Agropedology 2016, 26 (02), 222-229

Assessment of Weather Parameters for Groundnut (*Arachis hypogaea*) in Alfisols of Karnataka - a Regression Approach

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Abstract : In field trials for six years (2009-14) the influence of weather parameters on groundnut (Varieties namely TMV-2, JL-24, K-134 and C-2) grown in an Alfisole under varied sowing environments (July as normal sowing and August as late sowing months) was studied at Bengaluru, Karnataka. Rainy days (RD), bright sun shine hours (BSS), total pan evaporation (EVP. in mm), growing degree days (GDD) and rainfall, the cumulative of all measured during crop period influenced significantly the growth and yield of groundnut across the genotypes. However, Potential evapo-transpiration (PET) and length of growing period (LGP) during the cropping period did not have such significant influence. For achieving maximum yield, the optimum value of annual rainfall from the fitted quadratic curves, was found to be 650 mm. Bright sun shine hours, pan evaporation and GDD during the cropping period showed negative correlation with pod yield. Among the 11 multiple linear regression models, model III was found to be the most reliable in judging the yield potential of groundnut (Pod yield in $kgha^{-1}$ = -3058.24**+ 6.55 (RD) -2.01** (SSH) + 3.98* (GDD) -6.25 (evaporation in mm) + 8.01** (PET) -21.98** (LGP) + 3.38** (LAD) with R^2 (0.86**). Model IV (R^2=0.86**) and XI (R^2=0.60**)were effective in predicting the yield (R^2 =0.86**& 0.60**, respectively), however of the second order.

Keywords: Regression models, weather parameter, groundnut, Alfisols

Introduction

Groundnut (*Arachis hypogaea* L.) is an annual legume ranking 13th most important food crop and 4th most important oilseed crop of the world. Among oilseeds crops in India, groundnut contributes about 50% of area and 45% of oil production. Nearly 75% of the groundnut area lies in a low to moderate rainfall zones (Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra) with a short distribution of rainfall cause significant fluctuation in productivity. Assessment of weather parameters to groundnut goes a long way in (i) defining Agrometeorology for groundnut; (ii) quantifying the limits of weather parameters to achieve potential yield and ultimately establish crop weather relationship. The review of research reveals that higher air temperatures, evaporation rate and bright sunshine hours affected the reproductive phases. Whereas, the cooler temperatures, higher morning relative humidity (RH1) during pod initiation affected the biomass production. Therefore, study is conducted to ascertain the influence of different weather conditions on the performance of groundnut productivity in an Alfisols.

Materials and Methods

Field studies were conducted for six years (2009-14) with eight treatments combination varieties (TMV-2, JL-24, K-134 and C-2) and two dates of sowing (normal sowing and late sowing) replicated four times in Randomized Block Design at GKVK farm, Bengaluru (13^{0}05'N; 77^{0}34'E) at an elevation of 924m above mean sea level during the rainy cropping season (*Kharif* season from July-December). The area receives around 928 mm of rainfall in two peaks one during May and another during September (bimodal type).

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Daily weather parameters *viz*., Rainfall (RF), Rainy Days (RD), Potential Evapo Transpiration (PET), Length of growing period (LGP), Bright Sun Shine Hours (BSS), Growing Degree Day (GDD), total pan evaporation (EVP) and Leaf Area Duration (LAD) were recorded, calculated and pooled accordingly for developing the models.

The difference in moisture holding capacity (w/w) at 33 and 1500 kPa was multiplied by bulk density and soil depth to calculate the total plant available water holding capacity of the soil. The length of growing period was calculated following the FAO model (Higgins and Kassam, 1981). However, to calculate the LGP after the cessation of rains, the actual stored soil moisture (PAWC) in each soil unit was used instead of the assumed 100 mm in the FAO model. The crop was raised as per the package of cultivation practices recommended for the agro-climatic zone (University of Agricultural Sciences, 2012). The pod yield (kg ha^{-1}) was calculated from the sun-dried grain weights of harvested net plots of 5.4m x 4.8m.

Correlation matrix was worked out to study the relationship of the soil-site parameters among themselves and on crop yield. In order to find the optimum range of any given soil parameter (x) for obtaining maximum crop yield (y), a quadratic equation ($y = a+bx+cx^2$) was fitted. Further, the statistical relationships between the soil-site characteristics (x_1 to x_n) altogether and the pod yield were established by multiple linear regression (MLR) equations ($y = a + b_1x_1 + b_2x_2 + …….. + b_nx_n$).The R^2 value obtained was tested at or below 5% level of significance. Using the step-down regression analysis by least square technique, the less important soil parameters were dropped one after another and the MLR models with pod yield were developed with important parameters. Among the number of models so developed, the best models were chosen based on the criteria suggested by Barrie *et al*. (1986)

Results and Discussion

Long term trials have been carried out in alfisols and weather suitability models were worked out. With respect to dates of sowing (Table1), July sown crop recorded significantlyhigher groundnut yield (1326.1 $kgha^{-1}$) compared to late sowing (792.4 $kgha^{-1}$).

Table 1. Pod yield ($kgha^{-1}$) of groundnut as affected by sowing time and varieties (pooled data of 2009-2014)

Varieties	Normal sowing (July)	Late sowing (August)	Mean
	----------(Kg ha^{-1})----------		
TMV-2	1370.4	779.2	1074.8
JL -24	1223.9	741.9	982.9
K -134/C-2	1383.9	856.2	1120.1
Mean	1326.1	792.4	1059.2
Tests of significance	Variety	Sowing	Interaction
SEm±	27.44	22.40	38.81
CD (0.05 P)	166.97	136.33	236.13

The recently released varieties *viz*., K -134 ,C-2 performed well (1383.9 kgha^{-1}) under normal sowing window of July due to the advantage of higher and assured rainfall than that of late sowing in August, which is a common practice with the farmers. The pod yield of groundnut was regressed against weather and the consequent growth parameters individually and it showed that the four parameters *viz*., RD, BSS, GDD were significantly related. Rainy days contributed significantly (51%) on yield (Table 3) and it was quadratic in nature (y= 437.91 -14.48x + 1.11x^{2,} r =0.72**). The annual rainfall was positively correlated with pod yield (R^2 0.199) For achieving maximum yield, the optimum value of annual rainfall from the fitted quadratic curves, was found to be 650 mm (Fig. 1). Bright sun shine hours being negatively correlated with pod yield showed strong quadratic relation with pod yield to the extent of 62% (R^2= 0.623**). Pan evaporation and GDD were the second order negatively correlated (r = -0.673 and -0.421) parameters with R^2 value of 0.45 and 0.178, respectively. The weather parameters and corresponding total dry matter and yield of groundnut varieties have been given in table 2

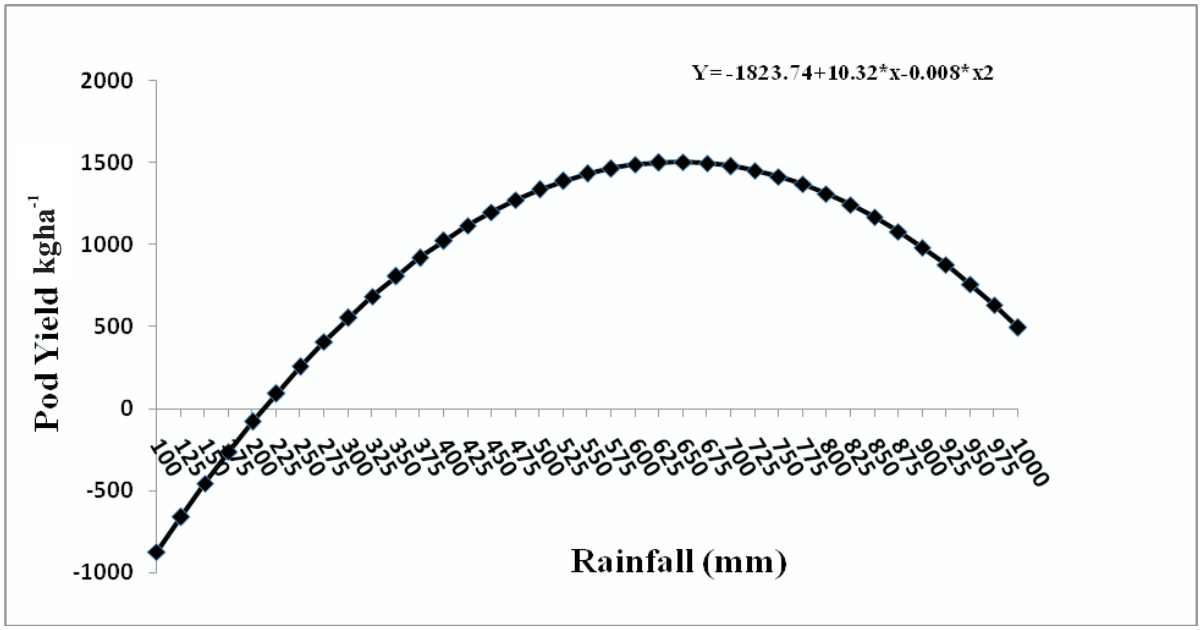

Fig. 1: Quadratic relationship between annual rainfall and pod yield of groundnut over the years in alfisols

Table 2. Master table of weather parameters and the corresponding growth and yield of groundnut during six years (2009-2014) of experimentation.

SL. No.	Date of Sowing	Variety	Rainfall (mm)	Rainy days	BSS	GDD (^{0}c)	EVP (mm)	PET (mm)	LGP (days)	LAD (days)	TDM (g plant^{-1})	Pod yield (kgha^{-1})
1	3.8.2009	TMV-2	377	27	694.5	1582	487	438	105	256	20.56	1325.0
2	3.8.2009	JL-24	377	27	694.5	1582	487	438	105	211	18.01	1127.0
3	3.8.2009	K-134	377	27	694.5	1582	487	438	105	257	19.92	1331.0
4	20.8.2009	TMV-2	347	24	746.2	1666	538	453	88	118	11.67	784.0
5	20.8.2009	JL-24	347	24	746.2	1666	538	453	88	130	13.46	853.0
6	20.8.2009	K-134	347	24	746.2	1666	538	453	88	109	15.64	896.0
7	13.7.2010	TMV-2	570	39	447.5	1567	359	424	118	198	16.82	1861.0
8	13.7.2010	JL-24	570	39	447.5	1567	359	424	118	169	17.28	1635.0
9	13.7.2010	K-134	570	39	447.5	1567	359	424	118	164	14.76	1425.0
10	29.7.2010	TMV-2	525	34	393.7	1513	343	376	115	209	19.57	1427.0
11	29.7.2010	JL-24	525	34	393.7	1513	343	376	115	184	18.03	1342.0
12	29.7.2010	K-134	525	34	393.7	1513	343	376	115	183	16.01	1302.0
13	6.7.2011	TMV-2	495	34	545.2	1586	397	416	116	226	21.40	1309.0
14	6.7.2011	JL-24	495	34	545.2	1586	397	416	116	233	24.74	1413.0
15	6.7.2011	K-134	495	34	545.2	1586	397	416	116	182	24.23	1413.0
16	27.7.2011	TMV-2	480	32	638.7	1574	401	421	119	172	24.27	1019.0
17	27.7.2011	JL-24	480	32	638.7	1574	401	421	119	201	18.01	930.0
18	27.7.2011	K-134	480	32	638.7	1574	401	421	119	235	15.51	1106.0
19	16.7.2012	TMV-2	411	21	735.4	1821	566	443	135	212	16.90	550.0
20	16.7.2012	JL-24	411	21	735.4	1821	566	443	135	225	18.60	541.7

21	16.7.2012	K-134	411	21	735.4	1821	566	443	135	231	17.70	758.3
22	6.8.2012	TMV-2	341	16	824.4	1752	571	434	113	211	20.10	495.8
23	6.8.2012	JL-24	341	16	824.4	1752	571	434	113	158	11.30	287.5
24	6.8.2012	K-134	341	16	824.4	1752	571	434	113	179	16.80	473.3
25	11.7.2013	TMV-2	551	33	566.6	1682	396	381	126	252	14.50	1721.0
26	11.7.2013	JL-24	551	33	566.6	1682	396	381	126	212	16.00	1423.0
27	11.7.2013	C-2	551	33	566.6	1682	396	381	126	315	22.70	1561.0
28	12.8.2013	TMV-2	536	30	685	1647	451	387	129	218	20.60	548.0
29	12.8.2013	JL-24	536	30	685	1647	451	387	129	219	17.90	468.0
30	12.8.2013	C-2	536	30	685	1647	451	387	129	392	19.70	697.0
31	10.7.2014	TMV-2	739	38	548	1731	454	431	127	200	12.00	1456.4
32	10.7.2014	JL-24	739	38	548	1731	454	431	127	196	9.70	1203.2
33	10.7.2014	C-2	739	38	548	1731	454	431	127	179	9.30	1815.5
34	9.8.2014	TMV-2	699	33	657	1612	443	407	123	149	10.70	400.8
35	9.8.2014	JL-24	699	33	657	1612	443	407	123	153	10.50	570.8
36	9.8.2014	C-2	699	33	657	1612	443	407	123	160	10.20	663.3

*TDM- Total dry matter

Table 3. Simple linear regression (SLR) and simple quadratic regression (SQR) climatic parameters and growth parameters of groundnut on pod yield (kg ha^{-1})

Parameters	Type	r Value	Equation	R^2 Value
Rainfall (mm)	Linear	+0.319 NS	Y=473.417 + 1.157 x	0.102 NS
	Quadratic	+0.445*	Y=-1823.74 + 10.32*x -0.008*x^2	0.199*
RD	Linear	+0.706**	Y=-366.75 + 47.401** x	0.500**
	Quadratic	+0.716**	Y=437.907 -14.476 x + 1.114 x^2	0.513**
BSS (hrs)	Linear	-0.769**	Y=2803.98**-2.798** x	0.592**
	Quadratic	-0.789**	Y=1069.86 + 3.185 x -0.005 x^2	0.623**
GDD (^{o}c)	Linear	-0.421*	Y=4614.82**-2.162* x	0.177*
	Quadratic	-0.421*	Y=7841.32 -6.044 x + 0.001 x^2	0.178*
EVP (mm)	Linear	-0.673**	Y=2876.45**-4.0340** x	0.453**
	Quadratic	-0.673**	Y=3139.176 -5.201 x + 0.001 x^2	0.453**
PET (mm)	Linear	-0.210 NS	Y=2680.902*-3.883 x	0.044 NS
	Quadratic	-0.218 NS	Y=-5696.43 + 36.91 x -0.049 x^2	0.048 NS
LGP (days)	Linear	-0.032 NS	Y=1202.165 -1.213 x	0.001 NS
	Quadratic	-0.327 NS	Y=-8038.25 + 166.74* x -0.752* x^2	0.107
LAD (days)	Linear	+0.159 NS	Y=784.79*+1.354 x	0.025
	Quadratic	+0.294 NS	Y=-294.50 +11.215 x -0.021 x^2	0.086
TDM (g/plant)	Linear	+0.161 NS	Y=775.49*+16.882 x	0.026
	Quadratic	+0.180	Y=1249.22 -43.81 x + 1.820 x^2	0.032

**: Significant at 5% level

The temperature in groundnut growing areas of Karnataka is highly variable and always remains above the optimum (36/22 ^{0}C) and therefore often have negative relationship with the pod yield. Craufurd *et al.* (2002) observed reduced dry weight, harvest index and seed yield at temperature 38/22^0 C and above. The quadratic relation with total rainfall ($y = -1823.74 + 10.32^*x - 0.008^*x^2$ with $R^2 = 0.20^*$) was not as important as the distribution of rainfall as measured by rainy days with more than 2.5 mm of rainfall.

The correlation matrix indicated LGP being closely related not only with rainfall distribution but also with available moisture holding capacity of the soil and thus combindly influenced the seed yield (Shivaramu *et al*., 1997). Therefore, instead of looking at the individual effects of any parameters, the overall interaction of different non collinear parameters on grain yield seemed to be appropriate (Shivaramu, 2012) and hence MLR equations were worked out. The significant R^2 values of these MLR equations worked out for groundnut ranged from 0.86 in model number I (Table 4), when nine weather parameters were regressed to 0.60 in model number XI involving only two significant weather parameters *viz*., Rainy days and BSS. Model VIII defined by SSH and LGP could explain up to 62% of the pod yield ($R^2 = 0.62^{**}$). Model III consisting of RD, SSH, GDD, pan evaporation, PET, LGP and the LAD together staked 86% of the pod yield and was found to be the best based on the set out criteria (Barrie *et al*., 1986), followed by model IV (R^2=0.858) and model XI (R^2= 0.60) with only Rainy days and BSS together. SSH and LGP in association gave an MLR of R^2 value of 0.62 which was also found to be significant (pod yield = 1766.96*-4.04** (sunshine hrs/day) + 2.15** (GDD) -19.57 (LGP) with R^2 value of 0.75**).

Table 4.Multiple linear regression models of climatic and growth parameters together against pod yield (kg ha^{-1}) of groundnut

Parameters	Model Number										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Rainfall (mm)	-0.467	-0.584	-	-	-	-	-	-	-	-	-
RD	21.487	22.788	6.551	-	-	-	-	-	18.675	18.914	12.007
BSS (hrs)	-1.979*	-1.965**	-2.008**	-2.038**	-2.712**	-4.041**	-2.964**	-2.916**	-2.850*	-2.865**	-2.240**
GDD (^{o}c)	3.913	3.881**	3.984*	4.095**	3.963**	2.150**	-	-	0.0569	-	-
EVP (mm)	-5.134	-5.132	-6.250	-6.951**	-4.046	-	-	-	1.6267	1.720	-
PET (mm)	6.609	6.565	8.006**	8.635**	-	-	-	-	-	-	-
LGP (days)	-20.44**	-19.974**	-21.984**	-21.569**	-25.369**	-19.573**	-11.284*	-6.637	-	-	-
LAD (days)	2.998**	3.043**	3.376**	3.343**	2.703**	2.876**	2.281*	-	-	-	-
TDM (g/plant)	2.612	-	-	-	-	-	-	-	-	-	-
A	-3242.02*	-3180.95*	-3058.24*	-3014.86*	497.060 NS	1766.96*	3774.43**	3659.48**	1447.81 NS	1501.63	2094.53*
S.E. of a	1314.09	1253.92	1222.41	1204.47	1052.11	839.61	542.99	577.96	1447.73 NS	1068.88	884.73
S.E. of Y	193.270	189.70	187.59	185.25	229.15	238.46	265.38	283.59	296.56	291.90	291.81
Adjusted R^2	0.813**	0.820**	0.824**	0.829**	0.738**	0.716**	0.649**	0.599**	0.561**	0.575**	0.576**
R^2	0.861	0.861	0.860	0.858	0.775	0.749	0.679	0.622	0.612	0.612	0.600

**: Significant at 5% level

Sys *et al.* (1993) have attempted to establish the crop requirements by setting the suitability classes and the range of limits of climate, landscape and soil characters for all the important crops including groundnut. Further, Naidu *et al*. (2003) attempted to establish the soil-site suitability criteria for groundnut for India but seemed to have generalized and hence needs refinement in the light of the present findings.

Conclusions

Based on the study it is recommended to take up the sowing in first fortnight. Rainy day is a critical factor deciding the growth and yield of groundnut followed by LAD. However, BSS and GDD, being abundant and beyond the optimum requirement for groundnut showed negative relationship with pod yield of groundnut.

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Received: July 2016 *Accepted: November 2016*