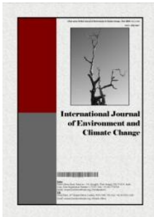

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Crop Weather Relationships of Maize (*Zea mays* L.) under Different Sowing Windows and Hybrids

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Author's contributions

This work was carried out in collaboration among all the authors. Author BHD conducted the field experiments and recorded observations and performed the statistical analysis. Author SS designed the concept of the experiment and supervised the experiment as well as corrected the manuscript. Author PG drafted the manuscript and statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to know the crop weather relationships under different sowing windows and hybrids in maize at the College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, during *Kharif* 2015. The experimental site is situated at 14°0[1] to 14°1[1] North latitude and 75°40[1] to 75°42[1] East longitude with an altitude of 650 meters above mean sea level. The experiment was laid out in a randomized complete block design (RCBD) with a factorial concept and replicated thrice. There were eight treatment combinations, including four-date of sowing (15th June, 30th June, 15th July and 30th July) and two hybrids (PAC-740 and CP-818). Maize sown on 15th June recorded significantly higher grain yield (7632.57 kg ha^{-1}) as compared to other dates of sowing and among the hybrids, CP-818 (7060.72 kg ha^{-1}) was found superior than PAC-740 (6776.93 kg ha^{-1}). Grain yield had a highly significant positive correlation with weather parameters such as cumulative pan evaporation (0.85**), cumulative solar radiation (0.83**), cumulative rainfall (0.79**) and average relative humidity (0.75**) during silking to maturity stage. The variation in grain yield was primarily affected by average maximum

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temperature (69%) followed by cumulative sunshine hours (68%) and cumulative pan evaporation (66%) during sowing to maturity and lower variation was observed in average relative humidity (54%) during silking to maturity. From the present findings it can be inferred that sowing maize on June 15th with CP-818 hybrid can be a better option to get higher productivity in southern transition zone of Karnataka.

Keywords: Crop-weather; evaporation; grain yield; maize; solar radiation.

1. INTRODUCTION

The agricultural productivity of the geographic area is dependent on many factors, such as inherent soil and terrain characteristics and climatic constraints [1]. The change in climate in terms of rainfall variability and temperature fluctuation projected to have significant impacts on agricultural production [2]. The introduction of high yielding single cross maize hybrids coupled with high input management and its spread to nontraditional rice-pulse system areas has resulted in more production. Maize is one of the important cereal crops of India next to rice and wheat. It has gained significant importance in the food chart due to its fast growing nature, high yielding ability, ease in cultivation, industrial processing and nutritional qualities. Its acreage and production are substantial, but its productivity is relatively low. Various biotic and abiotic factors play an essential role in decreasing productivity [3]. Maize development is primarily driven by key weather parameters such as temperature, rainfall, relative humidity, evaporation and sunshine hours. The heating unit or growing degree day (GDD) concept assumes that there is a direct and linear relationship between the growth of plants and temperature [4] and yield [5]. Very early sowing exposes the crop to a high risk of crop failure due to erratic rainfall distributions associated with the start of the rainfall season. In contrast, with late sowing dates, the crop is vulnerable to early rainfall cessation before it fully matures. Therefore, it is essential to strike a balance between reducing the risk of sowing too early and ensuring the crop is planted early enough to develop before the end of the season. The period between sowing date and cessation of rainfall season should cover the major part of the crop growth cycle that leads to the other important factor i.e, sowing strategy management and variety selection. Short growing cycle varieties, which generally have higher yield potential, will yield in a long rainfall season. A shift in sowing dates directly influences both thermal and photoperiod, and consequently, a great bearing on the phasic development and dry matter partitioning. The extent to which soil temperature affects yield varies with sowing time and latitude of growth location [6]. Quantification of these effects may help in the choice of sowing time and match phenology of crop in a specific environment to achieve higher grain yield. Maize is predominantly grown under rainfed conditions where the present investigation has been carried out which comes under southern transitional zone of Karnataka, thus the occurrence of mid season or late season drought is very common weather phenomenon resulting in lower productivity of the crop. Hence, there is a need to study the influence of different weather parameters on the performance of maize grown under different environments as affected by change in the sowing dates as well as identifying the suitable hybrids of contrasting duration to realise the higher yield of maize. Key planting factors influencing maize production are sowing date and cultivars. Different genotypes may behave differently under similar environmental conditions. With this backdrop considering all the above points, a study on crop weather relationships in maize was carried out at the College of Agriculture, Shivamogga, Karnataka.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted to understand the crop weather relationships under different sowing windows and hybrids in maize at the College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, during *Kharif* 2015. which is situated at 14°0^1 to 14°1^1 North latitude and 75°40^1 to 75°42^1 East longitude with an altitude of 650 meters above mean sea level. The soil of the experimental site was red sandy loam with pH 6.4, medium in soil organic carbon (0.55%), low available N (232 kg/ha), high available P_2O_5 (77.4 kg/ha) and deficient in soil available K_2O (193.5 kg/ha). Eight treatment combinations, which include four dates of sowing (15th June, 30th June, 15th July and 30th July) and two hybrids (PAC - 740 and CP - 818), were tried in a randomized complete block design with a factorial concept and replicated thrice.

2.2 Plant Protection Measures

The recommended dose of manure (10 t FYM ha^{-1}) was applied 15 days before sowing and incorporated into the soil. The recommended amount of fertilizer (150:75:40 kg NPK ha^{-1}) for each treatment was applied in the form of urea, SSP and MOP fertilizers. Furrows were opened at a 45 cm interval with the help of a hand hoe. A basal dose of fertilizers (50% N and 100% P and K) were applied at the time of sowing and the remaining 50% of N was applied in two splits at 30 and 60 days after sowing. The pre- emergent herbicide (Atrazine) was sprayed on the day of sowing to all the plots at the rate of 1.5 kg a.i.ha^{-1}. The plots were weeded manually twice at 30 and 50 days after sowing.

2.3 Weather Parameters Prevailed During the Study Period

The actual rainfall during the crop growth period of 2015 was 927.8 mm as against the normal of 752.7 mm. The mean monthly maximum temperature ranges between 28.5°C in July to 31.3°C in October. The mean minimum temperature was highest in August (22.3°C) and lowest in November (19.4°C). The mean monthly relative humidity was ranged between 76 per cent in November to 82.3 per cent in July. Sunshine hours was highest during October (7.2 hrs) and lowest during June (2.9 hrs).

2.4 Data Collection and Statistical Analysis

Growth observations are recorded at 30-day intervals and yield parameters like cob length, cob girth, grains per cob, grain yield per cob and test weight were recorded at harvest. The data on rainfall, temperature, relative humidity, sunshine hours, solar radiation and evaporation were obtained from the agro-meteorological observatory located in the study area. The correlation coefficient was worked out between prevailed weather parameters at and different phenophases with grain yield of maize. Regression analysis [7] was carried out considering those weather parameters, which significantly influenced crop growth, yield and yield attributes were entered in this analysis to derive prediction models separately. However, the best-suited regression equations are elaborated in this paper.

3. RESULTS AND DISCUSSION

Weather factors that prevailed during different phenophases of maize, sown under staggered dates, influenced the crop's final yield through their influence on different growth and yield attributes. The critical agrometeorological variables associated with agricultural production are rainfall, air temperature, relative humidity and solar radiation [8]. By relating and comparing the agro-climatological requirements of the crop with the existing agro-climatic conditions in an area, one can find the extent to which the needs are satisfied during the different phases of the crop growth and development [9].

3.1 Influence of Weather Parameters at Different Stages of Crop Growth

Weather prevailed during different crop phenophases were significantly influenced by yield and yield attributes (Tables 1 and 2). Weather parameters did not show a significant positive relationship during the early stage of crop establishment (sowing to emergence). However, during emergence to the knee-high stage, cumulative rainfall (0.50*) significantly influenced grain yield. During the grand growth stage (knee-high to tasseling), cumulative sunshine hours (0.70**), cumulative solar radiation (0.79**) and cumulative pan evaporation (0.77**) had a significantly positive relationship with grain yield. Tasseling to silking stage weather parameters did not show a significant positive relationship on grain yield. Final grain yield (silking to maturity) showed a significant positive correlation with cumulative rainfall (0.79**), cumulative sunshine hours (0.42*), average minimum temperature (0.51*), cumulative solar radiation (0.83**), average relative humidity (0.75**) and cumulative pan evaporation (0.85**). Environmental changes associated with different sowing dates (Rainfall, sunshine, temperature) have a modifying effect on maize plant growth and development. Each hybrid has an optimum sowing date and the greater the deviation from this optimum (early or late sowing), the greater the yield loss. These findings are in line with [10]. Similar results were observed with [11,12,13,14].

Table 1. Weather prevailed at different crop growth stages of maize during the experimental period

Treatment	Growth Stages	Period (Days)	C RF (mm)	Avg T_{max} (°C)	Avg T_{min} (°C)	C SSH (hrs)	CSR (MJ m^{-2})	Avg RH (%)	CE pan (mm)
PAC - 740 + June 15	S-E	6.3	53.6	27.3	21.1	3.1	69.0	86.4	14.8
	E-K	35.0	190.6	28.4	21.5	92.1	435.1	81.5	107.2
	K-T	52.3	95.9	28.2	21.5	93.7	302.9	84.5	67.4
	T-S	56.0	11.1	27.8	23.4	30.8	67.7	81.1	13.7
	S-M	117.0	335.0	30.3	22.2	299.9	990.3	81.1	272.7
PAC - 740 + June 30	S-E	6.3	7.2	28.7	22.1	23.2	100.1	79.2	23.9
	E-K	37.0	140.7	28.4	20.9	109.4	518.9	82.7	123.9
	K-T	51.3	36.1	28.6	22.3	122.2	284.7	81.2	60.7
	T-S	57.0	7.7	31.0	22.4	55.37	116.0	81.2	28.4
	S-M	114.0	359.0	30.2	22.1	265.9	862.9	80.8	247.5
PAC - 740 + July 15	S-E	6.6	78.2	27.8	21.5	19.7	95.3	86.1	24.1
	E-K	37.6	86.7	28.1	21.5	126.8	580.8	82.7	124.5
	K-T	47.6	16.2	30.9	22.3	121.8	201.5	80.8	54.7
	T-S	54.0	22.9	33.0	22.4	51.63	116.3	79.3	33.2
	S-M	112.0	324.0	30.0	22.1	258.7	795.7	79.0	225.6
PAC - 740 + July 30	S-E	6.6	42.5	28.2	21.6	47.1	127.0	81.9	27.1
	E-K	38.6	117.8	29.7	22.4	162.8	631.6	81.2	154.5
	K-T	48.6	113.6	31.3	22.1	89.5	106.9	84.3	34.2
	T-S	51.3	4.0	27.4	22.2	9.6	60.0	82.1	19.7
	S-M	111.6	231.4	30.9	21.8	307.7	771.1	76.7	213.
CP - 818 + June 15	S-E	6.6	53.6	27.5	21.2	3.0	72.5	86.6	15.1
	E-K	37.3	234.7	28.2	21.5	102.7	470.5	81.9	116.9
	K-T	55.6	61.8	28.3	21.2	95.1	326.6	83.5	70.3
	T-S	59.3	8.0	29.3	22.3	43.2	59.3	84.8	11.4
	S-M	124.6	380.2	30.4	22.2	302.4	1018.4	81.0	280.9
CP - 818 + June 30	S-E	6.3	7.6	28.8	22.0	17.4	100.1	79.2	23.9
	E-K	38.3	147.8	28.4	21.0	112.0	546.2	82.7	129.7
	K-T	53.3	32.1	29.4	22.4	125.7	299.2	81.5	63.6
	T-S	58.3	8.6	31.4	22.2	41.9	101.5	80.8	26.8
	S-M	122.0	355.0	30.2	22.1	268.6	901.9	80.3	258.5

Treatment	Growth Stages	Period (Days)	C RF (mm)	Avg T_{max} (°C)	Avg T_{min} (°C)	C SSH (hrs)	CSR (MJ m^{-2})	Avg RH (%)	CE pan (mm)
CP - 818 + July 15	S-E	6.6	78.8	27.8	21.4	21.6	95.3	86.1	24.1
	E-K	40.0	88.5	28.2	21.8	139.4	628.8	82.6	135.8
	K-T	50.0	13.8	31.5	22.4	137.8	195.7	81.0	55.5
	T-S	56.3	160.3	32.6	22.6	29.1	109.6	82.5	33.2
	S-M	119.6	228.3	30.2	22.0	290.3	842.7	77.9	238.4
CP - 818 + July 30	S-E	7.0	37.8	28.2	21.6	47.1	134.4	82.1	28.8
	E-K	40.6	180.0	29.8	22.4	163.2	656.3	81.4	163.2
	K-T	48.6	57.5	30.9	22.2	89.1	105.8	83.1	34.2
	T-S	54.6	13.2	27.4	22.2	8.5	82.8	79.3	26.7
	S-M	117.3	220.8	30.9	21.9	326.3	784.2	76.2	212.6

S – E: Sowing to Emergence; C RF: Cumulative Rainfall;E - K: Emergence to Knee high stage; Avg RH: Average relative humidity; K – T: Knee high stage to Tasseling; Avg T_{max}: Average maximum temperature;T – S: Tasseling to Silking; C E Pan: Cumulative pan evaporation; S – M: Silking to Maturity; Avg T_{min}: Average minimum temperature; C SSH: Cumulative sunshine hours;C SR: Cumulative solar radiation

Table 2. Relationship between weather parameters prevailed during different growth stages and grain yield of maize

Weather parameters	Cumulative rainfall (mm)	Cumulative sunshine hours (hrs)	Average maximum temperature (°C)	Average minimum temperature (°C)	Cumulative solar radiation (MJ m^{-2})	Average relative humidity (%)	Cumulative pan evaporation (mm)
Sowing to emergence	0.02	-0.75**	-0.29	-0.25	-0.69**	0.30	-0.68**
Emergence to Knee high stage	0.50*	-0.81**	-0.63**	-0.62	-0.76**	0.20	-0.73**
Knee high stage to Tasseling	-0.11	0.70**	-0.71**	-0.52	0.79**	0.05	0.77**
Tasseling to silking	-0.18	0.02	0.17	0.16	-0.11	0.30	-0.42**
Silking to maturity	0.79**	0.42*	-0.46	0.51*	0.83**	0.75**	0.85**

**: Significant at 5%, **: Significant at 1%*

3.2 Grain Yield (Kg Ha^{-1}), Stover Yield (Kg Ha^{-1}) and Harvest Index of Maize as Influenced by Different Dates of Sowing and Hybrids

The data on grain yield of maize hybrids as influenced by dates of sowing are presented in Table 3. Grain yield differed significantly due to dates of sowing. Significantly higher grain yield (7632.57 kg ha-1) was recorded with crop sown on June 15th which is on par with June 30th (7205.77 kg ha-1) followed by July 15th (6743.32 kg ha-1) and significantly lower grain yield (6093.63 kg ha-1) was recorded with July 30th. Between the hybrids, significantly higher grain yield (7060.72 kg ha-1) was recorded with CP - 818 which was superior over PAC - 740 (6776.93 kg ha-1). In maize shoot dry weight portioning to cob seems to be an important factor in controlling grain yield. The extent of partitioning of assimilates to grain portion was higher in long duration hybrid than short duration hybrid. Stover yield differed significantly due to dates of sowing. Significantly higher Stover yield (9512.56 kg ha^{-1}) was recorded with crop sown on June 15th followed by June 30th (9132.53 kg ha^{-1}), July 15th (8485.98 kg ha^{-1}) and significantly lower stover yield (7760.25 kg ha^{-1}) was recorded with July 30th. Between the hybrids, significantly higher Stover yield (8839.98 kg ha^{-1}) was recorded with CP - 818 which was superior over PAC - 740 (8605.68 kg ha^{-1}). This higher stover yield of CP - 818 may be attributed to higher dry matter accumulation in vegetative parts. Lower stover yield of PAC - 740 may be due to reduced size of photosynthesizing surface which might have caused reduction in growth. These consequently reduced the total stover yield.

The efficiency of dry matter partitioning is represented by harvest index (HI).This is the ratio between yield and total above ground biomass. Harvest index does not differed significantly due to dates of sowing. Numerically higher harvest index (44.52 %) was recorded with crop sown on June 15th and lower harvest index (44.03 %) was recorded with July 15th. Between the hybrids, CP - 818 has 1.25 per cent higher harvest index than PAC – 740 which may be due to higher partitioning and translocation of photosynthates to the economic part because of higher vegetative growth and higher interception and utilization of solar radiation might have produced higher above ground dry matter.

3.3 Assessment of Weather and Maize Grain Yield Relationship Using Multiple Linear Regressions

Multiple linear regression equations fitted to know the influence of weather parameters at different growth stages on maize grain yield (Table 4). The cumulative rainfall during emergence to the knee-high stage and silking to maturity is accounted for 65% of the variation in grain yield. In contrast, cumulative sunshine hours account for 68% of grain yield variation during entire growth stages (sowing to maturity).

Table 3. Grain yield (kg ha^{-1}), Stover yield (kg ha^{-1}) and Harvest index of maize as influenced by different dates of sowing and hybrids

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Dates of sowing (D)			
June 15	7632.57	9512.56	44.52
June 30	7205.77	9132.53	44.11
July 15	6743.32	8485.98	44.28
July 30	6093.63	7760.25	44.03
F – test	*	*	NS
S. Em ±	129.78	86.95	0.34
C.D. at 5%	393.64	263.75	-
Hybrids (H)			
PAC – 740	6776.93	8605.68	44.03
CP – 818	7060.72	8839.98	44.44
F – test	*	*	NS
S. Em ±	91.77	61.49	0.32
C.D. at 5%	278.35	186.50	-

Table 4. Multiple linear regression equations fitted to explain the influence of prevailed weather parameter at different growth stages on maize grain yield

Weather parameter	Regression equation	$\bar{R}^2$ value
Cumulative rainfall	Yield = 87.30 + 0.12 (RF E - K) + 0.32** (RF S - M)	0.65
Cumulative Sunshine hours	Yield = 87.72 - 0.35 (SSH S - E) - 0.2 (SSH E - K) + 0.25 (SSH K - T) + 0.4* (SSH S - M)	0.68
Average maximum temperature	Yield = - 306.34 - 60.04** (T.max. E - K) - 8.87** (T.Max. K - T) + 82.07* (T.max. S - M)	0.69
Average minimum temperature	Yield = 1325.19 - 30.17** (T.min. E - K) - 29.74** (T.min. K - T) + 8.51 (T.min. S - M)	0.62
Cumulative solar radiations	Yield = - 21.30+0.05 (SR S - E) + 0.04 (SR E - K) + 0.13 (SR K - T) + 0.18* (SR S - M)	0.68
Average relative humidity	Yield = - 681.27 + 11.15** (RH S - M)	0.54
Cumulative pan evaporation	Yield = - 33.61+ 0.13 (EVP S - E) + 0.05 (EVP E - K) + 0.37 (EVP K - T) + 0.13 (EVP T - S) + 0.82* (EVP S-M)	0.66

CRF: Cumulative rainfall, CSSH: Cumulative sunshine hours, T.max: Average maximum temperature, T.min: Average minimum temperature, CSR: Cumulative solar radiations, RH: Average relative humidity, CEVP: Cumulative evaporation, S - E: Sowing to Emergence, E-K: Emergence to knee high stage, K-T: Knee high stage to tasseling, T - S: Tasseling to Silking, S - M: Silking to Maturity

Similarly, the average maximum and minimum temperature contributed yield variations of 69% and 62% respectively from the emergence stage to maturity with the variation of temperature ranges 28.5°C to 31.3°C and 19.4°C to 22.3°C, respectively. The average mean relative humidity range of 76.0 to 82.3% was found to be optimum from emergence to maturity, with the variation of 54% during silking to maturity. Cumulative solar radiation and cumulative pan evaporation contribute 68% and 66% of grain yield variation. These results corroborate with the experimental results of [12,15].

4. CONCLUSION

From the present study it can be concluded that higher grain yield of maize was obtained by June 15th sown crop (*Kharif* season) due to higher growth and yield parameters with uniform distribution rainfall and better utilization of solar energy. Among the hybrids CP-818 was found superior than PAC-740 due to increase in yield attributes. Higher mean relative humidity with lower mean temperature during the early stages was unfavourable for maize crop, which affected biomass accumulation. Weather-based regression models showed utility for predicting the above-ground biomass, yield, and yield components of *Kharif* maize in Karnataka's Southern transitional zone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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