Influence of Weather and Growth Parameters on Yield of Pigeon pea in an Alfisol of Karnataka

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Abstract: In field trials for six years, the influence of weather parameters on pigeon pea was studied in an Alfisol of Bengaluru, Karnataka. Pooled analysis revealed that for delay in sowing by each day, the normal sowing month from June resulted in decreased yield of pigeon pea by 11.13 kg ha^{-1}, thus indicating the importance of early and timely sowing to get the advantage of higher rainfall, rainy days (RD), length of growing period (LGP in days), growing degree days (GDD) and leaf area duration (LAD in days). Among the above RD, LGP, GDD, LAD were found to have influenced the yield of pigeon pea significantly. For achieving maximum yield, the optimum values of the above parameters obtained from the fitted quadratic curves, were 90 RD, 2600 GDD and 300 LAD during the cropping period. Among the 10 multiple linear regression (MLR) models established, model V was found to be the most reliable in judging the yield potential of pigeon pea.

Introduction

Pigeon pea [*Cajanus cajan* (L.) Millsp.] is an important legume of the semi-arid tropics, grown pre-dominantly as rainfed crop in Alfisol and Vertisols of India. It is considered as a soil ameliorant due to its deep roots which breaks plough pans, prevents soil erosion due to its extensive ground coverage of the canopy, besides nitrogen fixation and addition of biomass back to the soil through leaf fall. Assessment of climatic suitability to pigeon pea goes a long way in (i) defining agrometeorology for the crop and (ii) quantifying the limits of weather parameters to achieve the potential yield. Therefore to establish crop weather relationship, long term trials of pigeon pea were carried out in an Alfisol and weather suitability models were worked out.

Materials and Methods

Field studies on the influence of weather parameters on pigeon pea were conducted with three replications (Randomized Block Design) consisting of 27 treatments on spacing, variety and date of sowing for six years (2009 - 14) in GKVK farm, Bengaluru during the rainy season (from July-December). The experimental site is situated at 13^{0}05' N latitude, 77^{0}34' E longitude and at 924m. above mean sea level. The area receives around 928 mm of rainfall in two peaks one in May and another in September (bimodal type).

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 seed yield (kg ha^{-1}) was calculated from the sun-dried grain weights of

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harvested net plots of 4.5m X 4.5m.

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 all the soil-site characteristics (x_1 to x_n) and the seed yield were established by fitting multiple linear regression (MLR) equations ($y = a + b_1x_1 + b_2x_2 + \ldots\ldots + b_nx_n$). 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 seed yield were developed keeping the remaining important soil site parameters. Among the number of models so developed, the better models were chosen based on the criteria suggested by Barrie *et al.* (1986).

Results and Discussion

Pooled analysis of the data (Table 1) for understanding the effect of sowing time, varieties and spacing revealed that early sowing in June enhanced the yield of pigeon pea across all the varieties and spacings. Higher yield could be achieved mainly due to the advantage of higher LGP and GDD requirement in case of early sown crop compared to the late sown crop. Delay in sowing by each day from June to August resulted in decrease in yield by 11.13 kg

ha[-1], thus indicating the importance of early and timely sowing of pigeon pea under rainfed situations. Increased spacing and reduced population significantly reduced the yield, particularly, in early sown crop. The recently released BRG varieties out yielded the national check (TTB-7), irrespective of the sowing windows and population implying the climate resilient characteristics of the BRG series.

It was observed that among the seven weather parameters and two growth parameters (Table 2) three weather parameters and one growth parameter *viz*., RD, LGP, GDD and LAD had significant correlation with seed yield of pigeon pea. Pigeon pea being a long duration crop, yield had a strong positive correlation with moisture availability period defined by LGP. The relationship further indicates that LGP alone contributes 24% of the yield variation. RD also had a strong positive correlation with seed yield of pigeon pea. From the curvilinear relationship between yield and RD, optimum Rainy day requirement was worked out to be 90 rainy days (Fig.1). The third important weather parameter in the order was GDD showing relationship of quadratic nature and explaining 20% of seed yield variation ($R^2 = 0.199$). From among the growth parameters, a significant quadratic relationship between LAD and seed yield of pigeon pea was observed explaining 17% yield variation while total dry matter (TDM) could explain 19% of variation in yield. Accordingly, the optimum values of LAD were worked out to be 300 days (Fig. 2) and 85 g/plant of total dry matter.

Table 1. Effect of sowing time, varieties and spacing on seed yield (kg ha⁻¹) of pigeon pea (pooled data of 2009-2014)

	Sowing months											
	June				July				August			
Spacing	60 cm x 22.5cm	90 cm x 22.5 cm	120 cm x 22.5cm	Mean x 22.5cm	60 cm x 22.5cm	90 cm x 22.5 cm	120 cm x 22.5cm	Mean x 22.5cm	60 cm x 22.5cm	90 cm x 22.5 cm	120 cm x 22.5cm	Mean x 22.5cm
Variety												
TTB-7	1323	1277	1007	1202	780	845	706	777	542	611	671	608
BRG-1	1625	1338	1199	1387	1241	840	830	970	581	810	876	756
BRG-2	1562	1501	1077	1380	932	1068	754	918	689	591	523	601
Mean	1503	1372	1094	1323	984	918	763	888	604	670	690	655

Tests of Significance	Spacing (S)	Variety (V)	Sowing month (M)	SxV	SxM	VxM	SxVxM
SE m ±	63.1	63.1	63.1	109.3	109.3	109.3	189.3
CD (0.05 P)	183.4	183.4	183.4	317.6	317.6	317.6	550.1

Table 2. Simple Linear Regression (SLR) and Simple Quadratic Regression (SQR) of maturity seed yield (kg ha⁻¹) of pigeon pea with climatic as well as growth parameters

| Parameters	Type of equation	r Value	Equation	R^2 Value	Adjusted R^2
Rainfall (mm)	Linear	+0.411**	$Y=-37.098 + 1.723^{**}X$	0.169	0.164
	Quadratic	+0.396**	$Y=-169.054 + 0.001^{*}X+0.916x^2$	0.157	0.146
Rainy days(RD)	Linear	0.474**	$Y=-119.098+31.797^{**}X$	0.224	0.219
	Quadratic	0.475**	$Y=-327.012+45.388x - 0.202x^2$	0.225	0.214
Sunshine hours	Linear	-0.066NS	$Y=1193.37^{*} -0.242x$	-0.002	0.004
	Quadratic	-0.11NS	$Y=2562.28 -2.823x + 0.001X^2$	-0.003	0.012
Growing Degree Days (GDD)	Linear	0.350**	$Y=-696.499^{**} + 0.739^{**}X$	0.122	0.116
	Quadratic	+0.446**	$Y=-11058.58^{**} + 9.236^{**}x -0.002^{**}x^2$	0.199	0.187
Evaporation (mm)	Linear	+0.09NS	$Y=498.677+0.677x$	0.008	0.002
	Quadratic	+0.09NS	$Y=364.26+ 1.06x -0.0003x^2$	0.007	0.04
Potential Evapo Transpiration (mm)	Linear	+0.335**	$Y=-1049.097^{*} + 3.265^{**}X$	0.112	0.107
	Quadratic	+0.467**	$Y=-20058.99^{**} + 64.53^{**}X -0.049^{**}X^2$	0.212	0.203
Length of Growing Period (LGP) (days)	Linear	+0.400**	$Y=-629.509^{**} + 10.629^{**}X$	0.160	0.154
	Quadratic	+0.490**	$Y=5568.997^{**} -74.723^{**}X+ 0.285 X^2$	0.240	0.230
Leaf Area Duration (LAD)(days)	Linear	+0.317**	$Y=702.717^{**} + 1.807^{**}X$	0.100	0.094
	Quadratic	+0.419**	$Y=290.067+ 6.230^{**}X -0.009^{**}X^2$	0.175	0.164
Total Dry Matter (TDM) (g/plant)	Linear	+0.332**	$Y=537.391^{**} + 7.046^{**}X$	0.110	0.104
	Quadratic	+0.431**	$Y=-31.325 + 29.303^{**}X -0.167X^2$	0.185	0.175

**: Significant at 5% level
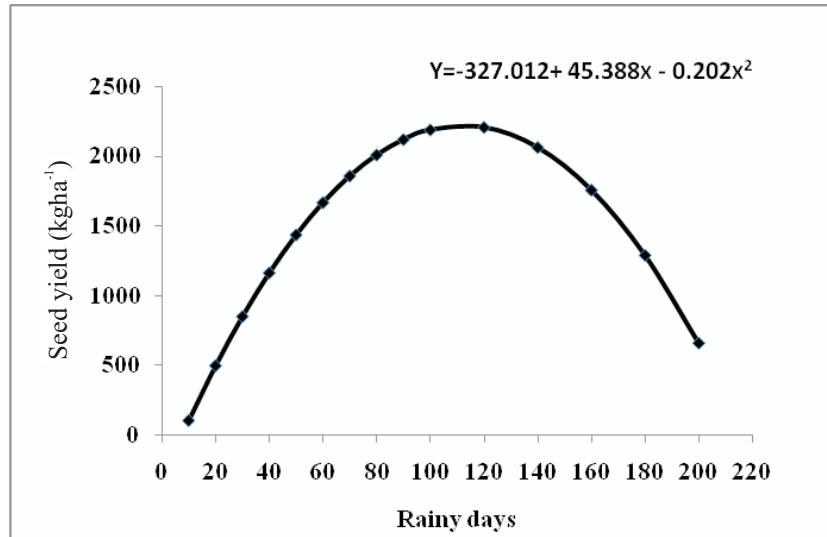
Fig. 1 Quadratic relationship between rainy days and seed yield of pigeon pea over the years in alfisols
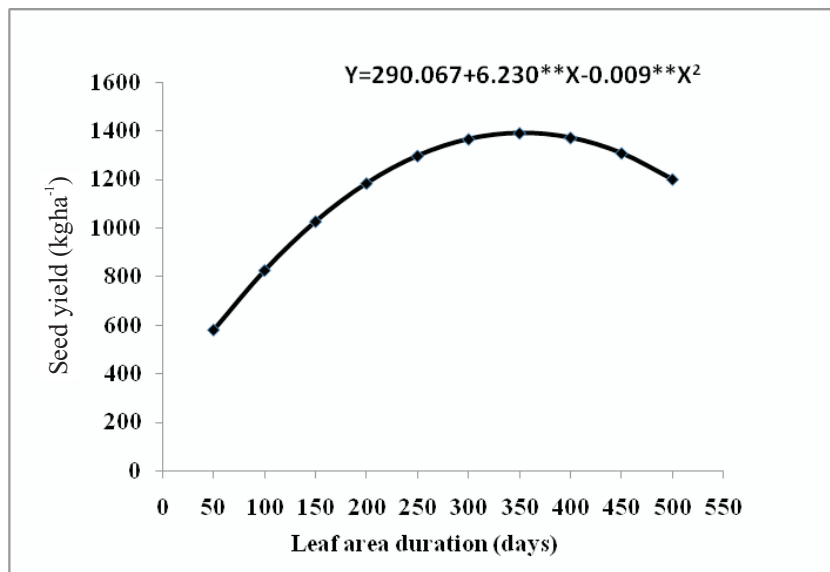

Fig. 2 Quadratic relationship between leaf area duration and seed yield of pigeon pea over the years in Alfisols

However, the accumulated sunshine in the range of 800 to 1500 hrs was found non-significant in influencing the yield (r= 0.07 [NS]), might be due to its nature of long duration and abundance of sunshine hours in the region. The results are in conformity with previous year's results of Bangalore (AICRPAM 2013). From the correlation matrix, LGP being closely related with not only rainfall distribution but also with available moisture holding capacity of the soil, influenced the seed yield of pigeon pea significantly (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 10 MLR equations were worked out. The significant R^2 values of these MLR equations ranged from 0.48 in model number I (Table 3), when nine weather parameters were regressed, to 0.32 in model number X, involving only two significant weather parameters *viz*., vainy days and LGP. Among these 10 models, as per the criteria set out by Barrie *et al*. (1986), model V (R^2 =0.442[**]), model VII (R^2 =0.362**) and model IX (R^2 =0.359[**]) were found to be the better one. However, one can use any of these models for judging the suitability of a land depending on the information generated on weather parameters however bearing the risk of associated standard errors.

Table 3. Multiple linear regression models of seed yield (kg ha⁻¹) of pigeon pea with climatic and growth parameters

Parameters					Model Number					
	I	II	III	IV	V	VI	VII	VIII	IX	X
Rainfall (mm)	-1.839**	-1.802**	-1.768**	-1.395**	-	-	-	-	-	-
Rainy days	51.751**	51.350**	60.873**	55.790**	34.749**	19.479**	13.59*	23.938**	15.77**	24.496**
Sunshine hours	-1.442**	-1.430	-1.219	-	-	-	-	-	-	-
GDD	0.568	0.547	-	-	-	-	0.448*	-	0.451**	-
Evaporation (mm)	5.056*	5.098*	6.20**	4.092**	3.673**	1.543**	-	1.403**	-	-
PET (mm)	-4.958**	-4.971**	-4.936**	-5.017**	-4.129**	-	-	-	-	-
LGP (days)	6.809*	6.827*	7.740**	9.913**	10.426**	9.065**	7.93**	8.825**	8.205**	7.630**
LAD (days)	-0.065	-	-	-	-	-	0.375	-	-	-
TDM (g/plant)	5.993**	5.937**	5.81**	6.198**	4.852**	4.292**	-	-	-	-
A	-1490.22**	-1492.45**	-1682.67**	-1804.26	-2126.11**	-2438.76**	-1868.03**	-2209.84	-1928.73**	-1097.45
S.E. of a	574.89	572.74	475.61	474.32	466.34	471.95	434.27	478.31	426.29	278.09
S.E. of Y	493.06	491.47	490.45	494.05	503.13	519.52	536.40	533.21	535.71	544.82
R²	0.477	0.477	0.476	0.465**	0.442	0.401	0.362**	0.365	0.359**	0.333
Adjusted R²	0.447**	0.4505**	0.452**	0.445**	0.424**	0.386**	0.345**	0.353**	0.347**	0.324**

**: Significant at 5% level

Sys *et al.* (1993) 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 pigeon pea. Further, Naidu *et al.* (2003) attempted to establish the soil-site suitability criteria for pigeon pea, but seemed to have generalized and hence needs refinement in the light of the present findings.

Conclusions

The long term studies on yield contributing weather parameters of pigeon pea revealed that the moisture availability period as reflected by LGP is a critical factor deciding the growth and yield. Besides, rainfall distribution as indicated by rainy days, thermal requirement as indicated by GDD and the cumulative leaf area as measured by LAD are also the significant parameters in the decreasing order contributing for the growth and yield of pigeon pea. The relationships of above parameters with seed yield of pigeon pea have been quantified individually and in combination.

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