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Inter-relationships between rainfall distribution and groundnut yield in Bhavnagar and Junagadh districts of Gujarat state

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ABSTRACT : Groundnut crop in Saurashtra region of Gujarat is predominantly grown as rainfed crop in *Kharif* season. The year to year fluctuation in the crop yields are mainly attributable to the variation in rainfall and its distribution. In order to study inter-relationships between rainfall distribution and groundnut yield in Bhavnagar and Junagadh districts of Gujarat state, correlation and regression analysis techniques were employed. The district-wise average yield data of groundnut and daily rainfall data were used over a period of 44 years *i.e.* from 1970-2014. Five broad approaches were tried to study the inter-relationships between rainfall distribution and groundnut yield. They were (1) aggregate rainfall, (2) monthly rainfall (3) fortnightly rainfall (4) week-wise rainfall and (5) crop phase-wise rainfall. In general it could be inferred that that the quantum of rainfall during different phenophases of the groundnut had appreciable influence on groundnut productivity.

KEY **W**ORDS : Inter-relationships, Rainfall, Distribution, Yield, Groundnut

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Groundnut is an important oilseeds crop grown in Saurashtra region of Gujarat state and occupies a very large area under *Kharif* cultivation in rainfed condition. Quantum and distribution of rainfall during the crop season is the most vital input for the groundnut. The region comprises of six districts *viz.*, Junagadh, Amreli, Rajkot, Bhavnagar, Jamnagar and Surendranagar. The year to year fluctuation in the crop yields are mainly attributable due to the variation in rainfall and its distribution.

Khatri and Patel (1982) studied the effect of rainfall distribution along with the eye estimates for five major groundnut growing districts of Saurashtra region using 21 years data (1957-77). The effects of rainfall pattern on the productivity of groundnut were studied by several scientists (Suryanarayana *et al.*, 1982 and Sahu *et al.*,2004). Patel and Vaishnav (2003) studied the effect of rainfall on groundnut yield under dry framing situation of Gujarat. Khatri and Patel (1990) tried to locate critical phases in groundnut crop by selecting rainfall variables through stepwise regression analysis technique. The effects of rainfall distribution on the yield of groundnut during its growth period were studied by Singh and Singh (1994) in Rajkot district of Gujarat. Forecasting of groundnut yield using rainfall variables for Saurashtra region of Gujarat was studied by Parmar *et al*. (2004). The present investigation has been taken upto study the inter-relationships between rainfall distribution and

groundnut yield in Bhavnagar and Junagadh districts of Gujarat state.

RESEARCH PROCEDURE

Bhavnagar and Junagadh districts were selected for the present study. The district-wise average yield data over a period of 44 years *i.e.* from 1970-2014 and the corresponding daily rainfall were collected from the Directorate of Agriculture, Gujarat state, Gandhinagar (Anonymous, 2015). Five broad approaches and correlation- regression analysis techniques were tried to study inter-relationships between rainfall distribution and groundnut yield. They were (1) aggregate rainfall, (2) monthly rainfall, (3) fortnightly rainfall, (4) week-wise rainfall and (5) crop phase-wise rainfall. In case of aggregate rainfall approach, the aggregate rainfall received during the crop period *i.e.* 23rd to 39th meteorological standard weeks (MSW) was considered *i.e.* pre sowing to pod maturation stage. For monthly rainfall approach, monthly total rainfall received during the months of June, July, August and September were worked out for each year. Usually monsoon gets withdrawn by the end of September and hence, October was not considered. Whereas, in case of fortnight rainfall approach, fortnightly total rainfall for the month of June, July, August and September were worked out for each year. In the week-wise rainfall approach, total rainfall received during each standard week (23rd to 39th) was worked out for each year. For crop phase-wise approach, the 17 weeks rainfall was divided into subgroups according to the five crop phases [(*i.e.* pre-sowing (23rd and 24th MSW), germination and vegetative growth (25th to 27th MSW), flowering and peg initiation (28th to 31st MSW), full pegging to pod development (32nd to 36th MSW) and pod maturation (37th to 39th MSW)] and total rainfall received during different physiological crop growth stages in each year was worked out for both the districts under study. Total growth period has been considered as 120 days.

RESEARCH ANALYSIS AND REASONING

The findings of the present study as well as relevant discussion have been presented under following heads :

Aggregate rainfall approach :

The result presented in Table 1 indicated that, the correlation co-efficient (r) between groundnut yield and aggregate rainfall were found positive and highly significant. Thus, the results revealed that groundnut productivity was directly associated with the aggregate rainfall received during its growing season in both the districts under study. The regression co-efficients along with the corresponding co-efficients of determination are presented in Table 2. The regression co-efficients corresponding to aggregate rainfall were positive and significant for both the districts. However, predictability of yield on the basis of aggregate rainfall was, in general, poor.

Table 1: Correlation co-efficients between groundnut yield and aggregate rainfall

Districts	Correlation co-efficients (r)
Bhavnagar	0.66**
Junagadh	0.58**

** indicate significance of value at P=0.01

Table 2: Fitted models for groundnut yield using aggregate rainfall approach

Variables	Bhavnagar	Junagadh
Constant	64.72	492.38
Reg. coeff.		
Aggregate rainfall	1.41** (0.31)	1.01** (0.27)
R^2	0.44	0.34

** indicate significance of value at P=0.01
Figures in parenthesis are standard errors (SE)

Monthly rainfall approach :

The correlation co-efficients (r) between groundnut yield and monthly total rainfall are presented in Table 3. The results indicated that correlation co-efficients (r) were positive and significant during June, July and August months for Bhavnagar district. For Junagadh district, the correlation co-efficients (r) were positive and significant during July and September months. Thus, the result revealed that, in both the cases the rainfall during July contributed significantly to the groundnut yield.

Table 3: Correlation co-efficients between groundnut yield and monthly total rainfall

Districts	Correlation co-efficients (r)			
	June	July	August	September
Bhavnagar	0.42*	0.48**	0.40*	0.28
Junagadh	0.19	0.47*	0.02	0.55**

* and ** indicate significance of value at P=0.05 and 0.01, respectively

The multiple regression equations were fitted for both districts are presented in Table 4. The results revealed that partial regression co-efficients were positive

and significant during June and July months for Bhavnagar district. In case of Junagadh districts, the partial regression co-efficients were positive and significant during June and September months. The R^2 values were 0.48 and 0.49 for Bhavnagar and Junagadh districts, respectively. Thus, the results indicated that splitting of total rainfall of the season into four monthly variables (Table 4) improved R^2 values when compared with R^2 values presented in Table 2. But increased predictability was not to the level of expectation. Alsberg and Griffing (1928) reported that in view of some of the critical period's monthly average were not adequate to explain the variation in yield, therefore, they suggested using much shorter interval than a month. In the present study it was observed that the monthly total rainfall could not sufficiently account for the total variation in the yield of groundnut.

Table 4: Fitted models for groundnut yield using monthly total rainfall approach

Variables	Bhavnagar	Junagadh
Constant	15.85	477.02
June	1.74* (0.807)	1.28* (0.62)
Reg. Coeff.		
July	2.23** (0.76)	0.69 (0.45)
August	1.43 (0.76)	-0.09 (0.56)
September	0.56 (0.77)	2.63** (0.90)
R^2	0.48	0.49

* and ** indicate significance of values at P=0.05 and 0.01, respectively
Figures in parenthesis are standard errors

Fortnightly rainfall approach :

Fortnightly total rainfall causes dampening of the fluctuation of rainfall so that some stability as well as simplicity is achieved in formalism. This formalism has a clear meaning because some water is retained in the soil for a fairly long time and act as buffer in emergency.

The correlation co-efficients (r) between groundnut yield and fortnightly total rainfall are presented in Table 5. For Bhavnagar district, the correlation co-efficients (r) were found positive and significant during 2nd fortnight of July and 1st fortnight of August months. In case of Junagadh district, the correlation co-efficients (r) were positive and significant during 2nd fortnight of July and 1st fortnight of September months. Thus, it could be observed from the result that, in both districts the rainfall during 2nd fortnight of July contributed significantly to the groundnut yield.

Stepwise regression technique was employed for fitting multiple regression equations (with F=1.25 to enter and <1.25 to remove) for both district. The partial

Table 5 : Correlation co-efficients between groundnut yield and fortnightly total rainfall

Districts	Correlation co-efficients (r)							
	June		July		August		September	
	Fortnight							
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Bhavnagar	0.35	0.16	0.19	0.51**	0.40*	0.10	0.25	0.11
Junagadh	0.36	-0.06	0.27	0.44*	-0.06	0.15	0.58**	0.09

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 6 : Fitted models for groundnut yield using fortnightly total rainfall approach

Variables	Bhavnagar	Junagadh
Constant	202.82	355.40
F_1	2.16* (1.04)	2.15* (0.84)
F_2	–	1.05 (0.54)
F_3	1.76 (1.28)	0.72 (0.43)
F_4	2.65* (1.11)	1.35* (0.62)
F_5	2.67* (0.99)	–
F_6	–	2.10* (1.02)
F_7	–	3.10** (0.83)
F_8	–	–
R^2	0.50	0.66

* indicate significance of values at P=0.05 and 0.01, respectively Figures in parenthesis are standard errors

regression co-efficients, their standard errors and the co-efficients of determination (R^2) are presented in Table 6.

where,

F_1=1st fortnight of June F_2=2nd fortnight of June

F_3=1st fortnight of July F_4=2nd fortnight of July

F_5=1st fortnight of August F_6=2nd fortnight of August

F_7=1st fortnight of September F_8=2nd fortnight of September

In case of Bhavnagar district, the partial regression co-efficients corresponding to F_1, F_4 and F_5 variables were positive and significant. For Junagadh district, the partial regression co-efficients were positive and significant for F_1, F_4, F_6 and F_7 variables. Thus, the result revealed that, rainfall during 1st fortnight of June and 2nd fortnight of July contributed significantly to the groundnut yield.

Weekly rainfall approach :

As suggested by Alsberg and Griffing (1928) shorter interval of time was considered in this approach. The standard weeks as prescribed by the Indian Meteorological Department were considered. The total rainfall received during standard weeks 23rd to 39th were correlated with groundnut average yield for both districts. The correlation co-efficients for 23rd to 39th standard week are presented in Table 7.

The result depicted in the Table 7 indicated that correlation co-efficient was positive and significant during 29th week in case of Bhavnagar district. In case of Junagadh district, correlation co-efficients were positive and significant during 29th, 35th and 36th weeks. Thus, it could be observed from the result that, in both districts the rainfall during 29th week contributed significantly to the groundnut yield.

Table 7: Correlation co-efficients between groundnut yield and meteorological standard week (MSW) total rainfall

MSW	Correlation co-efficients (r)	
	Bhavnagar	Junagadh
23	0.26	0.32
24	0.21	0.27
25	0.26	0.23
26	-0.02	-0.19
27	-0.07	0.10
28	0.26	0.30
29	0.42*	0.38*
30	0.31	0.28
31	0.31	-0.07
32	0.31	-0.04
33	0.10	0.05
34	0.08	0.23
35	0.30	0.44*
36	0.10	0.39*
37	0.06	0.11
38	0.125	0.02
39	0.14	0.15

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 8 : Pre-harvest prediction period for four different statistical models

No. of weekly rainfall variables considered		Variable codes	Prediction period
MSW	No. of weeks		
23-39	17	X_1 to X_{17}	2 weeks before harvest
23-37	15	X_1 to X_{15}	4 weeks before harvest
23-35	13	X_1 to X_{13}	6 weeks before harvest
23-33	11	X_1 to X_{11}	8 weeks before harvest

With a view to explore the possibility of pre-harvest prediction of groundnut productivity 2, 4, 6 and 8 weeks before the harvest, stepwise regression technique was employed for fitting four statistical models (with F=1.25 to enter and <1.25 to remove) for both districts. The pre-harvest predictions period tried are presented in Table 8. The results obtained thus, are discussed district wise.

Bhavnagar district :

The results depicted in Table 9 revealed that the fitted regression equation remained same for all the four period of prediction. The value of the co-efficient of determination (R^2) was 0.52 for all the four models. The results further revealed that none of the entered variable had significant partial regression co-efficients.

Junagadh district :

The results presented in Table 10 revealed that, in case of 17 and 15 weeks models, the partial regression co-efficients corresponding X_2, X_5, X_7, X_{13} and X_{14} were positive and significant. In case of 13 weeks model X_3, X_8 and X_{13} had positive and significant partial regression co-efficients. In case of 11 weeks model, X_1, X_3 and X_6 had positive and significant partial regression co-efficients. The value of R^2 ranged from 0.44 to 0.70. Thus, the results suggested that earliest prediction of groundnut yield is possible four weeks before harvest.

Khatri and Patel (1982) reported that for Bhavnagar, Jamnagar and Junagadh districts the weekly rainfall variables corresponding to flowering and peg initiation stage exerted favourable influence on the groundnut

Table 9 : Fitted models for groundnut yield using weekly rainfall at Bhavnagar district

Variables	17 Weeks	15 Weeks	13 Weeks	11 Weeks
Constant	232.45	232.45	232.45	232.45
Reg. Coeff.				
X_1	1.78 (1.37)	1.78 (1.37)	1.78 (1.37)	1.78 (1.37)
X_2	2.51 (1.77)	2.51 (1.77)	2.51 (1.77)	2.51 (1.77)
X_6	2.83 (1.70)	2.83 (1.70)	2.83 (1.70)	2.83 (1.70)
X_7	2.52 (1.55)	2.52 (1.55)	2.52 (1.55)	2.52 (1.55)
X_8	2.25 (2.01)	2.25 (2.01)	2.25 (2.01)	2.25 (2.01)
X_9	3.49 (1.92)	3.49 (1.92)	3.49 (1.92)	3.49 (1.92)
X_{10}	2.43 (1.36)	2.43 (1.36)	2.43 (1.36)	2.43 (1.36)
R^2	0.52	0.52	0.52	0.52

* and ** indicate significance of values at P=0.05 and 0.01, respectively Figures in parenthesis are standard errors

Table 10: Fitted models for groundnut yield using weekly rainfall at Junagadh district

Variables	17 Weeks	15 Weeks	13 Weeks	11 Weeks
Constant	375.90	375.90	467.26	489.43
Reg. Coeff.				
X_1	_	_	_	6.06* (2.35)
X_2	3.11** (0.94)	3.11** (0.94)	2.06 (1.08)	1.89 (1.29)
X_3	1.74 (1.01)	1.74 (1.01)	2.64* (1.08)	3.33* (1.33)
X_4	_	_	_	0.95 (0.79)
X_5	1.82* (0.70)	1.82* (0.70)	1.12 (0.73)	_
X_6	_	_	_	1.98* (0.85)
X_7	1.79* (0.77)	1.79* (0.77)	_	_
X_8	_	_	3.90* (1.57)	_
X_{10}	1.24 (0.90)	1.24 (0.90)	_	_
X_{11}	2.30 (1.27)	2.30 (1.27)	2.60 (1.39)	2.63 (1.66)
X_{13}	2.95** (1.09)	2.95** (1.09)	4.67** (1.158)	_
X_{14}	4.72** (1.39)	4.72** (1.39)	_	_
R^2	0.70	0.70	0.59	0.44

* and ** indicate significance of values at P=0.05 and 0.01, respectively Figures in parenthesis are standard errors

productivity. The rainfall variables belonging to full pegging to pod development stages were reported to have positive impact in case of Amreli, Jamnagar, Junagadh and Rajkot districts. For Jamnagar districts rainfall variable corresponding to germination and vegetative growth stage was also found to have positive influence on crop yield.

Kalawadia (1983) reported that the weekly rainfall variables belonging to flowering and peg initiation and full pegging to pod development stages had positive bearing on the groundnut yield for Junagadh district.

The present finding together with the reported work, revealed that the quantum of the influence of the rainfall variable differed over the districts. This could be attributed to the differing agroclimatic situation prevailing in different districts, varieties of groundnut grown, the cropping intensity, cultural practices and soil type.

Crop phase-wise rainfall approach :

Groundnut is subjected to moisture stresses (rainfall) at critical stages of crop growth resulting in wide fluctuations in yield. It is known that the moisture requirement of any crop varies with the physiological stages of the crop. Considering this, it was thought worthwhile to divide the aggregate rainfall into five different stages *viz.*,presowing, germination and vegetative growth, flowering and peg initiation, full pegging to pod development and pod maturation to study the effect of rainfall during these stages on the groundnut productivity.

The correlation co-efficients (r) between groundnut yield and total rainfall received during different physiological stages in both the districts are presented in Table 11. For both districts, the correlation co-efficients (r) were positive and significant during flowering and peg initiation and full pegging to pod development stages.

The rainfall received during these five crop stages were considered as independent variables and the average groundnut yield as the dependent variable. The multiple regression equations were fitted for both districts are presented in Table 12.

In case of Bhavnagar district, it could be observed from the results that the partial regression co-efficient corresponding to flowering and peg initiation stage was positive and significant. For Junagadh, it was observed from the results, that the partial regression co-efficients corresponding to pre-sowing, flowering and peg initiation, and full pegging to pod development stages were positive and significant. The value of the co-efficient of determination (R^2) was 0.51 for both the districts.

The result also showed that, positive and significant partial regression co-efficient corresponding to rainfall during flowering and peg initiation was observed in case

Table 11: Correlation co-efficients between groundnut yield and total rainfall received during different physiological stages

Physiological stages	Correlation co-efficients (r)	
	Bhavnagar	Junagadh
Pre-sowing	0.34	0.36
Germination and vegetative growth	0.14	0.01
Flowering and peg initiation	0.61**	0.42*
Full pegging to pod development	0.37*	0.45*
Pod maturation	0.15	0.13

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 12: Fitted models for groundnut yield using stage-wise rainfall approach

Stages/ variables	Bhavnagar	Junagadh
Constant	87.66	456.857
Reg. Coeff.		
Pre-sowing	1.89 (1.16)	2.392* (0.905)
Germination and vegetative growth	0.96 (0.97)	0.508 (0.421)
Flowering and peg initiation	2.58** (0.76)	0.966* (0.488)
Full pegging to pod development	0.79 (0.64)	1.870** (0.655)
Pod maturation	0.61 (1.07)	-0.577 (1.261)
R^2	0.51	0.51

* and ** indicate significance of values at P=0.05 and 0.01, respectively Figures in parenthesis are standard errors

of both districts. Thus, in general it could be inferred that sufficient rainfall at flowering and peg initiation crop stages is most critical for groundnut production in both districts.

Holdford (1971) reported positive correlation (r=0.99) between groundnut yield and amount of rainfall received during flowering to peg initiation in groundnut in Fiji.

Thus, it is clear from the discussion that the quantum of rainfall during different phenophases of the groundnut had appreciable influence on groundnut productivity, however, amount of rainfall or its distribution alone could not determine the groundnut yield. The related studies, suggested that water balance or soil moisture index, which integrates the effect of temperature, crop co-efficient at different phenophases, soil physical parameters along with the rainfall distribution could determine the groundnut productivity to a large extend.

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