



Impact assessment of rainfall on area, production and productivity of sesame in Himachal Pradesh

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Abstract

The present study was carried out to assess the influence of rainfall on the changes in spread, production and productivity of sesame in Himachal Pradesh during past forty years (1968-69 to 2007-08). The year-wise and pentad-wise trend analysis carried out following Mann-Kendall non parametric trend test indicated a significant decrease in area while no trend in production was observed under this crop. The dominance index also exhibited a gradual decrease in sesame area during past four decades. There was 48.7% reduction in area and 26.1% in production while only 1.2% decrease in quantum of rainfall was observed during 8th pentad over 1st pentad. The relationship between percent shift in area, production and productivity *vis-à-vis* rainfall was not significant. Hence, 41.4% increase in productivity during 8th pentad over the 1st pentad could be attributed to agro-technological interventions including varietal improvement.

Key words: Sesame, area, production, rainfall, Mann-Kendall trend test.

In India, the diverse agro-ecological conditions are favourable for growing of all the nine annual oilseeds which include seven edible oilseeds *viz.*, groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non-edible oilseeds (castor and linseed). Sesame is grown in this country over an area of 1,702.5 thousand hectares with total production of 748.2 thousand tonnes and productivity of 440 kg/ha accounting for 19.5% share of world production (Anonymous 2012a). In Himachal Pradesh, the crop is grown over an area of 3.59 thousand hectares with production and productivity of 1.7 thousand metric tonnes and 350 kg/ha, respectively (Anonymous 2012b). The crop is cultivated as a pure rain fed or mixed crop with maize, black gram/horse gram during *kharif* season. Based upon the average data over the past ten years (1998-99 to 2007-08), sesame has accounted for 27.7% area under total oilseeds and contributed about 29.2% to the total oilseeds production in the state. In general, the area and production of sesame in the state have exhibited a decrease due to lack of suitable improved varieties, cultivation on marginal and sub-marginal lands under poor management and input-starved conditions and occurrence of various diseases (*Phytophthora* blight, leaf spots and *phyllody*) and pests (hairy caterpillar and jassids). In Himachal Pradesh, 81.3% of the area is still not irrigated and is totally rain dependent. The

performance of crops is directly related to rainfall received during the crop season. The rainfall has shown variation in different districts *viz.*, in some, it was in excess whereas in others, it remained deficient. The present investigation aims to understand the inter-relations between changes in spread, production and productivity of sesame *vis-a-vis* rainfall pattern during past forty years (1968-69 to 2007-08) and suggest suitable interventions for making the farmers self-reliant in this crop.

Materials and Methods

The data on area, production and productivity of sesame for forty crop seasons were collected from the 'Statistical Outline of Himachal Pradesh'. The data on *kharif* rainfall for the same period were collected from India Meteorological Department, Pune. The whole period was split into eight pentads (five years period each) *viz.*, 1968-69 to 1972-73, 1973-74 to 1977-78, 1978-79 to 1982-83, 1983-84 to 1987-88, 1988-89 to 1992-93, 1993-94 to 1997-98, 1998-99 to 2002-03 and 2003-04 to 2007-08. The spatio-temporal changes in area, production and productivity *vis-a-vis* rainfall were worked out over these pentads. The spatial variation and temporal trends in area, production, productivity and rainfall were studied following Mann-Kendall (Mann, 1945; Kendall, 1975) non-parametric trend test. A non-parametric test is taken into

consideration over the parametric since it can evade the problem roused by data skewness (Smith, 2000). If Z_c (Kendall's tau) appeared greater than $Z_{\alpha/2}$ (where alpha depicted the significance level), then the trend was considered to be significant.

Mann-Kendall trend test: The test is often used in hypothesis testing (e.g. existence of trends) and therefore, considered as confirmatory data analysis tool.

Let: $x_1, \dots, x_n$ be a sequence of measurements over time, to test the null hypothesis,

H_0 : $x_1, \dots, x_n$ come from a population where the random variables are independent and identically distributed,

H_1 : $x_1, \dots, x_n$ follow a monotonic (e.g. increasing or decreasing) trend over time.

The Mann-Kendall test statistic is calculated as

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad \text{where}$$

$$\text{sgn}(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}$$

S is asymptotically normally distributed.

The mean and variance of S are given by

$$E(S) = 0$$

$$\text{Var}(S) = \begin{cases} \frac{\left\{ n(n-1)(2n+5) - \sum_{j=1}^p t_j(t_j-1)(2t_j+5) \right\}}{18} & \text{if ties} \\ \frac{\{n(n-1)(2n+5)\}}{18} & \text{no ties} \end{cases}$$

where p is the number of tied groups in the data set and t_j is the number of data points in the j^{th} tied group. A positive value of S indicates that there is an upward (increasing) trend (e.g. observations increase with time) while the negative value of S means that there is a downward (decreasing) trend. If S is significantly different from zero, then based on the data H_0 can be rejected at a preselected significance level and the existence of a monotonic trend can be accepted.

S is a count of the number of times $x_j - x_k > 0$ for $j > k$, more than $x_1 - x_k$.

The maximum value of S (called it D) occurs when $x_1 <$

$x_2 < \dots < x_n$

Kendall's τ is defined as $\tau = S/D$ where

$$D = \begin{cases} \sqrt{\left\{ \frac{n(n-1)}{2} - \sum_{j=1}^p t_j(t_j-1) \right\} \left(\frac{n(n-1)}{2} \right)} & \text{if ties} \\ \frac{n(n-1)}{2} & \text{no ties} \end{cases}$$

A positive value of τ indicates that there is an upward (increasing) trend while a negative value of τ means that there is a downward (decreasing) trend. If τ is significantly different from zero (e.g. value < 0.05 at 5% significance level or < 0.01 at 1% significance level), then based on the data, H_0 can be rejected at a preselected significance level (alpha = 5%) and the existence of a monotonic trend can be accepted.

Crop Dominance Index (D_i): Dominance indices were calculated for depicting the expansion of crops with time (Tonhasca 1993).

$D_i = N_i / N_r$, where N_i is the spread (thousand hectares) of the i^{th} crop and N_r equals the total spread.

Linear regression analysis: Linear regression models were estimated with all residuals and fit plots were autogenerated using SAS Software. Simple correlation was used to study association among different variables (Panse and Sukhatme 1985).

Results and Discussion

On an average, sesame crop occupied 6.6 thousand hectares area and produced 2.0 thousand tonnes of seed with productivity of 323 kg/ha in the state. The maximum area (9.1 thousand hectares) was covered during 1974-75. The highest production (3.9 thousand tonnes) and productivity (593 kg/ha) were recorded during 1968-69 and 1996-97, respectively.

Trend analysis in area, production and productivity

Year-wise trend analysis indicated a significant decrease in area and increase in productivity while no trend was observed in production (Table 1). Pentad-wise trend analysis also indicated a significant decrease in area while no trends in production and productivity were observed. A gradual decrease in area from 8.3 thousand hectares during 2nd pentad (1973-74 to 1977-78) to 4.0 thousand hectares during last pentad (2003-04 to 2007-08) was also noticed (Fig 1). Pentad-wise gradual decrease in production from 1st (2.3 thousand tonnes) to 4th pentad (1.3 thousand tonnes) followed by gradual increase thereafter up to 7th pentad (2.0 thousand tonnes) and decline further (1.7 thousand tonnes) during the last pentad was observed and as a result, no trends in production and

productivity of sesame were indicated by Mann-Kendall's trend test.

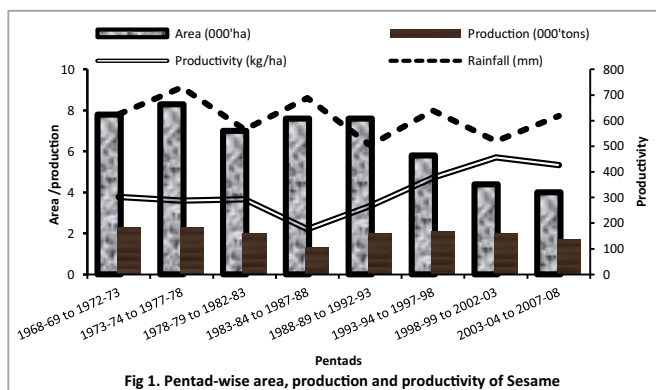


Fig 1. Pentad-wise area, production and productivity of Sesame

Pentad-wise percent shift in area, production, productivity and rainfall

The area under sesame showed decrease by 48.7% during 8th pentad over 1st pentad and as a result, reduction of 26.1% in production was also recorded (Table 2). The quantum

of *kharif* rainfall also exhibited 1.2% decline during 8th pentad over 1st pentad. Since, majority of *kharif* crops are raised under rainfed conditions, the decrease in area might be due to fluctuations in rainfall and shifting of area to other remunerative commodities although, an increase of 41.4% in productivity was observed.

The per cent shift in sesame area showed a positive and non-significant correlation with quantum of *kharif* rainfall ($r=0.144$) which indicated that variation in area covered was not due to rainfall variation. The decrease in area from 7.5 to 3.6 thousand hectares during 1968-69 to 2007-08 clearly indicated that the farmer's preference to this crop declined irrespective of quantum of seasonal rainfall received. The crop is negatively influenced by higher rainfall particularly during emergence and initial vegetative phases which is further substantiated by negative and non-significant correlation between the production ($r= -0.490$) and productivity ($r= -0.426$) with seasonal rainfall. Dominance Index also exhibited a gradual decrease in sesame area during past forty years of study (Fig 2).

Table 1. Year-wise and pentad-wise trend analysis in area, production and productivity of sesame during 1968-69 to 2007-08

Variable	Mann-Kendall's statistic (S)	Kendall's Tau	Var. (S)	p-value	Two-tailed test	Alpha value	Hypothesis accepted	Interpretation
Year-wise								
Area (000'ha)	-472.0	-0.611	7351.3	<0.0001		0.05	H _a	Decreasing trend
Production (000'tonnes)	-116.0	-0.152	7315.3	0.179		0.05	H ₀	No trend
Productivity (kg/ha)	187.0	0.240	7363.7	0.030		0.05	H _a	Increasing trend
Pentad-wise								
Area (000'ha)	-20.0	-0.714	0.000	0.014		0.05	H _a	Decreasing trend
Production (000'tonnes)	-12.0	-0.429	0.000	0.179		0.05	H ₀	No trend
Productivity (kg/ha)	10.0	0.357	0.000	0.275		0.05	H ₀	No trend

H₀: There is no trend in the observed data

H_a: There is a trend in the observed data

Table 2. Pentad-wise shift (%) in area, production, productivity and rainfall in sesame

Shift during	Area	Production	Productivity	Rainfall
2 nd pentad over 1 st pentad	6.4	0.0	-4.6	16.7
3 rd pentad over 2 nd pentad	-15.7	-13.0	3.9	-22.6
4 th pentad over 3 rd pentad	8.6	-35.0	-39.9	21.9
5 th pentad over 4 th pentad	0.0	53.8	51.7	-26.7
6 th pentad over 5 th pentad	-23.7	5.0	41.2	26.6
7 th pentad over 6 th pentad	-24.1	-4.8	21.0	-18.6
8 th pentad over 7 th pentad	-9.1	-15.0	-6.4	18.8
8 th pentad over 1 st pentad	-48.7	-26.1	41.4	-1.2

Studies on changes in the precipitation were conducted earlier by different workers (Mondal *et al.* 2012 and Rahman and Begum 2013) but, no such studies on relationship between quantum of rainfall received and spread, production and yield of sesame have been carried out in the state. However, similar studies were carried out in rapeseed-mustard in Haryana (Singh *et al.* 2004) and wheat (Kaur *et al.* 2006) and rice (Singh *et al.* 2006) in Punjab on district-wise basis wherein only spatio-temporal trends were studied. Likewise, a linear regression analysis on *rabi* oilseed crops of Himachal Pradesh indicated that the increase in seasonal rainfall may not be the sole reason for area expansion in rapeseed-mustard. However, a greater portion of variation in area as well as production in linseed was found to be due to variation in seasonal rainfall (Prasad and Kumari 2015). Studies on the effects of monsoon rainfall on yield of *kharif* rice indicated that the higher value of August rainfall than the long term average had a positive impact on the yield of *kharif* rice in Himachal Pradesh (Kumar *et al.* 2015).

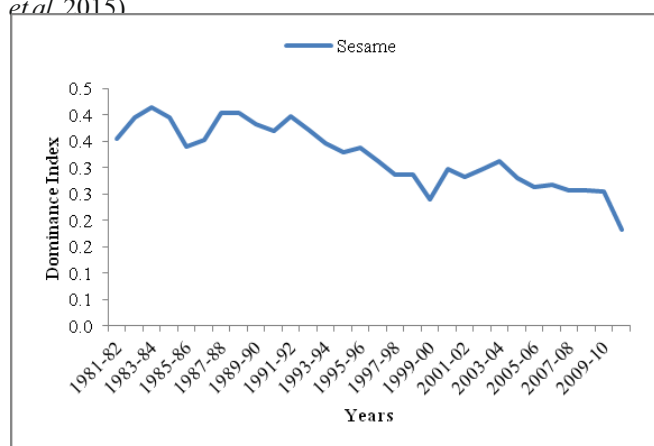


Fig 2. Year-wise Dominance Index in sesame spread

Regression analysis: Regression is used to study the empirical relationship between two variables. In order to model the area and production fluctuations based on rainfall, different linear regression models were fitted for the present data with area/production as Y (dependable variable) and rainfall as X (independent variable or predictor) and graphs were auto-generated along with residuals and fit plots. The results indicated an upward slope having positive and non-significant relationship ($F=0.71$) between sesame area and seasonal

rainfall indicating that with increase of rainfall by 1mm, average area predicted would increase by 0.0011 units only. Similar trend was also observed with production and rainfall having non-significant relation ($F=0.15$). This suggested that a significant portion of variation in area and production of sesame was not due to changes in seasonal rainfall (Fig. 3). All the residuals exhibited evenly scattered pattern and the average of residuals was zero which showed that the residuals appeared to be fairly normally distributed. Thus, the linear models fitted the data well. A non-significant negative relationship ($F=0.08$) with downward slope was also observed between productivity and seasonal rainfall *viz.*, if average rainfall increased by 1mm, average productivity is predicted to decrease by 0.028 units. The detrending between area, production and productivity *vis-à-vis* rainfall following standard statistical method also indicated weak, negative and non-significant association.

Cropping pattern of a region is closely influenced by the geo-climatic, socio-economic, historical and political factors (Nalawade *et al.* 2010). Cropping patterns in terms of area under major crops and crop groups underwent tremendous change in Himachal Pradesh during the last three and a half decades due to population pressure, urbanization and industrialization processes. Studies on land use and cropping pattern changes in the state have indicated 3.1% increase in area under maize from 1972-73 to 2004-05 (Kumar and Najibullah 2013; Kumar 2013). Cropping pattern has been shifted in favour of horticultural crops (apple, stone and other fruits and vegetables) and major cereals (maize and wheat). The scope to increase area under oilseeds is limited as the demand for land to produce other remunerative crops will continue to rise. Thus, strategies such as adoption of high yielding, photo- and thermo-insensitive varieties with multiple resistance, supply of quality seed, use of germplasm resources, adoption of farmers' participatory breeding approach and efficient transfer of various agro-techniques from lab to land seem imperative to improve the production and productivity of oilseed crops in the state (Kumari *et al.* 2006). As the oilseed growers are poorer among the farming community, the institutional support is imperative which will not only boost seed replacement rate but quality production as well.

The findings from the present investigation concluded that the sesame crop showed a significant decrease in area and increase in productivity while no trend was observed

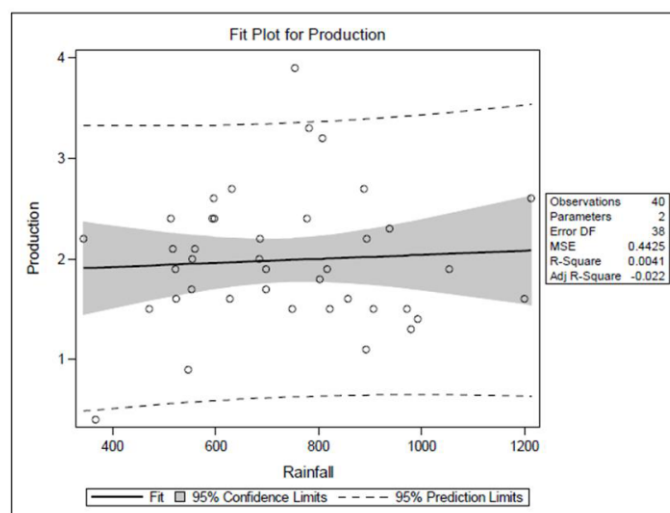
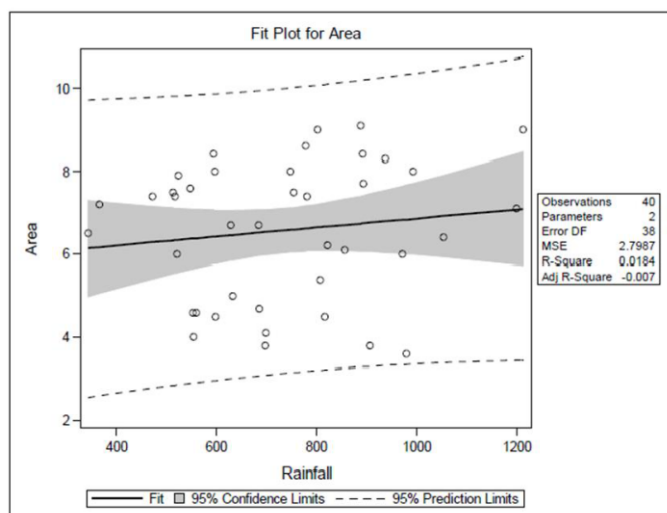


Fig 3. Fit plots for area and production in sesame

in production from 1968-69 to 2007-08 (forty years). Seasonal rainfall recorded 1.2% decrease during this period. Per cent shift in the area exhibited a non-significant positive correlation with sea-sonal rainfall while a non-significant negative correlation was observed between per cent shift in production and productivity with seasonal rainfall during past forty years of study. Linear regression analysis indicated that though, the relationship between area and seasonal rainfall was positive

yet, it may not be the sole reason of variation in area of sesame. On the other hand, production and productivity each exhibited a non-significant negative relationship with seasonal rainfall which suggested that the variation in production and productivity may not be due to variation in seasonal rainfall in sesame. Hence, 41.4% increase in productivity during 8th pentad over the 1st pentad could be attributed to agro-technological interventions including varietal improvement in sesame.

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