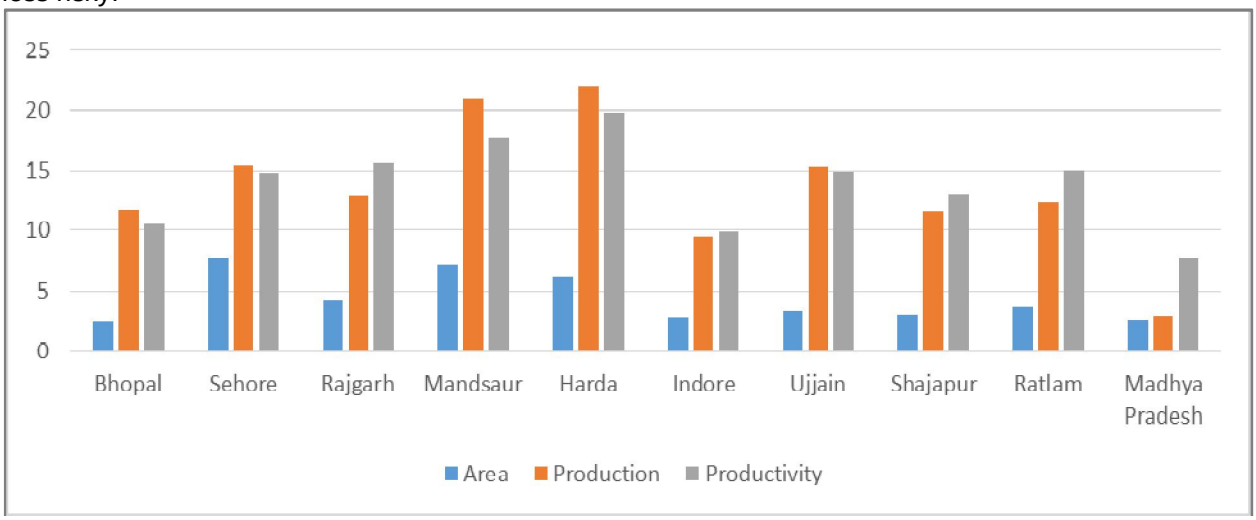

Fig 4: Instability of soybean in major soybean growing districts of Madhya Pradesh

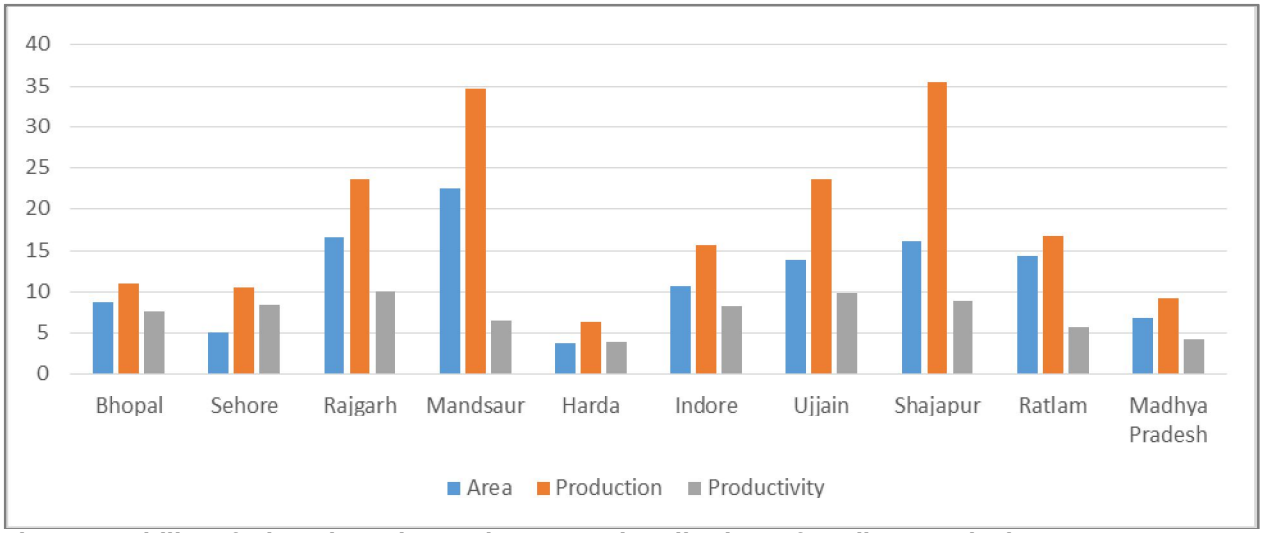

Fig 5: Instability of wheat in major soybean growing districts of Madhya Pradesh

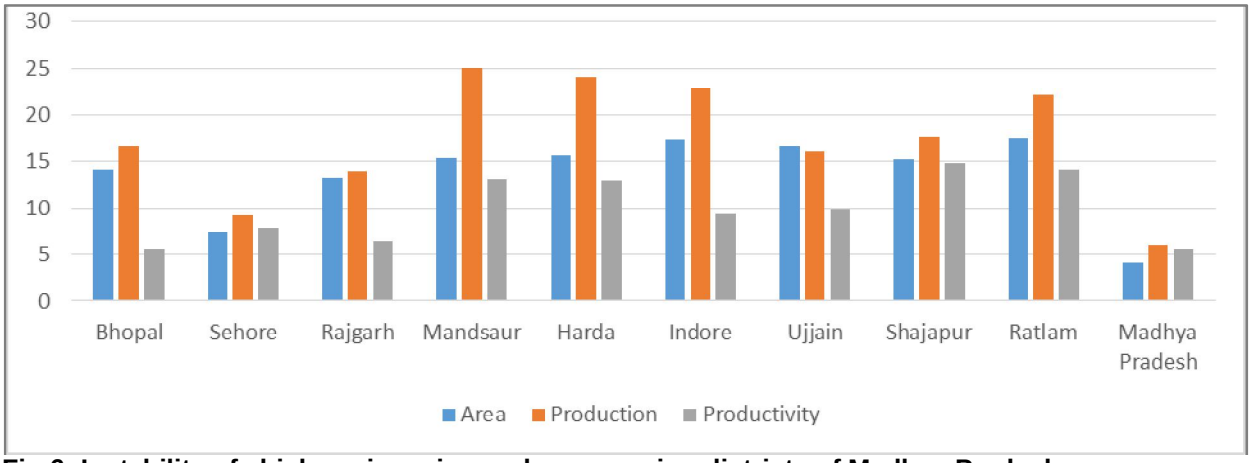

Fig 6: Instability of chickpea in major soybean growing districts of Madhya Pradesh

Table 3: Paradox of Growth-Instability in production of soybean crop in Madhya Pradesh

Production Instability Index	Crops	Compound Growth Rate of production		
		Low	Medium	High
Low	Soybean	Indore & Shajapur[#] (13.68)	Bhopal, Ratlam (7.2)	Rajgarh (6.03)
	Wheat	-	Bhopal, Sehore (4.35)	Harda (2.00)
	Chickpea	-	Sehore (3.37)	Rajgarh (2.74)
Medium	Soybean	Sehore, Harda, & Ujjain (16.24)	Mandsaur (4.17)	-
	Wheat	-	Indore, Ujjain, Ratlam (8.35)	Rajgarh (2.77)

	Chickpea	Bhopal, Mandsaur, Shajapur & Ratlam (7.17)	Harda, Indore, & Ujjain (8.75)	-
High	Soybean	-	-	-
	Wheat	-	Mandsaur, Shajapur* (6.06)	-
	Chickpea	-	-	-

[#]*Including Aagar Malwa*
(Figures in parentheses shows the percentage share of production to total production in the state)

The paradox of growth versus instability of soybean as major kharif crop and wheat and chickpea as major rabi crops was studies and information on the same is given in table 3. In case of soybean Indore and Shajapur districts were in the paradox segment of low growth rate and low instability in production and these two districts were accounts for 13.68 per cent of the total production soybean in the state. While, Bhopal and Ratlam districts were in the paradox segment of medium growth and low instability in production. These two districts accounts for 7.2 per cent of the production of soybean in the state. Only one district i.e. Rajgarh was in high growth and low instability segment for production of soybean in the state and this district alone accounts for 6.03 per cent of the production of soybean in the state. Districts Sehore, Harda and Ujjain were important soybean growing districts showing low growth in production with medium instability. These three districts account for 16.24 per cent of the total production of the soybean in the state. Mandsaur districts fall in the segment of medium growth and instability and accounts for 4.17 per cent of the total production of soybean in the state. This clearly indicated that nearly 30 per cent of the soybean production in the state of Madhya Pradesh was in low range of production growth with low to medium instability.
In case of wheat Bhopal and Sehore districts were in the segment of medium growth and low instability in production and these districts accounts for 4.35 per cent. While Harda districts were in the segment of high growth in production with low instability accounts for 2.0 per cent of the production of wheat in the state. Districts Indore, Ujjain and Ratlam were in the medium range in terms of growth and instability in production and accounts for 8.35 per cent of the wheat production in the state. In case of wheat also Rajgarh district was in the range of high growth in production with medium instability and accounts for 2.77 per cent of the wheat production in the state. Mandsaur and Shajapur districts were in the segment of high instability with medium growth in production and these two districts accounts for 6.06 per cent of the production of wheat in the state. These nine districts, growing wheat after soybean accounts for 23.53 per cent of the production of wheat in the state.
Sehore is major chickpea producing district accounts for 3.37 per cent of the total production of chickpea in the Madhya Pradesh falls under segment of low instability and medium growth in terms of production. Surprisingly Rajgarh district was in high growth rate with low instability segment in production accounts for 2.74 per cent of the chickpea production in the state. The four districts viz., Bhopal, Mandsaur, Shajapur and Ratlam were in the range of low growth with medium instability in production accounts for 7.17 per cent of the chickpea production in the state. While, Harda, Indore and Ujjain districts were in the segment of medium growth with medium instability in production of 8.75 per cent. These nine districts accounts for 22.03 percent of the production of chickpea in the state.

4. Conclusion:

The results of CGR clearly indicated that in Madhya Pradesh the districts which are dominating in soybean production did not shown any improvement in productivity of soybean since last more than three decades despite of huge investment in soybean research and development. On the contrary the wheat and chickpea after soybean is showing very good performance in terms of improvement in productivity. Among the district Rajgarh district is showing very good performance in improvement in productivity of all the three crops and thus planners and scientists may consider this district as an example district for developing short term strategies for improving the productivity especially of soybean. Instability analysis of area, production and productivity of soybean in the kharif and wheat and chickpea in the rabi clearly

indicated that in major soybean growing districts the production of soybean in the kharif and wheat and chickpea in the rabi season are assured and low risky crop and thus this cropping pattern is most popular in major soybean growing area of the Madhya Pradesh.

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