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Impact of Weather Parameters on Bengalgram Yield in Prakasam District

B Herold Deepak Roy, Shaik Nafeez Umar, V Srinivasa Rao and G Raghunadha Reddy
Department of Statistics and Mathematics, Agricultural College, Bapatla 522 101, Andhra Pradesh

ABSTRACT

This paper attempted to study the yield-weather relationship of chickpea (*Cicer arietinum*) in Prakasam district of AP. The annual yields and month wise weather parameters data for Prakasam district over fifteen years (2000-01 to 2014-15) were used to identify the quantum jumps and the technological changes. The yield-weather relationship was formulated using multiple linear regression.

Analogy of Control charts and Time trend equations suggested existence of quantum jumps. So, the time effect was found to be discrete in nature over time in the Bengal-gram yields creating two sub-periods which indicate technological changes in the study period. Crop yield-weather models revealed that Bengal-gram yields during 2000-01 to 2007-08 were influenced by January rainfall (positively) and during 2008-09 to 2014-15 by December rainfall (negatively) indicating differential weather response of respective technological periods. Thus it was inferred that overall yield-weather relationship may not be appropriate. Hence, individual relationships for the sub-periods prevailing in the yield data were found to be more meaningful.

Key words : Control Chars, Multiple Linear Regression,Quantum Jump, Time Trend.

Bengal-gram is called Chickpea or Gram (*Cicer aritinum L.*) in South Asia and Garbanzo bean in most of the developed world. It is also known as Egyptian pea or *Kabuli chana* . Its seeds are high in protein. It is one of the earliest cultivated legumes. Bengal-gram is a major pulse crop in India accounts for nearly 40 percent of the total pulse production. In Prakasam district Bengal-gram is cultivated as rainfed crop, as per latest statistics Bengal-gram production and productivity were 95,867 Ton and 1.89 Ton/hectare securing major share among pulse crops cultivated in the district. Hence, crop-weather modeling for such an important commercial crop is very important aspect of agricultural planning. The annual yields and month wise weather parameters data for Prakasam district over fifteen years (2000-01 to 2014-15) were collected from Error! Hyperlink reference not valid. (website of directorate of economics and statistics) and Meteorological observatory records of IMD, Prakasam Bhavan, Ongole, Andhra Pradesh were used for the study.

The influence of weather, rainfall in particular depends on its distribution over the crop period. However, this works suitably on the crop technology being adopted. There has been a significant increase in India's crop production since the introduction of technological innovations such as improved short duration crop varieties and modified cultural practices like optimum use of fertilizer, irrigation, insecticides and pesticides have been introduced into India during 1965-66. But, it has been observed that crop production under HYV technology has become more sensitive to weather fluctuations than under the traditional methods of cultivation (Ray, 1983).

MATERIALS AND METHODS

DISTRIBUTION OF RAINFALL

The present study was conducted to identify the distribution of rainfall in Prakasam district by employing Pearsonian Approach. That's based on calculating a measure, which is popularly known as constant 'K'. This constant 'K' is defined as:

$$K = \frac{\beta_1 [\beta_2 + 3]^2}{4 [2 \beta_2 - 3 \beta_1 - 6] [4 \beta_2 -3 \beta_1]}$$

Where,

"β_1 = Coefficient of Skewness and β_2 = Coefficient of Kurtosis.

On the basis of the range of 'K' values, Pearson listed certain distributions, which are known as "Pearsonian Distributions". These are as follows:

S. No.	Range of Constant 'K'	Type / Name of the Distribution
1.	K < 0	Type – I (or) Beta Distribution
2.	K > 1	Type – VI Distribution
3.	0 < K < 1	Type – IV Distribution
4.	K '! α	Type – III (or) Gamma Distribution
5.	K = 1	Type – V Distribution
6.	K = 0	Type – II (or) Type –VII i.e., Normal Distribution

Description of crop yield-weather model:
The general set-up of the crop yield-weather modelling can be viewed as follows (Sakamoto, 1981):

$$Y = f(t) + e$$

where, $e = f(w) + e_1$

so that, $Y = f(t) + f(w) + e_1$.

where, f(t) and f(w) are suitably chosen functions of time(t) and weather(w) variables which are assumed to be independently affecting the crop yield(Y), and hence 'e' and 'e_1' are the random errors.

Time Effect or Technological Impact on Crop yields

To measure the time effect, which also accounts for the technological impact on crop yields, the approach generally followed is fitting of suitable trend equation to the crop yield data. The effect of technological innovations on the crop yields is generally in the form of quantum jumps and it fluctuates over these jump levels. It was indicated by Kulkarni and Pandit (1988) that whenever quantum jumps are present in crop yield data there is a possibility of discrete time effect in the crop yield instead of the continuous one.

The points of discontinuity or the quantum jump in the crop yields was identified by analogy of control charts. If there is clustering of points at different levels of crop yields which are distinct, then we can assume the possibility of a discrete time effect revealing a single quantum jump in the crop yield, then the entire time series data can be grouped into two sub-periods. After the choice of the time effect is made by identifying significant trends in respective sub periods and overall period, the residual may be analyzed for the effect of weather.

RESULTS AND DISCUSSION

RAINFALL DISTRIBUTIO OF PRAKASAM DISTRICT

Prakasam district received highest average monthly rainfall in the month of October (184.48 mm). The other peak rainfall months are July (87.44), August (110.98), September (114.20) and November (108.31) and least amount of rainfall was received in the month of January (7.15).

The distributional characteristics of rainfall represented through the coefficient of skewness ("β_1) and coefficient of kurtosis (β_2) are presented in Table 1. It can be observed that the distribution of rainfall in all the months is non-normal i.e., these distributional characteristics never coincided with those of normal distribution ($\beta_1 = 0$ and $\beta_2 = 3$). The distributional characteristics, which measure the deviation from symmetry and peakedness, indicated that the distribution of rainfall in July, September, October and November was 'platykurtic', because β_2 for these three months was less than 3. The distribution of rainfall in rest of the months was 'leptokurtic' as β_2 was greater than 3. The coefficient of skewness for July and September was less than zero and for the remaining months it was greater than zero. This indicates that the rainfall distribution for July and September is 'negatively skewed' and for all other months it is 'positively skewed'.

The value of the Pearsonian criterion 'K' was found to be negative for most of the months except July, September and November. Rainfall distribution in the months of July and September was "Pearsonian Type II (or) Type VII" i.e., Normal distribution for which the value of 'K' is equal to zero. For the month of November the distribution of rainfall was identified as "Pearsonian Type IV" since the value of 'K' lies between zero and one. Whereas for rest of the months it was "Pearsonian Type I" i.e., Beta distribution.

Bengal-gram Yield-Weather Relationships

The Rabi-cropping season of Bengal-gram in Prakasam district extends from October to March. The annual Bengal-gram yields (kg/ha) of Prakasam district are presented in a line graph (Figure 1). The overall average yield of Bengal-gram for the period of 15 years (2000-01 to 2014-

Table 1. Distributional Characteristics of Rainfall in Prakasam District .

Parameters	June	July	August	September	October	November	December	January	February	March	April	May
Mean	66.69	87.44	110.97	114.20	184.48	108.31	16.25	7.15	10.75	14.15	17.70	43.21
S.D.	63.58	41.85	78.57	38.74	97.46	84.54	27.32	14.59	24.17	29.17	20.58	50.93
C.V. (%)	95.34	47.86	70.80	33.92	52.83	78.05	168.17	204.14	224.93	206.09	116.25	117.86
Coefficient of skewness	2.35	-0.09	1.81	-0.23	1.21	1.03	3.39	2.37	2.81	2.48	1.91	2.38
Coefficient of kurtosis	6.61	-0.80	3.87	-1.30	1.95	-0.14	12.32	4.50	7.96	5.55	3.33	5.95
K	-1.38	0.00	-0.85	0.00	-0.41	0.06	-2.87	-5.02	-2.12	-2.27	-1.49	-1.51

Table 2. Mean Bengal-gram yield (kg/ha) for different periods of Prakasam district.

Type	Mean	S.D.	C.V. (%)
Sub-Period I (2000-01to 2007-08)	1567.88	180.30	11.50
Sub-Period II (2008-09 to 2014-15)	1812.14	102.48	5.66
Overall(2000-01 to 2014-15)	1681.87	191.48	11.39

* Significant at 10% levels ** Significant at 5% levels
*** Significant at 1% levels

Table 3. Trend equations for Bengal-gram yields in Prakasam district .

Eq. No.	Type	Equations	R^2
1.	Sub-Period I	Y = 1746.75 – 39.75 t	0.29
2.	Sub-Period II	Y = 1648.85 + 40.82 t**	0.74
3.	Overall	Y = 1501.49 + 22.54 t*	0.27

* Significant at 10% levels ** Significant at 5% levels
*** Significant at 1% levels

Table 4. Bengal-gram yield – weather relationships for Prakasam district.

Eq. No.	Period of Relationship	Equations	R^2
1.	Sub-period I	Y = 1501.25 + 10.05* JANRF	0.53
2.	Sub-period II	Y = 1694.26 + 36.49**T – 1.14* DECRF	0.91
3.	Overall	Y = 1579.29 - 3.64** MARRF + 19.26* T	0.58

* Significant at 10% levels ** Significant at 5% levels
*** Significant at 1% levels

15) was 1681.87 kg/ha. It is obvious from the graph that yields for the years up to 2007-08 are mostly below the overall average yield, while the yields in subsequent years are mostly above it. This implies that there is a possibility of ‘time trend’ over the period. From 2008-09 onwards the average yields were more than overall average. Therefore the first 8 years (2000-01 to 2007-08) can be considered as group of ‘low yield’ years, while the next 7 years (2008-09 to 2014-15) are the ‘high yield’ years.

In the present study, convention of ‘control charts’, was used to study time trend effects by obtaining the σ limits, which represents the ‘Upper Control Limit’ (X + σ) and the ‘Lower Control Limit’ (X – σ). These limits for the group of low yield years i.e., sub-period I were 1748.17 kg/ha and 1387.58 kg/ha respectively, while for the high yield years i.e., sub-period II these limits were 1914.62 kg/ha and 1709.67 kg/ha respectively. It can be observed from Figure 1 that yields within each of these sub-periods are randomly scattered around the respective mean values. The randomness of crop yields was checked by using “One sample Run test” for sub-periods as well as the overall period. This behaviour of the crop yields suggests the evidence of a ‘quantum jump’ in the yields instead of a smooth increase over the years.

The quantum jump in the yields may be attributed to the “yield increasing technology” which mainly comprises of three components viz., biological (high yielders or hybrid varieties), chemical (fertilizers and plant protection chemicals) and mechanical (improved machinery and implements). Bengal-gram yields thus leads to investigation for the existence of discrete time trend, in contrast to a continuous time trend. It can be observed from the Table 2 that the yields of sub-period II exhibited a significant continuous trend (r = 0.86), while there is no significant evidence of a continuous time trend within sub-period I (r = 0.54). In case of overall yields the time trend was statistically significant. This ‘differential’ trend effect on the yields of sub-periods indicated differential weather response also. Hence, it is appropriate to fit the crop yield-weather relationships separately for each of the two sub-periods as well as for overall period.

The crop yield-weather relationships were developed separately for the yields of sub-period I and sub-period II as well as overall period by fitting multiple regression equations. Step wise regression procedure was applied for screening the independent variables (Kulkarni and Acharya, 1986). The results are presented in Table 3. Bengal-gram yields exhibited a differential response to weather fluctuations. The coefficient of determination (R^2) for sub-period I was 0.53 and for sub-period II, it was 0.91 (Table 3).

The weather parameters that were found to be significantly influencing Bengal-gram yields

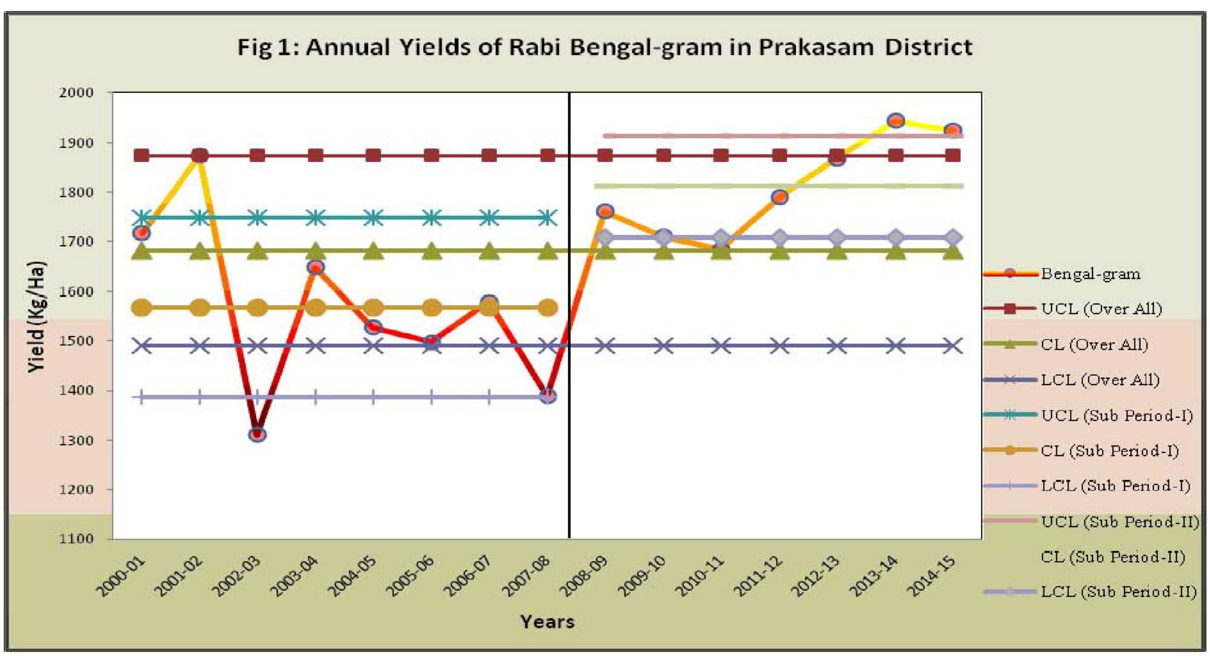

Fig 1: Annual Yields of Rabi Bengal-gram in Prakasam District

under sub-period I (Table 3 Eq.1) was January rainfall (positively related). January is the pod filling stage of the crop. Good rainfall during this phase may compensate irrigation and enhances translocation of photosynthates from source to sink (pod) thus contribute to yield.

The variables identified for sub-period II (Table 3, Eq.2) were time trend (positively related) and December rainfall (negatively related). In the month of December, flowering stage of chickpea commences so rains during this stage may hinder pollination and also result in the infestation of pod-borers which drastically reduce the yield.

In the crop yield-weather relationship for the overall period (Table 3, Eq.3), the regressors found significantly influencing the crop yield were March rainfall (Negatively related) and time trend (T) (positively related). These variables however were different from those of sub-periods relationships. Since the crop yield-weather relationships developed for Bengal-gram exhibited differential behaviour of yields in the two sub-periods i.e., the response of crop to the weather under two sub-periods was different. Hence, it can be concluded that the relationship obtained with overall data may not be reasonable for estimation of yields.

LITERATURE CITED

Kendall M and Stuart R A Text Book of "Advanced Theory of Statistics" – Vols. 1 and 2 by, Griffin Publishers.

Krishnamurthy K N, Bhoomika R R, Gowda D M and Raje G B M 2015 Fitting statistical distributions for maximum daily rainfall at GKVK station. *International Journal Of Pure And Applied Research In Engineering And Technology*, 3 (12): 64-74.

Kulkarni B S and Acharya H S 1986 The stepwise regression procedure for estimating sorghum yield-weather relationship. *Journal of Maharashtra Agricultural University*, 11 (1): 40-42.

Kulkarni B S and Pandit S N, Narahari 1988 A discrete step in the technology trend for sorghum yields of Parbhani, India. *Agricultural and Forest Meteorology,* 42:157-165.

Ray S K 1983 An empirical investigation of the nature and causes for growth and instability in Indian Agriculture 1950-1980. *Indian Journal of Agricultural Economics*, 38 (4): 459-479.

Sakamoto C M 1981 Climate crop regression yield model: An Appraisal. In A. Berg (ed.), *Application of remote sensing to agricultural forecasting.* A.A. Balkema, Rotterdam. 131-138.

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