Himachal Journal of Agricultural Research 41(1): 6-12 (2015)

Impact of rainfall on area and production of *rabi* oilseed crops in Himachal Pradesh

Rajendra Prasad and Vedna Kumari*

Department of Agronomy
*Department of Crop Improvement
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062
drvedna@gmail.com

Received: 10.10.2014; Accepted: 05.01.2015

Abstract

The present study was carried out to assess the impact of rainfall on the spread, production and yields of *rabi* oilseed crops in Himachal Pradesh during the past forty years (1968-69 to 2007-08). Year-wise trend analysis in rapeseed-mustard indicated a significant increase in area, production and productivity while a significant decrease was observed in linseed with time. Pentad-wise shift indicated 71.7% increase in the area under rapeseed-mustard during 8th pentad over 1st pentad which might be due to 92.6% increase in rain fall during 8th pentad over 1st pentad. The technological inputs including improved varieties resulted in 105.6% increase in production and 20.4% increase in productivity. Pentad-wise shift in rapeseed-mustard area also exhibited a significant positive correlation with rainfall. In linseed, pentad-wise shift indicated a drastic reduction in area (78.8%), production (89.3%) and productivity (51.2%) during 8th pentad over 1st pentad. There was a negative and non-significant correlation of area with rainfall. The study indicates that under rainfed conditions, the farmers preferred rapeseed-mustard over linseed. Linear regression analysis indicated that the increase in seasonal rainfall may not be the sole reason for area expansion in rapeseed-mustard. On the other hand, a much part of variation in area as well as production in linseed appeared be due to variation in seasonal rainfall.

Key words: Area, production, rapeseed-mustard, linseed, rainfall, Mann-Kendall trend test

Oilseeds being a rich source of fats and vitamins, occupy an important position in Indian agricultural economy and daily diet. The diverse agro-ecological conditions in the country are favourable for growing the seven edible oilseeds (groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger) and two non-edible oilseeds (castor and linseed). India is the fifth largest vegetable oil economy in the world, next only to USA, China, Brazil and Argentina and has an annual turnover of about INR 80000 crores. India accounts for 12-15% of oilseeds area, 6-7% of vegetable oils production, 9-11% of the total edible oils consumption and 14% of vegetable oil imports. India has imported 51% of her requirements at a huge cost of INR 56910 crores during 2013-14 (Anonymous, 2015). India ranks first in the production of groundnut, second in rapeseed-mustard and fifth in soybean and thus, oilseed crops contribute a significant proportion to the agricultural GDP. The per capita consumption of edible oils in the country has witnessed a steep rise due to rise in population, change in life style, rising per capita income, availability of cheaper edible oil, luxuriant intake of edible oils and the consumer friendly import tariff policy which has resulted in dependency on imports to meet the additional requirement. The area expansion in oilseeds during the last two and half decades was a major source of growth in oilseeds production (Hegde, 2012).

In Himachal Pradesh, the major oilseed crops (rapeseed-mustard, sesame and linseed) are grown over an area of 13.0 thousand ha. Of which nearly 74.6% area is occupied by *rabi* oilseed crops *viz*., rapeseed-mustard and linseed. Rapeseed-mustard group of crops are grown over an area of 9.0 thousand ha with a total production of 2.4 thousand tonnes and productivity 267 kg/ha (Anonymous, 2012). Based upon the average data over the past ten years (1998-99 to 2007-08), rapeseed-mustard and linseed crops have accounted for 59.8 and 12.5% area under total oilseeds and contributed about 63.8 and 7.0% to the total oilseeds production in the state, respectively. The present investigation aims to understand the inter-relations between changes in spread, production and productivity of *rabi* oilseed crops *vis-a-vis* rainfall pattern during past forty years (1968-69 to 2007-08).

Material and Methods

The area, production and productivity statistics of rapeseed- mustard and linseed for forty crop seasons were taken from the 'Statistical Outline of Himachal Pradesh'. The data on winter rainfall for the same period were collected from Indian Meteorological Department, Pune. To quantify whether trends appear particularly severe during a particular time interval of the reference period, 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 and the spatio-temporal changes in area, production and productivity *vis-a-vis* rainfall were worked out. Year-wise trend analysis was done for area, production and productivity by following Mann-Kendall (Mann, 1945 and Kendall, 1975) non-parametric trend test. This is a statistical method used to study the spatial variation and temporal trends of hydro-climatic series. A non-parametric test is taken into consideration over the parametric one since it can evade the problem roused by data skewness (Smith, 2000).

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

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

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

The Mann-Kendall test statistic is calculated as

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

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

S is asymptotically normally distributed.

The mean and variance of S are given by

$$E(S) = 0$$

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

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 pre-selected 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 $x_j — x_k$.

The maximum value of S (called it D) occurs when $x_1 < x_2 < \ldots < x_n$

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

$$D = \begin{cases} \sqrt{\left\{ \dfrac{n(n-1)}{2} - \sum_{j=1}^{p} t_j(t_j-1) \right\}} \sqrt{\left(\dfrac{n(n-1)}{2} \right)} & \text{if ties} \\ \dfrac{n(n-1)}{2} & \text{noties} \end{cases}$$

A positive value of *tau* indicates that there is an upward (increasing) trend while a negative value of *tau* means that there is a downward (decreasing) trend. If *tau* 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 pre-selected significance level (alpha = 5%) and the existence of a monotonic trend can be accepted. Besides, Sen's Slope Estimator was used for the determination of trend and slope magnitude (Sen, 1968).

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

$D_i = N_i / N_T$, where N_i is the spread (thousand hectares) of the *i*th crop and N_T equals the total spread.

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

Results and Discussion

Crop-wise area, production and productivity (average of forty crop seasons) revealed that the rapeseed-mustard occupied 1st position in terms of area (7.4 thousand ha), production (2.6 thousand tonnes) and productivity (342 kg/ha) followed by linseed which exhibited an area of 4.3 thousand ha, production 1.6 thousand tonnes and productivity 335 kg/ha (Fig.1). Perusal of individual year's data revealed that in rapeseed-mustard, the maximum area (9.7 thousand hectares) and production (4.9 thousand tonnes) were recorded during the year 1999-2000 while in linseed, maximum area was covered during 1972-73 (6.9 thousand ha) and the maximum production (3.7 thousand tonnes) and productivity (561 kg/ha) were recorded during 1973-74.

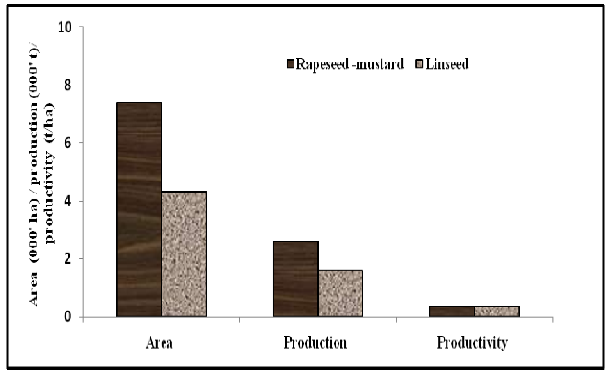

Fig 1. Area, production and productivity of *rabi* oilseed crops in Himachal Pradesh

Trend analysis in area, production and productivity

Year-wise trend analysis indicated a significant increase in area, production and productivity in rapeseed-mustard (Table 1a). A gradual increase in area from 5.3 thousand ha during 1st pentad (1968-69 to 1972-73) to 9.1 thousand ha during last pentad (2003-04 to 2007-08) was also noticed (Fig. 2). Pentad-wise trend analysis also indicated a significant increase in area while no trend in production and productivity was observed (Table 1b).

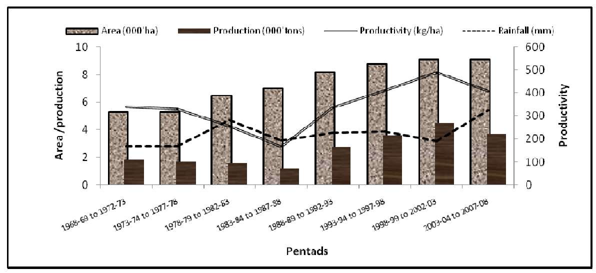

Fig 2. Pentad-wise rainfall, area, production and productivity in rapeseed-mustard

Table 1a. Year-wise trend analysis in area, production and productivity of *rabi* oilseed crops

Variable	Mann-Kendall's statistic (S)	Kendall's Tau	Var. (S)	p value Two-tailed test	Interpretation
		Rapeseed-mustard			
Area (000'ha)	573.0	0.705	7908.3	<0.0001	Increasing trend
Prod. (000'tonnes)	361.0	0.444	7913.0	<0.0001	Increasing trend
Productivity (kg/ha)	178.0	0.217	7924.7	0.047	Increasing trend
		Linseed			
Area (000'ha)	-737.0	-0.906	7912.3	<0.0001	Decreasing trend
Prod. (000'tonnes)	-566.0	-0.701	7892.7	<0.0001	Decreasing trend
Productivity (kg/ha)	-425.0	-0.522	7909.7	<0.0001	Decreasing trend

Pentad-wise gradual decrease in production from 1st (1.8 thousand tonnes) to 4th pentad (1.2 thousand tonnes) followed by rapid increase thereafter up to 7th pentad (4.5 thousand tonnes) was observed and as a result, no trend in production and productivity of rapeseed- mustard was indicated by Mann-Kendall's trend test. On the other hand, both year-wise and pentad-wise trend analysis indicated a significant decrease in area, production and productivity in linseed.

Pentad-wise per cent shift in area, production, productivity and rainfall

Rapeseed-mustard

Pentad-wise percent shift indicated that the area under rapeseed-mustard showed an increase of 71.7% during 8th pentad over 1st pentad (Table 2). Since majority of the *rabi* crops are raised under rainfed conditions, the increase in area might be due to 92.6% increase in rainfall

Table 1b. Pentad-wise trend analysis in area, production and productivity of *rabi* oilseed crops

Variable	Mann-Kendall's statistic (S)	Kendall's Tau	Var. (S)	p value Two-tailed test	Interpretation
			Rapeseed-mustard		
Area (000'ha)	26.00	0.929	0.000	0.000	Increasing trend
Prod. (000'tonnes)	14.00	0.500	0.000	0.109	No trend
Productivity (kg/ha)	10.00	0.357	0.000	0.275	No trend
			Linseed		
Area (000'ha)	-28.00	-1.000	0.000	<0.0001	Decreasing trend
Prod. (000'tonnes)	-22.00	-0.786	0.000	0.006	Decreasing trend
Productivity (kg/ha)	-20.00	-0.714	0.000	0.014	Decreasing trend

Table 2. Pentad-wise change (%) in area, production, productivity and rainfall in *rabi* oilseed crops

Change during	Area	Production	Productivity	Area	Production	Productivity	Rainfall
	Rapeseed-mustard			Linseed			
2^{nd} pentad over 1^{st} pentad	0.0	-5.6	-3.2	-4.5	10.7	4.1	0.41
3^{rd} pentad over 2^{nd} pentad	22.6	-5.9	-22.3	-12.7	-41.9	-31.6	67.2
4^{th} pentad over 3^{rd} pentad	7.7	-25.0	-34.9	-3.6	-27.8	-24.5	-31.6
5^{th} pentad over 4^{th} pentad	17.1	133.3	103.6	-24.5	15.4	44.8	17.2
6^{th} pentad over 5^{th} pentad	7.3	28.6	21.0	-15.0	-26.7	-14.6	2.4
7^{th} pentad over 6^{th} pentad	3.4	25.0	19.6	-32.4	-45.5	-19.7	-18.4
8^{th} pentad over 7^{th} pentad	0.0	-17.8	-16.6	-39.1	-50.0	-8.5	71.2
8^{th} pentad over 1^{st} pentad	71.7	105.6	20.4	-78.8	-89.3	-51.2	92.6

and technological interventions including improved varieties during the corresponding period which resulted in 105.6% increase in production and 20.4% increase in productivity. The percent shift in area also showed a significant positive correlation with quantum of *rabi* rainfall (r=0.86) which indicated that nearly 74% variation in area sown was due to rainfall variations. Earlier studies on comparative performance of karan rai, an important member of rapeseed-mustard group, indicated that though, the total seasonal rainfall contributed towards the seed yield; yet, about 30% or more if received during flowering to pod formation phase, increased the yields to a larger extent (Prasad and Kumari, 2006).

Linseed

A drastic reduction in area from 6.6 to 1.4 thousand ha was recorded. The production as well as productivity also declined from 1^{st} to 8^{th} pentad (Fig. 3). Pentad-wise per cent shift also indicated a drastic reduction in area by 78.8% thereby the reductions of 89.3% in production and 51.2 percent in productivity were registered during 8^{th} pentad over 1^{st} pentad (Table 2). The shift in linseed area showed a negative and non-significant correlation with seasonal rainfall (r= -0.68) which indicated that nearly 44% variation in area covered was due to rainfall . Studies on changes in the precipitation were also conducted earlier (Mondal *et al.*, 2012 and Rahman and Begum, 2013) but, no such studies 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. The increase in area from 5.3 to 9.1 thousand ha under rapeseed-mustard and decrease in area from 6.6 to 1.4 thousand ha in linseed during 1968-69 to 2007-08 clearly indicated that the farmers prefer rapeseed-mustard over linseed under rainfed conditions. Dominance Index also exhibited an increase in area over years under rapeseed-mustard while a drastic reduction in linseed spread was observed during past forty years of study (Fig. 4).

Regression analysis: Regression is often used to look for empirical relationship between two variables. In order to model the area and production fluctuations based on rainfall, different linear regression models were fitted both for rapeseed-mustard and linseed 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=3.83) between rapeseed-mustard area and seasonal rainfall *viz*., if average rainfall increased by 1 mm, average area is predicted to increase by 0.00668 units. Similar trends were also observed with production and rainfall having non-significant F=1.21 which indicated that a significant portion of variation in area and production of rapeseed-mustard was not due to changes in seasonal rainfall (Fig. 5a).

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. In linseed, a significant negative relationship (F=9.52) with downward slope was observed between area and seasonal rainfall viz., if average rainfall increased by 1mm, average area is predicted to decrease by 0.0109 units. Similar trends were observed between production and rainfall with significant F=10.27 indicating that a significant portion of variation in area as well production are explained by variation in seasonal rainfall in linseed (Fig. 5b).

There appears a limited scope to bring additional area under oilseeds as the demand for land to produce other remunerative crops will continue to rise due to population increase. The strategies such as adoption of high yielding, drought tolerant, 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 are imperative to improve the production and productivity of oilseed crops in the state (Kumari *et al.*, 2006).

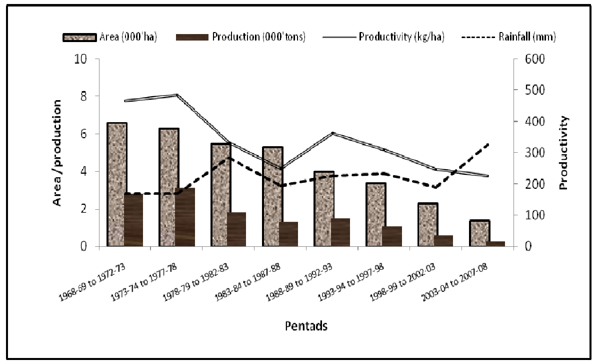

Fig 3. Pentad-wise rainfall, area, production and productivity in linseed

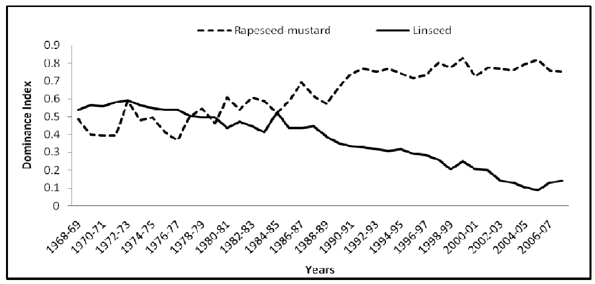

Fig 4. Year-wise Dominance Index in rapeseed-mustard and linseed spread

The findings from the present investigation concluded that the rapeseed-mustard crop showed a significant increase in area, production and productivity while a significant decrease was observed in linseed area, production and productivity from 1968-69 to 2007-08 viz., forty years of study period. Seasonal rainfall recorded 92.6 per cent increase during this period. Per cent shift in rapeseed-mustard area exhibited a significant positive correlation with seasonal rainfall while a non-significant negative correlation was observed between per cent shift in area and seasonal rainfall in linseed. Linear regression analysis indicated that though, the relationship was positive yet, it may not be the sole reason for its area expansion in rapeseed-mustard. On the other hand, both area and production exhibited a significant negative relationship with seasonal rainfall based on regression analysis which suggested that a much part of variation in area as well as production appeared be due to variation in seasonal rainfall in linseed.

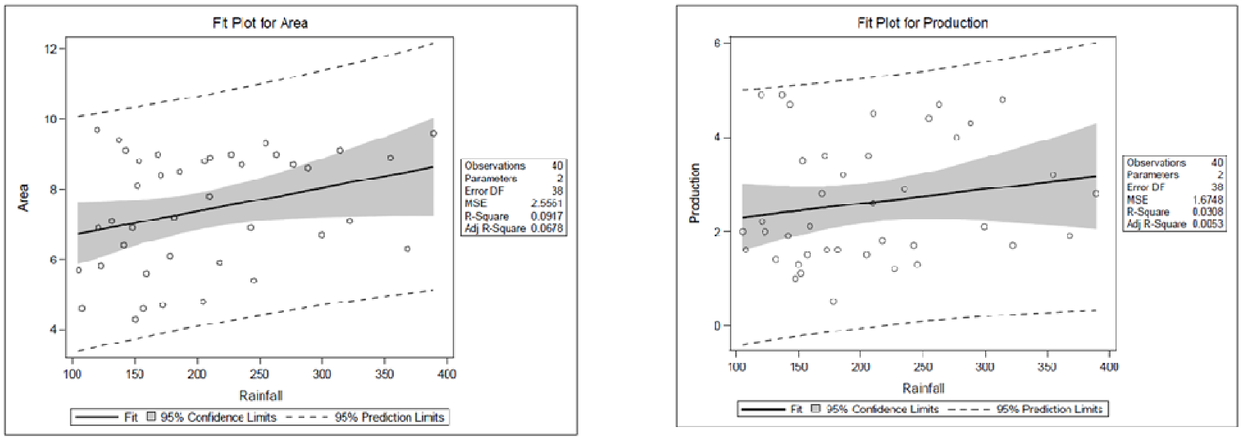

Fig 5a. Fit plots for area and production in rapeseed-mustard

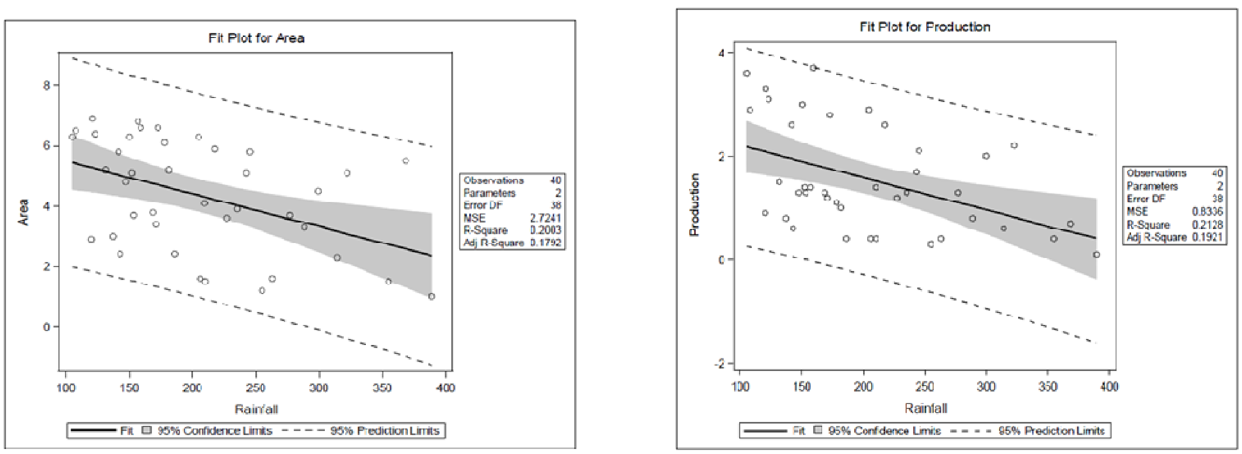

Fig 5b. Fit plots for area and production in linseed

References

Anonymous 2012. *Statistical Outline of Himachal Pradesh*. Department of Economics & Statistics (Govt. of H. P.), India.

Anonymous 2015. *Proceedings of National Seminar on strategic interventions to enhance oilseeds production in India* (February 19-21, 2015), Bharatpur (www.isorseminar.com).

Hegde DM 2012. Carrying capacity of Indian agriculture: oilseeds. Curr. Sci. **102** (6): 867- 873.

Kaur P, Singh H and Hundal SS 2006. Spatio-temporal changes in area, production and productivity of wheat (*Triticum aestivum*) in Punjab. Ind. J. Agril. Sci. **76** (1): 52-54.

Kendall MG 1975. *Rank Correlation Methods*, 4th edition. Charles Griffin, London, UK.

Kumari V, Kumar A and Prasad R 2006. Current status of rapeseed-mustard in Himachal Pradesh: Production constraints and future strategies. Ind. Farm. Dig. (February):19-22.

Mann HB 1945. Non - parametric test against trend. Econometri. **13**: 245–259.

Panse VG and Sukhatme PV 1985. *Statistical Methods for Agricultural Workers*. 4th Eds. ICAR, New Delhi, pp 97.

Prasad R and Kumari V 2006. Performance of karan rai (*Brassica carinata*) in relation to rainfall pattern in North western Himalayas. J. Agrometeorol. **8**(2): 230-236.

Sen PK 1968. Estimates of the regression coefficient based on Kendall's tau. J. Amer. Stat. Assoc. **39**: 379–1389.

Singh D, Pahadia KK and Rao VUM 2004. Spatio-temporal changes in area, production and productivity of rapeseed and mustard in Haryana. J. Agrometeorol. **6**(1): 115-118.

Singh H, Kaur P and Hundal SS 2006. Spatial and temporal changes in area, production and productivity of rice in Punjab. J. Agrometeorol. **8**(1):137-140.

Smith LC 2000. Trends in Russian Arctic river-ice formation and breakup, 1917 to 1994. Phy. Geog. **20** (1), 46–56.

Mondal A, Kundu S and Mukhopadhyay A 2012. Rainfall trend analysis by Mann-Kendall test: A case study of North-Eastern part of Cuttack district, Orissa. Inter. J. Geol. Earth and Environ. Sci. **2** (1):70-78.

Tonhasca AJ 1993. Carabid beetle assemblage under diversified agricultural systems. Entomol. Exp. Appl. **68**: 279-285.

Rahman MA and Begum M 2013. Application of non parametric test for trend detection of rainfall in the largest island of Bangladesh. ARPN J. Earth Sci. **2**(2): 40-44.