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Research Paper

Sources of Crop Production Instability in Rajasthan State, India

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Abstract: An empirical investigation was conducted on the sources of crop production instability in Rajasthan State, India. Time series data spanning from 1994-2015 (post-green revolution) *viz.* area, yield and production of 17 crops produced in 27 potential districts and the state were used and meticulously analyzed using Coefficient of Variation and Hazell technique. Results indicated high variability/fluctuation in yield to be the major cause of production instability in all the *kharif* crops and some *rabi* crops *viz.* wheat and mustard. On the contrary, high instability in area was the major source of production instability for crops *viz.* taramira, gram, barley, cumin and coriander. Performance of *kharif* crops were poor in general, as the production and productivity of crops were observed to be declining. Therefore, location specific technology development is needed in order to give higher yield even in adverse weather condition, along with price support, which would eventually expand the production. Rabi crops performed better; as well their production increase was contributed by increased area and yields. However, this performance was subjected to high instability in both area and yields. Technological inputs *viz.* seeds, fertilizers, pesticides and location-specific production technologies, timely and assured electricity supply were important factors that will minimize instability, thus, further increase in production. Furthermore, creation of other infrastructural facilities like irrigation is imperative to increase acreage and production stability.

Keywords: Instability, Area, Yield, Production, *Kharif* and *Rabi* crops, Rajasthan, India

Introduction

The fundamental postulate of the modern welfare state is to help the people in fulfilment of their needs for a decent and comfortable livelihood. In this context, it is widely recognized that in the hierarchy of human needs, food ranks first since the survival of Homo-sapiens hinges on it. As such, it is a matter of paramount importance for the state to accord overriding priority to the concerns for food security, more so, in a world where aid and trade in food have to be tools of international diplomacy. There is a growing concern in different quarters on the issues, "will there be enough food for our children"? This question does cause alarm, particularly in developing countries, because developed countries have successfully tackled this problem through sustained growth over time. In India, the expanding population which is at present estimated to be Indian Rupees (IR) 110 crores (1 crore = 10 million) is likely to cross IR 145 crores by the year 2030. This will necessitate on an average above 4 percent growth in food production in order to achieve self-sufficiency. To be fed, the population needs at least 270 million t of food grains and more in the near future; which will necessitate an overall increase in food production. The country has put food security high on the national agenda; from being a substantial net food importer in the 1970s, it became self-sufficient in grain production from the early 1980s and more than self-sufficient in the 1990s till date.

The darker side of Indian development during the last half century has been that the economic growth did not percolate to the rural poor as "trickle down" has failed to work. The critical appraisals of Indian planning strategy have clearly shown that land reforms neither could be carried out to the extent of eliminating unequal land holdings nor the economic growth could bring prosperity to the rural small and marginal farmers to the extent as would have been expected. Therefore, the future crisis in the food front emanates not entirely in meeting the expected rise in the demand in the production front but more importantly in the distribution front-equitable distribution of not only resources but also equitable distribution of gains from economic growth. However, the country often proclaimed self-sufficiency in food production, yet things do not seem to be very bright particularly in near future. If another green revolution is not experienced by India in near future, it is expected to import annually 40 million t of food grains by the year 2030.

Agricultural production in Rajasthan State has undergone substantial changes; production in the state has increased due to adoption of high yielding varieties, use of chemical fertilizer and development of irrigation structures. Studies carried out by Sadiq and Grema (2016); Vanpal *et al.* (2015); Swain (2013); Swain *et al.* (2012); Dutta and Kapadia (2011); Kumawat and Meena (2005), found that the growth in agricultural production of the Rajasthan State in India was associated with instability, which adversely affected production, employment and income distribution, thus, hampering economic growth.

To promote economic development, it becomes imperative to identify risk inducing factors in crop production in the state and potential district levels. Therefore, the essence of this research is to describe empirically sources of production instability of various selected crops of Rajasthan State in the last two decades. These sources of instability were quantified by decomposing variance of production into various sources *viz.* area variance, yield variance, area-yield covariance and higher order interaction between area and yield.

Methodology

The present study made use of time series data on area, production and productivity, covering post-green revolution period spanning from 1994-2015 were obtained from secondary data sources of the Rajasthan State, India *viz*. Statistical Abstract, Directorate of Economics and Statistics (manual), Vital Agriculture Statistics, and the Directorate of Agriculture at Jaipur. Cultivation extent of a minimum of 250,000 ha during the last 4-5 years (2010/11-2015) was considered as a criterion for crop selection for this study. As the aggregate analysis may not depict a true picture, only potential districts that account for 50% share in the total area under cultivation of a particular crop were selected. Thus, selected crops with respective potential producing districts are presented in Table 1.

The spanning period was divided into two phases; Period I (1994-2004) and Period II (2005-2015), in order to have decade-wise comparisons. Coefficient of Variation (CV), Instability Index model and Hazell technique were used to analyze the data.

Table 1. Selected crops with respective potential producing-Districts in the Rajasthan State, India

Crops	Local Name	Districts in Rajasthan State
Pearl millet [*Pennisetum typhoides* (L.) R. Br.]	Bajra	Barmer, Jodhpur, Churu and Nagaur
Barley (*Hordeum vulgare* L.)		Jaipur, Sikar, Ajmer and Bhilwara
Coriander (*Coriandrum sativum* L.)		Kota
Cotton (*Gossypium hirsutum* L.)		Sri-Ganganagar
Cumin (*Cuminum cyminum* L.)		Barmer and Jalore
Chickpea (*Cicer arietinum* L.)	Gram	Sri Ganganagar, Churu, Jaipur and Jhunjhunu
Groundnut (*Arachis hypogaea* L.)		Jaipur, Chittorgarh, Sawai-Modhopur and Bikaner
Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]	Guar	Churu, Barmer, Sri-Ganganagar and Nagaur
Sorghum [*Sorghum bicolor* (L.) Moench]	Jowar	Ajmer, PaliTonk and Nagaur
Maize (*Zea mays* L.)		Udaipur, Bhilwara and Chittorgarh
Green gram [*Vigna radiata* (L.) R. Wilczek]	Moong	Nagaur, Jodhpur, Jalore and Ajmer
Moth bean (*Phaseolus aconitifolia* Jacq.)	Moth	Bikaner, Churu and Barmer
Rapeseed (*Brassica napus* L.) and Mustard [*Brassica juncea* (L.) Czern.]		Sri-Ganganagar, Bharatpur, Alwar, Sawai-Madhopur and Tonk
Sesame (*Sesamum indicum* L.)	Sesamum	Pali, Jodhpur and Nagaur
Soya bean [*Glycine max* (L.) Merr.]		Kota and Jhalawar
Rocket salad (*Eruca sativa* Mill.)	Taramira	Nagaur, Bikaner and Pali
Wheat (*Triticum aestivum* L.)		Sri Ganganagar, Jaipur, Bharatpur, Alwar, Kota and Bundi

Empirical model

Measurement of Instability: The measurement of instability requires that an implicit or explicit judgment be made as to what constitutes the acceptable variability and unacceptable variability. In time series analysis, the trend is removed from the data before instability is measured on the ground that, those trends are predictable and do not constitute instability. Deviation from the trend constitutes the variability in question, hence used for measurement of instability. Therefore, area and productivity for each crop with respect to each selected districts and the state as a whole were de-trended for each time period separately using linear functional form (Equation 1).

$$Y_t = \alpha + \beta_t + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(Equation 1)}$$

where, Y_t = dependent variable (area or productivity); t = time trend, and ε_t = random residual. After de-trending the data, the residuals (ε_t) were centered on the mean area or productivity for each period, $\bar{Y}$, resulting in de-trended time series data of the following form (Equation 2):

$$\bar{Y} = \varepsilon_t + \bar{Y} \dots\dots\dots\dots\dots\dots \text{(Equation 2)}$$

De-trended production data for each crop with respect to each district and the state as a whole were obtained by multiplying the de-trended area with de-trended productivity. Instability was measured for all the time period by estimating the coefficient of variation of production, area and productivity. Following Sadiq (2015), CV is specified as given in Equation 3:

$$CV = \frac{\sigma_{ij}}{X_{ij}} \dots\dots\dots\dots\dots\dots \text{(Equation 3)}$$

where, CV = coefficient of variation, σ_{ij} = standard deviation of the i^{th} variable in the j^{th} crop; and, X_{ij} = mean of the i^{th} variable in the j^{th} crop.

Sadiq and Grema (2016) stated that CV is the most commonly used index for measuring instability. The CV has an easy interpretation in the context of measuring an overall variation in the data not showing any trend. However, usually when time series data for variables show a trend, which may be linear or non-linear, the CV does not take into account any such time trends of data while measuring the instability in the variate values. Therefore, it may be desirable for general applicability that an index of instability should be so derived to provide information about the trend exhibited in the data on the variable under study.

Sadiq and Grema (2016) applied the following index (Equation 4) as a measure of instability in time series data:

I = CV^2 (1-R^2) …………………(Equation 4)

where, I = Instability; CV = coefficient of variation and R^2 = coefficient of determination.

Sources of Instability: To examine instability sources, production instability was decomposed into its sources, *viz.*, area variance, yield variance, area-yield covariance and higher order interaction between area and yield, by using the Equation 5 according to Hazell technique (Hazell, 1982):

$$V(Q) = A^2V(Y) + Y^2V(A) + 2AY(A,Y) - COV(A,Y)^2 + R \text{ ……………(Equation 5)}$$

where, V(Q) = Production Instability/Production variance, $\bar{A}$ = Mean area, $\bar{Y}$ = the mean yield, $\bar{V}$ (Y) = Yield variance, V(A) = Area variance, COV(A,Y) = Area-yield covariance, $COV(A,Y)^2$ = Higher order covariance between area and yield, and R = Residual term. In this study, the sources of production instability was expressed under two cultivating seasons, namely *Kharif* season (from July to October during the south-west monsoon) and *Rabi* season (from October to March; winter season)

Results and Discussion

Sources of production instability of *Kharif* cereal crops

Sorghum Crop: Results in Table 2 revealed production instability of sorghum crop in Ajmer and Pali districts to be 83.4% and 81.3%, respectively, during Period I. This remained almost the same in Pali district in Period II, with a marginal decline observed in the Ajmer district during Period II. However, the Nagaur district witnessed a decline while the Tonk district experienced an increase in production instability from Period I to Period II (Table 2).

Further, the state observed an increase in production instability of the sorghum crop. Yield variance was observed to be the major production instability source of sorghum crop in all the selected districts and the state during the period under consideration. The yield variance declined in Ajmer, Nagaur districts and the Rajasthan State decreased in Period II compared to that of Period I while it increased in Pali and Tonk districts. In the Nagaur district, the area-yield covariance was observed to be the nullifying factor of production instability. The high yield variance needs to be tackled to reduce the production instability of sorghum crop in the Rajasthan State in India.

Maize: The production instability of maize was low when compared to other *Kharif* cereals of Rajasthan State (Table 2). Results showed a decline of maize production in Udaipur, Bhilwara and Chittore districts, and the Rajasthan State in the Period II compared to that of Period I. Results of the present study revealed that maize production variance was mainly due to the yield variance, where estimated yield variance were 92% in Udaipur, 93.3% in Bhilwara. 113% in Chittore and 86.2% Rajasthan State during the Period II. However, area variance was found to be less than 3% in all the districts as well as the state in both periods. Therefore, it can be inferred that maize is the stable food crop of the studied area of Rajasthan State.

Pearl millet: Production instability of pearl millet increased in Churu and Barmer districts, decreased in Jodhpur and Nagaur districts and Rajasthan State from in the Period II compared to that of Period I (Table 2). Decomposition analysis of production variance indicates yield variance to be the major contributor of production instability in all the districts and Rajasthan State during both the periods. However, the yield variance declined in Jodhpur, Barmer, Nagaur districts and Rajasthan State over time. In the Churu district, the yield variance increased from 75.5% (Period I) to 82.6%

(Period II). The area-yield covariance was found to be the next important source of production instability in both periods in the Nagaur district (Table 2).

Sources of production instability of *Rabi* cereal crops

Wheat: Instability in the production of wheat declined over time in Jaipur, Alwar, Bharatpur and Sri-Ganganagar districts (Table 3). Major sources of production instability in these districts were area variance and yield variance. Further, the area-yield covariance contributed in reducing the production instability in these districts. In Kota and Bundi districts and the whole Rajasthan State, the instability in wheat production was found to increase due to increase in area-yield covariance.

Table 2. Sources of production instability of *Kharif* crops

District/State	Production Instability (%)	Area variance (%)	Yield variance (%)	Area-yield covariance	Higher order covariance
			Sorghum crop		
			Period I		
Ajmer	83.41	0.77	105.13	-1.48	-4.41
Nagaur	83.20	17.02	130.62	-64.29	16.65
Pali	81.28	4.74	73.54	-3.09	24.81
Tonk	47.20	2.94	82.85	8.37	5.84
Rajasthan	31.09	5.47	94.02	-5.48	5.99
			Period II		
Ajmer	81.10	0.72	93.59	5.66	0.03
Nagaur	54.93	17.05	92.76	-10.81	1.01
Pali	81.89	0.87	100.33	-0.43	-0.77
Tonk	57.30	3.11	87.93	3.24	5.71
Rajasthan	37.82	5.53	87.66	2.83	3.97
			Maize crop		
			Period I		
Udaipur	42.74	1.62	93.86	13.26	-8.75
Bhilwara	42.57	3.13	102.39	10.36	-15.89
Chittore	30.01	0.80	93.64	6.92	-1.37
Rajasthan	36.04	2.57	100.37	6.8	-9.73
			Period II		
Udaipur	25.30	0.19	92.04	5.81	1.97
Bhilwara	25.62	1.01	93.27	5.82	-0.1
Chittore	17.97	2.39	113.01	-11.08	-4.33
Rajasthan	14.43	1.99	86.17	9.79	2.05
			Pearl millet crop		
			Period I		
Churu	68.61	3.38	75.47	15.28	5.87
Jodhpur	85.14	1.7	103.36	2.08	-7.13
Barmer	82.36	3.88	96.05	2.73	-2.66
Nagaur	66.22	3.28	83.86	12.24	0.63
Rajasthan	47.59	5.71	82.99	17.32	-6.03
			Period II		
Churu	77.71	0.68	82.55	9.68	7.1
Jodhpur	80.58	1.23	77.32	15.8	5.64
Barmer	88.09	1.04	83.12	13.11	2.72
Nagaur	30.93	6.71	63.14	28.35	1.8
Rajasthan	36.4	3.31	70.38	23.26	3.05

Barley: Production instability of barley crop in Jaipur district was observed to be the lowest (Table 3) and it further declined to 12.8% in Period II from 16.5% in Period I. Ajmer district showed the maximum production instability which showed an increase in Period II (34.6%) from that of Period I (29%). However, Sikar district witnessed a decline in production instability, while Bhilwara district and the state observed increased production instability. In Ajmer district, yield variance emerged as the major source of production variance. Furthermore, in Jaipur, Sikar, Bhilwara districts and Rajasthan State, area variance was found to be the major determinant of production variance. Decomposition analysis of production variance indicated area variance and yield variance to be the major sources of production instability (Table 3).

Table 3. Sources of production instability of *Rabi* cereal crops

District/State	Production Instability (%)	Area variance (%)	Yield variance (%)	Area-yield covariance (%)	Higher order covariance (%)
			Wheat crop		
			Period I		
Jaipur	15.39	18.13	90.62	-11.28	2.53
Alwar	14.81	37.17	85.75	-28.09	5.18
Bharatpur	15.19	54.91	101.3	-48.93	-7.27
Sri Ganganagar	24.31	42.81	71.31	0.88	-15
Kota	17.03	30.93	44.69	23.46	0.93
Bundi	16.51	21.74	95.46	-22.03	4.82
Rajasthan	13.40	43.59	46.66	12.00	-2.25
			Period II		
Jaipur	12.55	26.83	70.79	4.17	-1.78
Alwar	9.09	23.54	132.85	-53.75	-2.65
Bharatpur	6.96	22.06	128.58	-23.73	-18.91
Sri Ganganagar	17.18	19.97	69.37	18.94	-8.28
Kota	17.45	32.31	110.82	-41.13	-2
Bundi	22.69	17.52	60.48	17.85	4.15
Rajasthan	14.75	34.66	50.24	18.83	-3.74
			Barley crop		
			Period I		
Ajmer	29.03	31.25	33.74	23.31	11.7
Jaipur	16.53	56.57	27.25	11.54	4.65
Sikar	29.84	77.83	28.45	-1.3	-4.97
Bhilwara	27.23	27.26	33.63	30.98	8.14
Rajasthan	16.54	64.76	18.03	13.75	3.45
			Period II		
Ajmer	34.60	47.00	52.99	1.5	-1.49
Jaipur	12.81	80.74	41.58	-17.27	-5.04
Sikar	24.19	53.22	31.75	2.72	12.31
Bhilwara	33.15	53.01	17.38	41.09	-11.48
Rajasthan	17.19	64.15	31.47	11.61	-7.23

Sources of production instability of *Kharif* pulse crops

Moth bean: Production instability of moth crop declined over the period in all the districts as well as in the Rajasthan state (Table 4). In Bikaner district, yield variance declined from 85.7% in Period I to 71.5% in Period II, and the area-yield covariance increased from 13.4% in Period I to 25.3% during Period II. Estimated yield variance of moth bean in the Churu and Barmer districts increased in Period II compared to that in Period I. The observed yield variance was the major determinant of production instability in all the districts and the Rajasthan state as a whole.

However, area variance was observed to be low in all the districts and the state, which indicates possible sustainability of moth bean crop in the studied area. Therefore, production of moth bean can be expanded by adoption of agricultural technology such as development of drought tolerant variety, thus, minimizing yield fluctuations.

Table 4. Sources of production instability of *Kharif* pulse crops

District/State	Production Instability (%)	Area variance (%)	Yield variance (%)	Area-yield covariance (%)	Higher order covariance (%)
			Moth bean crop		
			Period I		
Bikaner	73.51	4.6	85.73	13.36	-3.69
Churu	77.01	0.56	96.93	2.73	-0.22
Barmer	112.07	27.53	42.59	18.42	11.46
Rajasthan	67.93	3.99	91.79	19.32	-15.1
			Period II		
Bikaner	64.11	5.1	71.52	25.27	-1.89
Churu	44.61	5.03	99.86	0.74	-5.63
Barmer	94.17	8.16	69.64	12.35	9.85
Rajasthan	53.92	3.75	78.35	19.67	-1.77
			Mung bean crop		
			Period I		
Ajmer	74.20	11.63	86.09	5.96	-3.68
Jodhpur	106.81	7.77	72.11	13.44	6.68
Jalore	124.35	4.63	80.91	1.2	13.26
Nagaur	74.61	22.36	61.91	39.01	-23.28
Rajasthan	Period II	6.41	87.84	13.84	-8.09
			Period II		
Ajmer	74.20	11.63	86.09	5.96	-3.68
Jodhpur	106.81	7.77	72.11	13.44	6.68
Jalore	124.35	4.63	80.91	1.2	13.26
Nagaur	74.61	22.36	61.91	39.01	-23.28
Rajasthan	64.57	6.41	60.13	13.84	-8.09
			Cluster bean crop		
			Period I		
Churu	71.98	1.14	86.32	11.13	1.41
Sri Ganganagar	63.40	37.13	171.53	-45.57	-63.09
Barmer	94.97	10.19	67.29	30.22	-7.7
Nagaur	61.36	1.19	92.48	11.8	-5.47
Rajasthan	63.71	8.06	74.17	32.81	-15.03
			Period II		
Churu	49.33	6.22	134.64	26.17	-14.71
Sri Ganganagar	42.50	53.51	55.82	-10.47	1.14
Barmer	88.26	3.96	79.75	9.99	6.3
Nagaur	62.87	19.15	195.75	-68.29	-46.61
Rajasthan	48.16	12.69	111.67	-18.45	-5.91

Mung bean: Production of mung bean crop was high in Jalore district (124.4%), followed by Jodhpur district (106.8%) and Nagaur district (74.6%) in Period I, which marginally declined in Period II (Table 4). Production instability remained almost the same in Ajmer district and Rajasthan State in both periods. The production variance of mung bean in Ajmer district was explained by yield variance (86.1%) and area variance (11.6%) during Period I, while yield variance (78.5%) and higher order area-yield covariance (13.7%) were the major factors during Period II. Jodhpur district experienced an increase in yield variance over time while it remained constant in the Jalore district in both periods (Table 4). In the Nagaur district, the major source of mung bean production variance was the yield variance (61.9%) and area-yield covariance (39%) during Period I. In the Period II, the major sources of production instability were the yield variance (68.9%) and area variance (24.5%). In Rajasthan State, yield variance (87.8%) was the major source of production variance in Period I, which declined in Period II. However, the dominant source of production instability in the studied area was the yield variance (Table 4).

Cluster bean: Production instability of guar crop declined in Churu, Sri-Ganganagar, Barmer districts and Rajasthan State in Period II compared that of Period I (Table 4). However, the production instability of cluster bean in Nagaur district was found to be constant (62%) in both periods. Results of decomposition analysis revealed a high share of yield variance in production variance, with it increasing overtime for all districts except for Sri-Ganganagar district. The results inferred that area-yield covariance and higher order area-yield covariance emerged as nullifying factors of production variance in Sri-Ganganagar and Nagaur districts (Table 4).

Sources of production instability of *Rabi* pulse crop

Chick pea: Estimated production instability of chick pea in Jaipur, Sri-Ganganagar, Churu districts and Rajasthan State increased during Period II compared to that of Period I (Table 5). In Jhunjhunu district, the production instability declined from 97.7% during Period I to 76.99% during Period II. Decomposition analysis of production variance of chick pea crop showed that area variance was the major determinant of production variance in Jaipur, Jhunjhunu districts and Rajasthan State during the Period II. Area-yield covariance was the major source of production variance in Sri-Ganganagar and Churu districts. However, in Churu district, four factors *viz.* area variance, yield variance, area-yield covariance and higher order area-yield covariance contributed almost equally in Period II (Table 5).

Table 5. Sources of production instability of *Rabi* pulse crops

District/State	Production Instability (%)	Area variance (%)	Yield variance (%)	Area-yield covariance (%)	Higher order covariance (%)
	Chick pea crop				
	Period I				
Jaipur	33.45	32.03	33.00	37.92	-2.95
Sri Ganganagar	27.20	77.79	48.74	-28.70	2.17
Jhunjhunu	97.74	46.75	37.37	-17.54	33.41
Churu	60.87	19.35	56.77	37.78	-13.90
Rajasthan	28.41	55.29	19.09	20.99	4.61
	Period II				
Jaipur	50.57	75.52	11.11	17.34	-3.97
Sri Ganganagar	61.36	25.20	29.90	34.23	10.66
Jhunjhunu	76.99	91.25	23.55	1.38	-16.17
Churu	120.57	19.99	27.50	26.83	25.67
Rajasthan	49.66	64.98	8.72	23.14	3.16

Sources of production instability of *Kharif* oil seed crops

Groundnut: Estimated production instability of groundnut in Sawai-Madhopur, Bikaner and Chittore districts during Period I (Table 6) declined during Period II. The major contributing factor in production variance was the yield variance, followed by area variance and area-yield covariance. The yield variance in Rajasthan State was 115.6% in Period I, declined to 60.1% during Period II. For Bikaner district, the production variance was due to the area variance (67.6%), followed by yield variance (55.1%). The area-yield covariance and higher order covariance of area and yield were the nullifying factors of production variance in the Bikaner district (Table 6).

Table 6. Sources of production instability of *Kharif* oilseed crops

District/State	Production Instability (%)	Area variance (%)	Yield variance (%)	Area-yield covariance (%)	Higher order covariance (%)
			Groundnut crop		
			Period I		
Jaipur	37.92	25.39	52.76	21.95	-0.11
Sawai-Madhopur	51.96	15.76	52.75	16.91	14.58
Bikaner	50.22	20.32	51.19	14.79	13.7
Chittore	23.63	26.48	81.11	-5.95	-1.64
Rajasthan	20.10	31.88	115.92	-34.84	-12.96
			Period II		
Jaipur	42.08	19.70	49.48	17.53	13.29
Sawai-Madhopur	41.30	31.75	62.71	20.25	-14.71
Bikaner	25.02	67.63	55.05	-10.78	-11.89
Chittore	18.70	31.57	78.97	-10.23	-0.31
Rajasthan	27.03	8.53	60.11	26.98	4.38
			Soya bean crop		
			Period I		
Kota	19.94	189.31	52.55	-114.57	-27.29
Jhalawar	65.55	32.54	75.76	31.52	-39.83
Rajasthan	20.08	113.38	66.10	-49.91	-29.57
			Period II		
Kota	39.72	41.45	37.24	6.44	14.87
Jhalawar	30.38	6.63	95.12	-1.14	-0.6
Rajasthan	27.60	24.32	54.37	12.38	8.93
			Sesame crop		
			Period I		
Jodhpur	108.00	7.05	78.86	17.42	-3.33
Nagaur	880.78	17.61	66.61	28.79	-13.01
Pali	72.46	7.77	82.97	15.77	-6.51
Rajasthan	66.97	12.49	68.02	28.12	-8.63
			Period II		
Jodhpur	94.98	3.86	74.82	6.60	14.7
Nagaur	51.66	18.00	53.69	17.37	10.94
Pali	70.21	8.41	63.92	17.56	10.1
Rajasthan	38.76	19.05	88.33	-6.12	-1.26

Soya bean: The Jhalawar district showed a decline in the production instability of soya bean from Period I to Period II while the Kota district and Rajasthan State showed an increase of the parameter in Period II compared to that of Period I. The area variance emerged as the major factor in production variance, followed by yield variance during both periods in Kota district. However, both the area variance and yield variance declined from 189.3% and 52.4% in Period I to 41.5% and 37.2%, respectively, during Period II. Jhalawar district experienced a production instability due to high yield variance in both the periods. The share of yield variance in production instability increased over time in Jhalawar district (Table 6).

Sesame: The estimated production instability of sesame crop in Jodhpur, Nagaur, Pali districts and Rajasthan State declined in Period compared to that of Period I (Table 6). The major sources of production instability was the yield variance, followed by area-yield covariance, in both the study periods. However, yield variance of sesame crop in Jodhpur, Nagaur and Pali districts declined in Period II compared to that of Period I. At the Rajasthan state level, the yield variance showed in Period II (88.3%) compared that of Period I (68%). Therefore, policies to minimize the yield risk would assist in boosting production of sesame crop in the Rajasthan state.

<u>Sources of production instability of *Rabi* oilseed crops</u>

Rapeseed and mustard: Sources of production variance of rapeseed and mustard crops in the districts and Rajasthan State are presented in Table 7. Results revealed that Alwar and Sri-Ganganagar districts experienced an increase in production instability over time, while Bharatpur, Sawai-Mahopur and Tonk districts showed a decline in production instability. Production instability of rapeseed and mustard in Rajasthan State was approximately 19% for both periods. During the Period I, area variance was observed to be the dominant factor in production variance in all the districts, as well as in the state. However, in Period II, production variance was caused by both area variance and yield variance. In Alwar, Bharatpur and Sawai-Madhopur districts, the yield variance emerged as major component of production variance, while in Sri-Ganganagar and Tonk districts and in the state, area variance was observed to be the major source of production variance (Table 7). The area-yield covariance emerged as nullifying factor in Sawai-Madhopur and contributing factor to production variance in Sri-Ganganagar district during Period II.

Table 7. Sources of production instability of *Rabi* oilseed crops

District/State	Production Instability (%)	Area variance (%)	Yield variance (%)	Area-yield covariance (%)	Higher order covariance (%)
	Rapeseed and Mustard crop				
	Period I				
Alwar	14.89	67.58	39.72	-1.53	-5.76
Bharatpur	23.17	36.64	36.58	22.44	4.34
Sawai-Madhopur	35.02	42.74	34.1	25.54	-2.38
Siri-Ganganagar	21.49	63.63	46.64	-5.51	-4.76
Tonk	47.23	57.72	21.94	9.82	10.52
Rajasthan	19.01	96.37	10.54	-4.03	-2.9
	Period II				
Alwar	18.24	15.93	67.66	13.98	2.44
Bharatpur	19.84	20.76	85.28	-6.97	0.93
Sawai-Madhopur	18.05	72.81	76.95	-48.37	-1.39
Siri-Ganganagar	28.72	43.31	30.58	28.92	-2.81
Tonk	29.29	49.97	44.36	4.95	0.72
Rajasthan	19.03	75.45	33.21	-8.42	-0.25
	Rocket salad crop				
	Period I				
Bikaner	115.02	399.62	29.74	-113.98	-215.38
Nagaur	138.81	16.26	51.97	9.74	22.03
Pali	106.47	126.31	21.24	-4.68	-42.87
Rajasthan	37.11	113.95	78.54	-46.34	-46.15
	Period II				
Bikaner	191.95	74.60	3.35	4.65	17.4
Nagaur	166.50	149.05	8.80	-27.92	-29.93
Pali	130.57	152.39	13.53	-20.04	-45.87
Rajasthan	105.88	104.76	1.47	-6.16	-0.07

Rocket salad: The production instability of the rocket salad crop increased in Bikaner, Nagaur and Pali districts and in the Rajasthan State in Period II compared to that of Period I (Table 7). The area variance was the major source of production instability in the studied area in both periods, because the area under rocket salad crop depends on seasonal rainfall.

Sources of production instability of other crops

Cotton crop: The production instability of cotton declined in Sri-Ganganagar district and Rajasthan State in Period II compared to that of Period II (Table 8). Decomposition analysis of production instability indicated that yield variance increased from 67.7% in Period I to 73.2% during Period II in Sri-Ganganagar district. In the Rajasthan State, it declined from 68.99% to 54.5% during period II. The area variance was the second important contributor to the production instability of cotton crop (Table 8). *Cumin*: Decline in production instability of cumin crop was observed in Rajasthan State (Table 8). In the Jalore district, area variance was the major source of production instability in both the study periods. In the Barmer district, area variance was the major determinant in Period I, and yield variance was the major determinant factor in Period II of production instability. However, in Rajasthan State, area variance was the major source of production instability in both the periods, but declined over time (Table 8).

Coriander: The production instability of coriander in the Kota district and Rajasthan State declined over time (Table 8). The production variance of coriander crop due to yield variance was 67.8%, followed by area variance (38%) in the Kota district during Period I. However, during Period II, production variance in the same district was mainly due to the area variance (127.9%), followed by yield variance (31.7%). The area-yield covariance was observed to be the nullifying factor of production variance in Kota district during Period II (Table 8).

Table 8. Sources of production instability of other crops

District/State	**Production Instability (%)**	**Area variance (%)**	**Yield variance (%)**	**Area-yield covariance (%)**	**Higher order covariance (%)**
			Cotton crop		
			Period I		
Siri-Ganganagar	32.38	20.03	67.83	9.40	2.73
Rajasthan	31.58	16.79	68.99	19.05	-4.84
			Period II		
Siri-Ganganagar	28.94	8.32	73.18	4.75	13.75
Rajasthan	20.78	28.6	54.50	5.27	11.62
			Cumin crop		
			Period I		
Jalore	52.58	66.14	33.09	-14.15	14.92
Barmer	56.50	45.65	39.39	11.70	3.27
Rajasthan	50.00	81.17	16.36	-8.08	10.55
			Period II		
Jalore	39.72	69.11	37.63	8.51	-15.25
Barmer	44.32	9.71	105.6	-1.86	-13.45
Rajasthan	36.177	67.2	13.54	18.45	0,82
			Coriander crop		
			Period I		
Kota	47.94	38.03	67.84	2.00	-7.87
Rajasthan	40.7	44.92	49.23	12.87	-7.02
			Period II		
Kota	21.79	127.92	31.67	-45.31	-14.28
Rajasthan	28.52	69.86	113.67	-125.69	42.16

<u>The maximum contributing sources of production instability</u>

Table 9 shows the maximum contributing sources of production variance in Rajasthan State. Results revealed that the production instability of all the *Kharif* crops was caused mainly by yield variance in all the selected districts as well as in the state, except in Bikaner district for groundnut crop and Kota district for soya bean crop. A mix of area variance and yield variance contributed to production variability in *Rabi* crops. However, the area variance emerged as the major contributor of production variance. The production variance of wheat crop in all the selected districts, except Bharatpur district, was explained by yield variance. The yield variance was also responsible for production variance in rapeseed and mustard crops in Alwar, Bharatpur and Sawai-Madhopur districts. Yield variance was the major determinant of production variance in Churu district for chickpea, Ajmer district for barley and Barmer district for cumin.

Table 9. The maximum contributing sources of production instability in different districts in the Rajasthan state

Crop	Area variance	Yield variance	Area-yield covariance
Moth bean		Bikaner, Churu, Barmer, **Rajasthan**	
Sesame		Jodhpur, NagaurPali, **Rajasthan**	
Sorghum		Ajmer, Nagaur, Pali, Tonk, **Rajasthan**	
Mung bean		Ajmer, Jodhpur, Jalore, Nagaur, **Rajasthan**	
Maize		Udaipur, Bhilwara, Chittore, Rajasthan	
Cluster bean		Churu, S/Ganganagar, Barmer, Nagaur, **Rajasthan**	
Pearl millet		Churu, Jodhpur, Barmer, Nagaur, **Rajasthan**	
Groundnut	Bikaner	Sawai-Madhopur, Chittore, **Rajasthan**	
Cotton		Siri-Ganganagar, **Rajasthan**	
Soya bean	Kota	Jhalwara, **Rajasthan**	
Wheat	Bharatpur	Jaipur, Alwar, Siri-Ganganagar, Kota, Bundi, **Rajasthan**	
Rapeseed & mustard	Siri-Ganganagar, Tonk, Rajasthan	Alwar, Bharatpur, Sawai-Madhopur	
Rocket salad	Bikaner, Nagaur, Pali, **Rajasthan**		
Chick pea	Jaipur, Jhunjhunu, **Rajasthan**	Churu	Siri-Ganganagar
Barley	Jaipur, Sikar, Bhilwara, **Rajasthan**	Ajmer	
Cumin	Jalore, **Rajasthan**	Barmer	
Coriander	Kota	**Rajasthan**	

Note: The name in bold letters refers to the whole state

Conclusion

The sources of production instability were quantified by decomposing production variance into various sources *viz.* area variance, yield variance, area-yield covariance and higher order interaction between area and yield. Highly fluctuating cultivated areas and yield levels were the main causes of crop production instability in all *Kharif* crops, mainly because of its high dependence on rainfall. This is a cause of concern for policy makers to ensure sustained growth of agriculture and livelihood of farmers, given that virtually all of them depend on agriculture for income. The *Rabi* crops such as wheat and mustard also showed fluctuating yield levels despite overall growth over the years. However, high instability in cultivated area was the major contributing source of production instability of crops like rocket salad (taramira), chick pea (gram), barley, cumin and coriander. In most of the crops considered in this study, the yield variability was more and farmers are advised to avail benefits of crop insurance scheme launched by government to commensurate their returns. Further, the government should endeavour to enact insurance scheme for those crops which are yet to be covered by insurance.

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