Journal of Agrometeorology 12 (1): 128-132 (June 2010)

Forecasting pearl millet productivity from the rainfall distribution of Rajkot district*

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ABSTRACT

With a view to find out the most suitable forecasting model for productivity of pearl millet by using past rainfall records of Rajkot district and to identify and quantify the effect of rainfall distribution, 47 consecutive years (1960 to 2006) weekly rainfall data from 23rd to 39th meteorological standard weeks (W), for the cropping season of the pearl millet were collected from Main Dry Farming Research Station, Targhdia (Rajkot). The time trend (T) was also included as an explanatory variable. The district yield of pearl millet (kg/ha) was considered as a response variable. The full model multiple linear regression equation explained 91% variation in pearl millet grain yield. For testing of this fitted model for future, six subsequent years (2001 to 2006) were not included for obtaining prediction equation and verified with actual yields of the district. The deviations between simulated forecasts and actual yields ranged from 2 to 20%. High deviations were due to irregular sowing period, erratic and uneven rainfall distribution of the district. Therefore, high standard error was observed in fitted model. However, this model could be considered for earliest (10 weeks after showing period) forecasting of pearl millet grain yield in Rajkot district.

Key words : Crop stages, forecasting model, multiple linear regression, pearl millet

The agricultural crop productivity largely depends on the rainfall distribution and its intensity during the rainy season (Singh and Singh, 1994; Ray and Butala, 2005). Rainfall variability both in time and space influences agricultural productivity and sustainability of a region. The large variation in any crop yield from year to year and place to place is dominantly due to weather of the monsoon (Pandey and Gupta, 1990; Dubey *et al.*, 1995; Agrawal *et al.*, 2001). Pearl millet is important cereal and food crop of North Saurashtra Agro-climatic Zone and Rajkot district, grown under rainfed condition during *kharif* season. The productivity of the pearl millet depends mainly on rainfall distribution and several weather factors (Sahu *et al.*, 1994; Sarkar, 2001; Kumar and Bhar, 2005). The rainfall in the zone is not only insufficient, but uneven distribution and erratic also. Hence, the yield of pearl millet crop is governed by vagaries of monsoon. There is need to forecast the yield of this crop under vagaries of monsoon. The objectives of study for effectiveness and its contribution to rainfed crops were to identify and quantify the effect on productivity of pearl millet for Rajkot district caused by rainfall distribution and to find out the most suitable forecasting model for yields of pearl millet, using past rainfall records of Rajkot district for pearl millet crop by testing and verification of the fitted model for future.

MATERIALS AND METHODS

For achieving the objectives, past 47 years (1960 to 2006) weekly rainfall (in mm) data of Rajkot district were collected from Dry Farming Research Station (DFRS), Junagadh Agricultural University, Targadia (Rajkot), period from 23rd to 39th standard meteorological weeks (SMW), for the cropping season of the pearl millet (Table 1). The yield (kg ha^{-1}) for the Rajkot district was collected from final forecast reports, published by Government of Gujarat. The time trend was also included as an explanatory variable. The simple linear regression (SLR) equations for time and each W_j were worked out separately. The full model multiple linear regression equation was fitted and partial regression coefficients for time and each W_j were determined. The significant explanatory variables influencing the yield were identified by step-wise regression method. Using years from 1960 to 2000 (41 years' time series data), the earliest and most suitable forecasting model was fitted and remaining six subsequent (2001 to 2006) years simulated forecasts were verified with actual productivity of the district. The mathematical expression of multiple linear regression model is given by :

$$Y_i = A_o + Sb_j W_j + cT_i$$

*Papers presented at and reviewed for proceeding of national seminar on "Agrometeorology-Needs, Approaches and Linkages for Rural Development" held at CCSHAU, Hisar during 26-27 November 2009.

Table 1: Standard meteorological weeks (SMW) and phenological stages of pearl millet crop (stages are varied as per sowing period i. e. commencement of monsoon in the district)

S. No.	SMW (W_j)	Month	Date	Phenological stages of pearl millet
1.	W_{23}	June	4-10	Pre-sowing to sowing
2.	W_{24}		11-17	
3.	W_{25}		18-24	Sowing to germination
4.	W_{26}		25-01	
5.	W_{27}	July	8-08	Germination to tille ring
6.	W_{28}		9-15	
7.	W_{29}		16-22	Tille ring to boot stage
8.	W_{30}		23-29	
9.	W_{31}	Aug.	30-05	Boot stage to ear head emergence
10.	W_{32}		6-12	
11.	W_{33}		13-19	Earhead emergence to flowering
12.	W_{34}		20-26	
13.	W_{35}		27-02	Flowering to grain formation
14.	W_{36}	Sept.	3-09	
15.	W_{37}		10-16	Grain formation to physical maturity
16.	W_{38}		17-23	
17.	W_{39}		24-30	Physical maturity to harvesting
18.	Time (Ti)	No. of years included as an explanatory variable (year 1960 to 2006)		
19.	Yield (Yi)	Yield of pearl millet (kg ha^{-1}) for Rajkot district as dependent variable		

Where, Y_i is Av. pearl millet yield of the district (kg ha^{-1}) for i^{th} year ($_I$=1, 2…47); A_o is Constant (intercept); W_j is Observed value of rainfall (in mm) variable, in $_j^{th}$ SMW ($_j$ = 23, 24, …….39); T_i is Year number included to correct for the long term upward or downward trend in yield (T_i = 1, 2, ……47) b_j and c's are partial regression coefficient associated with each W_j (rainfall variables) and time trend (T_i), respectively.

RESULTS AND DISCUSSION

Productivity of pearl millet for time series data

The results are presented in Table 2 for different statistical measures obtained during study period (1960 to 2006) for full model regression analysis of variables for rainfall distribution, W_{23} to W_{39} (seasonal rainfall of standard meteorological week number 23 to 39) for Rajkot district including time trend which are influencing the pearl millet grain yield and explained 91% variation with 187 kg ha^{-1} estimated standard error of mean. The high variability in rainfall distribution was observed in beginning (commencement of monsoon; W_{23}), middle of monsoon (W_{32}) and ending period of monsoon (W_{37}). The influence of rainfall variable upto 35th standard meteorological week (W_{35}) were observed to be favourable or ineffective to productivity of pearl millet for Rajkot district. The influence of 24th standard meteorological week rainfall was observed to be most favourable or beneficial in increasing the yield of pearl millet. Negative or detrimental effect of rainfall during standard meteorological week numbers of 36, 37, 38 and 39 was observed. The influence was significant during 37th standard week (W_{37}) and it is stage of physical maturity period in pearl millet, indicating that latter rainfall beyond 35th standard meteorological week would be harmful to the pearl millet productivity. The correlation coefficients of 24th SMW and time were positively and highly correlated with yield, whereas 25th, 31st and 38th SMW were positively correlated with yield and other variables were non- correlated with yield considering them independent of each other. The maximum seasonal rainfall of the district during study period (1960 to 2006) was noted in 1979 (1384 mm), whereas it was minimum (160 mm) in cropping season of 1985. The average rainfall of 29th standard meteorological week was (55.34 mm) maximum, whereas it was noted minimum (8.08 mm) in 23rd standard meteorological week. During 1988, the maximum rainfall (376 mm) was noted in 29th standard meteorological week. The recorded crop yield of pearl millet was maximum (1800 kg ha^{-1}) in 2003 and minimum record was noted in 1987 only with 17 kg ha^{-1}.

Forecasting model

It could be revealed from the results of Table 3 for

Table 2: Different statistical measures obtained for different variables considering rainfall (Wj) and time of 47 years (1960 to 2006) as an explanatory variables and yield as an effective variable.

Variables	PRC	Inter. a0	SRC	Mean	Min.	Max.	Corr. (r)	SD	S. Em	CV (%)
W23	0.39*	742.67	-0.11	8.08	0	92.14	-0.004	16.81	2.69	208.15
W24	13.29**	582.3	11.19	14.25	0	66.2	0.51**	19.09	3.45	133.96
W25	0.62*	639.39	2.74	37.41	0	242.6	0.342*	52.21	9.70	139.57
W26	2.18**	698.4	0.98	44.23	0	278.3	0.15	63.78	7.37	144.21
W27	0.95	676.32	1.39	47.03	0	160.4	0.142	42.73	6.59	90.87
W28	2.32**	675.09	1.72	38.73	0	290.7	0.284	61.71	8.74	159.34
W29	2.55*	674.62	1.21	55.34	0	376.1	0.203	69.97	8.00	126.44
W30	1.4	639.94	2.34	43.38	0	186.3	0.267	47.57	8.19	109.66
W31	2.06	660.9	1.82	44.43	0	226.6	0.289*	66.41	8.58	149.47
W32	0.11	739.3	0.05	52.04	0	76.08	0.013	116.85	10.72	224.54
W33	2.01	735.06	0.32	21.04	0	129.2	0.022	28.63	4.92	136.05
W34	0.91	708.5	1.57	21.25	0	133.7	0.117	31.13	4.02	146.48
W35	1.14	720.35	0.74	29.08	0	248.6	0.093	52.59	7.60	180.85
W36	-1.4	709.82	2.19	14.59	0	111.00	0.126	24.11	3.75	165.25
W37	-4.39**	722.8	0.89	21.44	0	351	0.119	56.04	4.31	261.36
W38	-2.16	656.19	4.03	22.22	0	173.4	0.322*	33.36	3.59	157.21
W39	-2.05	707.59	2.1	16.29	0	91.00	0.118	23.57	3.12	144.74
Time	4.44	314.8	17.79	24.00	1960	2006	0.57**	13.56	3.92	56.52
Yield	Depen.	0.00	1.00	741.79	17 (1987)	1800 (2003)	1.00	418.38	60.27	56.40

*,**Signifciant at P=0.05 and P=0.01 level, respectively. Constant=-241.78 (MLR), SE of estimate = 187.15 kg ha^{-1} for full model MLR, R2=91.48%, PRC=Partial reg. coefficient with yield, a0=Intercept of yield, SRC=Simple reg. coefficient with yield.

earliest forecast in Rajkot district, using upto W_{35} rainfall variables and step-wise regression method significant explanatory variables were identified. The yield of pearl millet was observed to be increased by 10.30 kg ha^{-1} /year due to technological advancement. The most beneficial impact of rainfall for 23rd and 24th was observed on pearl millet productivity followed by contribution of 25th, 28th, 30th, 31st and 33rd standard meteorological weeks towards productivity of the crop. The finally selected significant variables which were positive or beneficial accounted for about 79% variation in grain yield of pearl millet. The fitted equation is as under :

$$Y=-3.54 +10.30T^{**}+5.69W_{23}^{**}+6.64W_{24}^{**} + 2.31W_{25}^{**} + 2.55W_{28}^{**} + 1.29W_{30}^{*}+1.35W_{31}^{*}+1.95W_{33}^{*}$$

(S.E.=192.44 & R^2=79%).

Testing and verification of the fitted model

For testing and verification of the above fitted model, six subsequent years (2001 to 2006) were not included for obtaining prediction equation presented in Table 4. It could be observed from the fitted model that deviations between simulated forecasts and actual yields ranged from 2 to 20%. High deviations were due to high standard error in fitted model. However, this model could be considered for earliest (10 weeks after showing) forecasting of pearl millet grain yield in Rajkot district.

CONCLUSIONS

With the help of regression model developed, the yield of pearl millet can be predicted after 33rd meteorological standard week (SMW) i. e. 10th week after sowing of pearl millet, with limitations it could be deviated from 2 to 20% from actual yield of Rajkot district. It could also be concluded that due to technological advancement the productivity of pearl millet was observed to be increased more than 10 kg ha^{-1} during study period.

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Table 3 : Regression equation obtained by using time trend and rainfall variables for earliest forecasting

Variables in the equation	Years of prediction equation from 1961 to 2004				
	1961 to 2000	1961 to 2001	1961 to 2002	1961 to 2003	1961 to 2004
Constant	22.05	-4.76	14.08	09.60	-3.54
Time	8.22**	9.36**	10.12**	10.42**	10.30**
W_{23}	5.98**	5.91**	5.63**	5.70**	5.69**
W_{24}	5.81**	5.71**	6.46**	6.74**	6.64**
W_{25}	2.42**	2.32**	2.21**	2.30**	2.31**
W_{28}	2.60**	2.64**	2.51**	2.54**	2.55**
W_{30}	1.17*	1.24*	1.16*	1.28*	1.29*
W_{31}	1.60*	1.52*	1.36*	1.44*	1.35*
W_{33}	1..65*	1.25*	1.77*	1.80*	1.95*
S. E.	190.28	198.44	197.11	195.25	192.44
R^2 (%)	72.09	73.65	73.15	78.34	78.98

*,**Significant at P=0.05 and P=0.01 level, respectively.

Table 4 : Simulated forecast based on the fitted equation

Year	Observed yield (kg ha^{-1})	Years of prediction equation from 1961 to 2004				
		1961-2000	1961-2001	1961-2002	1961-2003	1961-2004
2001	1559	1254 (19.56)	-	-	-	-
2002	651	549 (15.67)	571 (12.29)	-	-	-
2003	1800	1585 (11.94)	1660 (7.77)	1650 (8.33)	-	-
2004	1188	1170 (1.50)	1233 (3.78)	1226 (3.20)	1258 (5.89)	-
2005	1400	1177 (15.92)	1211 (13.50)	1209 (13.64)	1239 (11.50)	1200 (14.28)
2006	1500	1233 (17.80)	1257 (16.20)	1241 (17.26)	1267 (15.53)	1269 (15.40)

Figures in parentheses are per cent deviations from observed yields.

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