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Impact of Weather Variables on Yield and Yield Attributes of Rabi Maize (*Zea mays* L.)

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ABSTRACT

Two years field experiment on maize cv. Ganga Safed-2 under different environmental conditions created by different dates of sowing and varied moisture regimes during the Rabi season was conducted to study the impact of weather on final yield of maize crop. The relationship between grain yield and total biomass produced were analyzed with respect to micrometeorological features observed within the canopy during different growth stages and their various combinations. The results indicate that grain yield was best related with afternoon vapour pressure during silk emergence to dough stage and total biomass with temperature range during emergence to silk emergence stage. Appropriate regression models were developed.

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INTRODUCTION

Maize (*Zea mays* L.) is grown as Rabi crop where irrigation facilities are available due to its higher production potentiality. The middle Gujarat region and parts of North Gujarat region follow this practice. The prevailing weather greatly influence the final yield. Particularly important is the impact of weather in individual phenophase of the crop, leading to determine critical stages with respect to different weather variables. Further, prior knowledge on onset of critical stages would help in proper crop management. With this in view an attempt was made in this paper to predict onset of different phenophases in maize and to relate grain yield and biomass with micrometeorological features in various phenophases.

Ali and Janabi (1980) determined the optimum sowing date and predicted the tasseling, silking and maturity dates making an use of heat unit accumulation technique, and also observed that the temperature explained most of the variation within plant characters for different season and sowing dates. Girardin (1980) related the global radiation with the rate of appearance of leaves. Gardner *et al.* (1981) found the summation of canopy temperatures and determined the growth stages in corn. Kiniry *et al.* (1983) reported a linear relationship between tassel initiation and degree days. Bonhomme *et al.* (1982) found that the amount of the photosynthetically active radiation (PAR) trapped by corn was dependent on leaf area index and was higher at silking than maturity. Lee and Jung (1988) reported PAR use

efficiency of 4.87 gm/MJ for dry matter production. Baktash (1985) observed significant association of grain yield with air temperature and relative humidity at flowering and pollination stages.

MATERIALS AND METHODS

A field experiment on maize crop cv. Ganga Safed-2 was conducted on the Agronomy Farm of the Gujarat Agricultural University, Anand (22°35 'N; 72°55 'E) during the Rabi season of the years 1989-90 and 19901-91. The soils of the experimental site are of alluvial origin having sandy loam texture with bulk density 1.5 g/cc and pH 8.1. The experiment was laid out in split plot design with three dates of sowing and four irrigation regimes under six replications. The crop was at a spacing of 60 x 20 cm. and fertilized with 40 N + 60 P + 40 K kg/ha as basal dose and 40 kg/ha N each at 25-30 days after sowing (DAS) and 45-50 DAS was given as top dressing. The treatment details are as under :

D_1 : First date of sowing October 5
D_2 : Second date of sowing October 20
D_3 : Third date of sowing November 4
I_1 : Irrigation when IW/CPE=0.8
I_2 : Irrigation when IW/CPE=1.0
I_3 : Irrigation when canopy-air-temperature differential = ± 0.5°C.
L_4 : Farmer's method (12 days interval)

For plots of I_1 and I_2 treatments measured irrigation was given with the help of a parshall flume. For plots of I_3 treatment canopy-air-temperature differential (CATD) was measured everyday at 1400 hrs. using an Infra-red thermometer (Teletemp, Inc, AG- 42). The various agronomical measurements were made at an interval of 10 days. Daily micrometeorological observations within the crop environment were recorded through micro-climatic tower (OMNI – DATA) INTL U.S.A.). The photosynthetically active radiation was recorded by Datalogger (Licor-Inc. U.S.A.) at 10 days interval. Regression models were developed for grain yield and total biomass procduction using the daily weather data. The models are then tested using three years' data of Godhra research station (1990-91, 1991-92 and 1992-93) situated in the same agroclimatic region at Anand.

TABLE 1

Regression of dry matter production on intercepted solar and photosynthetically active radiation under different dates of sowing.

Parameter	*Treatments*	*Constant (a)*	*Slope (b)* gms^{-1}	R^2
ISR	D_1	-181.33	2.63	0.89**
ISR	D_2	071.27	2.02	0.97**
ISR	D_3	-90.61	1.88	0.97**
IPAR	D_1	-38.53	4.55	0.82**
IPAR	D_2	5.08	3.70	0.96**
IPAR	D_3	-47.45	3.47	0.97**

RESULTS AND DISCUSSION

3.1 Dry matter production and radiation use efficiency

To choose the optimum date of sowing as a function of harvest of radiation by the crop canopy, the intercepted solar radiation (ISR) and photosynthetically active radiation (IPAR) use efficiencies were computed, and regressed over dry matter production through the growing season separately for each date of sowing. The results for the data of the two years are presented in Table 1.

The values of slope given in the table represents the ISR and IPAR use efficiencies, which are highest for first date of sowing (October 5) followed second and third date of sowing. It is thus clear that, the first date of sowing is optimum.

3.2 Relationship between grain yield and weather parameters

The correlation analysis between grain yield and the prevailing weather parameters in different phenophases (Table 3) indicates that, the afternoon vapour pressure during silk emergence to dough stage played the most prominent role. Stepwise regression analysis showed that, the afternoon vapour pressure and the mean temperature during silk emergence to dough stage was most appropriate in model development.

The obtained model was :

$$Y = 63.69 + 9.22^{*} VP_2(P_8) - 4.46^{*} \text{Mean T } (P_8) \quad R^2 = 0.94 \ldots\ldots\ldots \text{Eq. 1}$$

Where,

Y = Grain yield (q/ha)

$VP_2(P_8)$ = Mean afternoon vapour pressure (mm of Hg) during silk emergence to dough stage

Mean T (P_8) = Average mean temperature deg. C during the same stage.

This model predicts grain yield of maize about 20-30 days before maturity.

3.3 Relation between total biomass and weather parameters

Similar analysis in case of biomass indicated the best negative highly significant correlation with daily temperature range during emergence to silk emergence period (Table 4). The regression analysis gave the linear relationship.

$$Y=308.57 - 10.09 \text{ TR } (P_3) \ldots R^2=0.85 \ldots\ldots \text{Eq-2}$$

Where,

Y=Total biomass (q/ha)

TR (P_3) = Mean daily temperature range during emergence do silk emergence period in deg. C

In order to improve prediction efficiency, additional agrometeorological indices were considered and stepwise regression analysis

TABLE 2

Correlation of grain yield with weather parameters and agrometeorological indices observed during different phenological phases of maize crop.

Weather parameters/ Agrometeorological Indices	Phenological Phases								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
Ep	-0.197	-0.508	-0.661	-0.628	-0.346	-0.123	-0.206	-0.227	0.301
BSS	-0.735	0.484	0.118	0.314	0.563	-0.536	-0.135	0.202	0.451
Max T	0.349	0.382	0.296	-0.074	-0.288	-0.071	-0.882*	-0.801	-0.747
Min T	0.738	0.769	0.660	0.550	0.359	0.510	0.211	-0.483	-0.807
TR	-0.549	-0.394	-0.750	-0.871*	-0.836*	-0.794*	-0.808	-0.729	-0.594
Mean T	0.606	0.569	0.483	0.259	0.001	0.280	-0.554	-0.830*	-0.783
SR	0.103	-0.851*	-0.798	-0.572	-0.361	-0.225	-0.219	-0.159	0.825*
PAR	0.100	-0.853*	-0.798	-0.572	-0.359	-0.226	-0.219	-0.158	0.825*
VP1	0.747	0.864*	0.838*	0.826*	0.826*	0.699	0.617	0.280	-0.379
VP2	0.729	0.786	0.873*	0.888*	0.864*	0.758	0.871*	0.903*	0.874*
VPR	0.705	0.692	0.709	0.685	0.590	0.194	0.193	0.241	-0.048
GDD	0.308	-0.652	-0.287	-0.093	0.547	0.059	0.081	0.079	0.854*
HTU	0.335	-0.202	-0.228	-0.033	0.595	-0.050	0.044	0.107	0.820*
TIR	-0.650	-0.804	-0.574	-0.395	-0.059	-0.150	0.036	0.391	0.925*

* Significant at 5% level

** Significant at 1% level

P1 = Emergence to 6 leaf stage
P2 = Emergence to tassel emergence
P3 = Emergence to silk emergence
P4 = Emergence to dough stage
P5 = Emergence to maturity
P6 = Tassel emergence to silk emergence
P7 = Tassel emergence to dough
P8 = Silk emergence to dough
P9 = Silk emergence to maturity

TABLE 3

Correlation of total biomass production with weather parameters and agrometeorological indices observed during different phenological phases of maize crop.

Weather parameters/ Agrometeorological Indices	Phenological Stages								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
Ep	-0.536	-0.865*	-0.473	-0.218	0.370	0.500	0.351	0.119	0.707
BSS	-0.301	0.008	-0.042	0.440	0.692	-0.015	0.525	0.490	0.842*
Max T	-0.385	-0.227	-0.277	-0.609	-0.697	-0.280	-0.747	-0.468	-0.227
Min T	0.337	0.262	0.123	0.033	-0.133	0.052	-0.183	-0.109	-0.188
TR	-0.877*	-0.825*	-0.922**	-0.885*	-0.863*	-0.376	-0.459	-0.467	-0.220
Mean T	-0.006	-0.015	-0.086	-0.305	-0.479	-0.098	-0.697	-0.447	-0.220
SR	0.011	-0.890*	-0.257	-0.170	-0.181	-0.441	0.242	-0.028	0.613
PAR	0.007	-0.891*	-0.255	-0.169	0.184	0.414	0.243	-0.028	0.611
VP1	0.436	0.546	0.466	0.481	0.524	0.301	0.316	0.485	0.133
VP2	0.569	0.797	0.682	0.744	0.694	0.348	0.560	0.804	0.278
VPR	0.310	0.359	0.290	0.321	0.407	-0.371	0.050	0.668	0.583
GDD	0.329	-0.777	0.348	0.385	0.950**	0.696	0.596	0.302	0.881*
HTU	0.306	-0.627	0.307	0.043	0.697**	0.620	0.569	0.361	0.915*
TIR	-0.149	-0.346	0.045	0.142	0.486	0.375	0.434	0.353	0.540

* Significant at 5% level.

** Significent at 1% level.

P1 = Emergence to 6 leaf stage
P2 = Emergence to tassel emergence
P3 = Emergence to silk emergence
P4 = Emergence to dough stage
P5 = Emergence to maturity
P6 = Tassel emergence to silk emergence
P7 = Tassel emergence to dough
P8 = Silk emergence to dough
P9 = Silk emergence to maturity

TABLE 4

Testing of the models developed for grain yield and total biomass production.

Year	*Parameter*	*Eq. No. tested*	*Simulated q/ha*	*Actual q/ha*
1990-91	grain yield	1	45.09	57.51
1991-92	grain yield	1	49.84	38.58
1992-93	grain yield	1	69.49	47.59
	Mean		54.81	47.89
1990-91	total biomass	2	161.26	153.06
		3	150.19	153.06
1991-92	total biomass	2	148.95	107.75
		3	111.76	107.75
1992-93	total biomass	2	141.08	N.A.
		3	149.00	N.A.
	Mean	2	150.43	130.40
		3	136.98	130.40

revealed a multiple linear relationship with temperature range in emergence to dough stage and heliothermal unit in emergence to maturity as independent variables. The following relationship had R^2 of 0.96.

$$Y=75.36-3.61\ TR\ (P_4) + 0.0071\ HTU\ (P_5) \quad \text{Eq. 3.}$$

Though, the model with simple variable has a lower efficiency 11%, it can provide prediction of biomass 42 to 50 days before maturity. The above models may be used as per the requirement.

3.4 Validatiom of models

The models developed for grain yield and total biomass of maize have been tested for their validity by comparing the simulated for the model of Godhra research station with the observed data. Since the number of data points is less, statistical analysis could not be performed. The results presented in Table 4 indicate that there exist an error of about 20% (Eq. 1) in case of grain yield and 40% (Eq. 2) and 5% (Eq. 3) in case of total biomass production. The errors are seen to be significant and therefore indicate a need for refinement of the models, and point to the limitation of their predictability, which may be attributed to the non-availability of the data on duration of various phenophases of the crop and also to the soil factor at Godhra. However, it is observed that, even with these limitations, the models developed under Anand conditions may be used for Godhra conditions.

The study has provided with the following conclusions.

1. Study on dry matter production vs. radiation use efficiencies showed that, the October 5 sowing is most beneficial.

2. The grain yield could be predicted using the afternoon vapour pressure and mean temperature during silk emergence to dough stage (21 to 30 days before maturity) with an accuracy of 94%.

3. Temperature range during emergence to silk emergence period could predict total biomass with 15 per cent error, while temperature range during emergence to dough stage and heliothermal unit during emergence to maturity provided a prediction accuracy of 96 per cent.

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