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Phenology and Productivity of Maize (*Zea mays* L.) Cultivars as Influenced by Crop Weather Environment

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A field experiment was conducted during *kharif* 2012 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur to study the phenology and productivity of maize cultivars under different sowing environments. The crop sown on June 16 required significantly higher number of days and accumulated GDD to attain various phenophases compared to July 1 and July 16 sown crops. Higher day temperature coupled with low humidity caused reduction in grain yield under July 16 sown crop. Soil moisture content at different depths was significantly lower at 75 DAS under July 16 sown crop as compared to June 16 and July 1 sown crop. The row spacing was not able to bring any significant difference in growing degree days. Among the cultivars, HQPM-1 required significantly more number of days and GDD for attaining reproductive and maturity as compared to PEHM-2 and Pratap-1. A significant negative correlation between grain yield and maximum temperature during reproductive phase was recorded.

Key words: Phenology, Weather, Row spacing, Cultivars, Maize, GDD and Soil moisture

Weather is one of the key component influencing agricultural production and productivity. In spite of cultivation of high yielding varieties, improved cultural practices and plant protection measures, favorable weather is a must for good harvests (Rao *et al.,* 1999). For increasing growth and productivity of crops, date of sowing plays an important role. It governs the crop phenological development and total biomass production along with efficient conversion of biomass into economic yield. Phenology is the science that relates climate to periodic events in plant life. The agrometeorological indices, like growing degree days (GDD) and helio thermal units (HTU) (product of GDD and bright sunshine hours) used in the present study, are important inputs for predicting phenophases and yield of the crop.

GDD concept is useful in deciding optimum sowing time, forecast of crop harvest dates, crop yield prediction and making crop zonation for the region.

Genetic potential of different cultivars are varied under various weather conditions. Selection of suitable cultivar according to length of growing period is key factor for sustainable production of maize in rainfed condition. Earlier available cultivars were of long duration which are not suitable for present set of environmental conditions, as the rainfall pattern is changed in the region (Solanki, 2007). Hence, the present study is carried out to find out a suitable sowing time for maize under Udaipur region.

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Materials and Methods

A field experiment was conducted during *kharif* 2012 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur, situated at South-Eastern part of Rajasthan at an altitude of 582.0 m above mean sea level, at 24º34' N latitude and 73°42' E longitude. The region falls under agro-climatic zone IV A "Sub-humid Southern Plain and Aravali Hills" of Rajasthan and agro climatic zone VIII (Central plateau and hills) of India. The annual rainfall is 600.8mm with maximum and minimum temperatures ranged between 28.7 to 39.8 ºC and 18.3 to 28.1ºC, respectively during *Kharif,* 2012. The soils of experimental field is clay loam in texture and slightly alkaline in reaction (pH 7.9) and calcareous in nature. It is medium in available nitrogen (250.4 kg/ha), phosphorus (22.5 kg/ha) and rich in available potassium (289.8 kg/ha).

The experiment consisted of 18 treatment combinations comprising three dates of sowing (June 16, July 1 and July 16), two row spacing (45 and 60 cm) and three cultivars (HQPM-1, PEHM-2 and Pratap-1). HQPM-1 (Haryana Quality Protein Maize-1) is yellow seeded cultivar and belongs to full maturity group. PEHM-2 (Pusa Early Hybrid Maize-2) has orange seeds and belongs to early maturity group. Pratap-1 is white seeded hybrid variety and belongs to early maturity group. The experiment was laid out in split plot design taking dates of sowing and row spacing in main plots and cultivars in sub plot treatments and replicated three times. Maize cultivars were sown on the stipulated dates as per treatment with a seed rate of 25 kg/ ha.

and fertilizer dose of 100 kg N and 40 kg P_2O_5 during crop growth period. The growing degree-days (GDD) were computed by following formula:

Accumulated GDD = $(T_{mean} – T_{base})$

where,

T base = Base temperature of maize crop (10^0C) as suggested by Rao, 2008.

Results and Discussion

Yield attributes and yield

The crop sown on June 16 registered significant increase in yield and yield attributes *viz.,* cob girth, weight of grain cob^{-1}, number of grain row cob^{-1}, test weight, grain yield, stover yield and harvest index over rest of the sowing dates *viz.,* July 1 and July 16 (Table 2). The reduction in yield attributing characters and yield with delayed sowing might be due to shortening of crop growth period and exposed to higher day temperature coupled with low soil moisture and relative humidity during the reproductive phase of the crop resulting into low dry matter accumulation plant^{-1} and ultimately low yield. The highest grain yield of 39.81 qha^{-1} was obtained in June 16 sown crop which was significantly superior over July 1 and July 16 sown crops by 19.2 and 59.2 %, respectively (Table 2).The results are in close agreement with the findings of Sandhu and Hundal (1991) and Mittal *et.al.* (1999). A negative

Table 1. Effect of date of sowing and row spacing on duration of phenological stages of maize cultivars

Treatment	Phenological stages							
	Emergence	5th leaf	Knee high	Tassel initiation	Silk initiation	Milking	Dough	Maturity
Date of sowing								
				48.6	53.7	68.3	81.6	88.5
				47.8	52.1	68.4	81.1	85.8
				44.8	49.5	65.6	78.5	81.5
				1.2	1.4	1.0	1.3	1.6
				2.7	3.3	2.4	NS	3.5
				45.9	50.0	66.3	78.8	83.8
				48.3	53.5	68.6	82.0	86.7
				1.0	1.2	0.8	1.1	1.3
				2.2	2.7	1.9	2.4	2.9
HQPM-1	4.0	13.3	37.2	51.3	55.9	71.4	84.8	90.9
PEHM-2	4.0	13.3	32.1	45.4	50.8	67.1	79.9	84.7
Pratap-1	5.0	13.4	31.2	44.5	48.6	63.8	76.5	80.2
SEd	0.1	0.1	0.9	0.9	0.7	0.72	1.2	1.6
CD (P=0.05)	0.2	NS	1.9	1.9	1.5	1.50	2.5	3.2

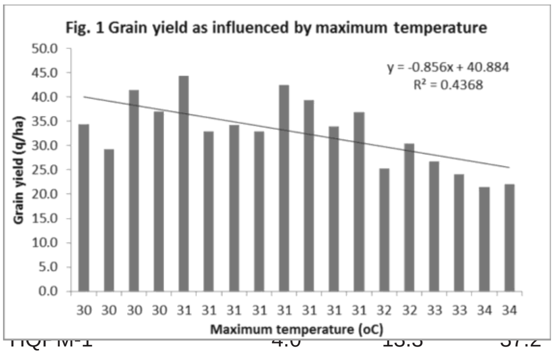

Fig. 1 Grain yield as influenced by maximum temperature

and significant correlation existed between grain yield and maximum temperature during milking to maturity (r = -0.779), also revealed that dependence of yield on day temperature. Higher temperature reduced dry matter accumulation during grain filling stage of maize was also reported by Apraku *et al.* (1983). The significant increase in test weight under early sown crop (June 16) might be due to better uptake and translocation of photosynthets during the reproductive phase of the crop, thus increasing the size and weight of grains. A significant positive correlation existed between test weight and dry matter accumulation at 75 DAS (r = 0.563). Late sown crop (July 16) experience high day temperature during milking to maturity phase coupled with low soil moisture at 75 DAS resulted in shriveled grain and ultimately low grain yield. Maximum temperature during both vegetative (emergence to cob initiation) and reproductive (cob initiation to maturity phase) stage showed significantly adverse relationship with yield (CRIDA, 2008). Higher day temperature decreased grain yield (Fig.1).

The yield attributing characters were not significantly influenced by row spacing; whereas, the grain, stover and biological yields were significantly higher under 45 cm row spacing compared to 60 cm row spacing. Significant improvement in various yield attributes *viz.,* number of grains cob^{-1}, number of grain row cob^{-1} was exhibited under the cultivar of HQPM-1 compared to Pratap-1 (Table 1). However, it was at par with PEHM-2. The highest grain yield of 33.70 q ha^{-1} was recorded in HQPM-1 which was superior over Pratap-1 by 8.3 per cent but it was at par with PEHM-

Table 2. Effect of date of sowing and row spacing on yield attributes and yield of maize cultivars

Treatment	Number of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	Weight of grain cob^{-1}(g)	Number of grain row^{-1}	Number of grain cob^{-1}	1000-grain weight (g)	Yield (qha^{-1})			Harvest index (%)
								Grain	Stover	Biological	
Date of sowing											
June 16	1.06	12.41	11.75	60.22	18.11	294.78	210.28	39.81	59.75	99.56	40.15
July 1	1.05	11.52	11.22	53.47	17.67	282.67	196.40	33.41	56.95	90.36	37.09
July 16	1.03	11.88	10.93	43.74	16.22	259.56	171.40	25.04	56.84	81.88	30.49
SEd	0.04	0.46	0.21	1.19	0.47	9.02	6.73	1.02	22.28	1.71	1.40
CD (P=0.05)	NS	NS	0.46	2.65	1.03	20.09	14.98	2.28	NS	3.80	3.11
Row spacing											
45 cm	1.07	11.64	11.31	51.99	17.11	275.44	195.28	33.92	60.28	94.20	35.77
60 cm	1.03	12.23	11.32	52.97	17.56	282.56	190.10	31.58	55.41	86.99	36.04
SEd	0.03	0.38	0.17	0.97	0.38	7.36	5.49	0.84	1.82	1.39	1.14
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	1.86	4.05	3.10	NS
Cultivars											
HQPM-1	1.09	11.93	11.11	53.30	18.00	289.67	180.27	33.70	56.95	90.65	36.72
PEHM-2	1.02	12.22	11.42	51.61	17.56	282.56	191.46	33.38	59.88	93.26	35.56
Pratap-1	1.03	11.66	11.42	52.52	16.44	264.78	206.36	31.17	56.71	87.88	35.44
SEd	0.03	0.35	0.16	1.08	0.41	6.38	3.84	0.43	1.25	1.54	0.43
CD (P=0.05)	NS	NS	NS	NS	0.84	13.17	7.92	0.88	2.57	3.18	0.88

2. The difference in grain yield of cultivars may be due to differences in various yield attributes. Grain yield of crop is usually governed by the genetic potential, but it is a very complex phenomenon depending on various climatic, soil and yield attributing characters. The positive and significant correlation (Table 5) between grain yield and test weight (r = 0.595), grain weight cob^{-1}(r = 0.895) and dry matter accumulation at 75 DAS (r = 0.614) validates this hypothesis. The findings of present investigation are in close agreement with the finding of Saindas *et.al.* (2009).

Table 3. Effect of date of sowing and row spacing on growing degree day (^{0}C day) during different phenological stages of maize cultivars

Treatment	Phenological stages							
	Emergence	5thleaf	Knee high	Tassel initiation	Silk initiation	milking	Dough	Maturity
Date of sowing								
June 16	87.0	297.0	846.4	931.3	1029.8	1268.5	1496.0	1604.3
July 1	83.0	264.3	753.3	842.3	916.0	1187.5	1387.5	1465.8
July 16	96.1	233.0	664.0	751.0	814.1	1099.3	1303.8	1371.0
SEd	1.70	2.81	8.03	26.05	28.20	48.24	38.38	35.64
CD (P=0.05)	3.80	6.28	17.90	58.03	62.84	107.48	85.51	79.40
Row spacing								
45 cm	88.7	264.6	752.3	836.4	919.4	1183.7	1380.8	1471.4
60 cm	88.6	264.8	756.9	846.6	920.5	1186.4	1410.7	1489.3
SEd	1.39	2.31	6.56	21.27	23.02	39.39	31.34	29.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
HQPM-1	88.8	265.0	755.2	929.8	996.8	1257.3	1473.1	1566.5
PEHM-2	88.6	264.6	754.3	813.5	903.8	1168.1	1374.2	1457.0
Pratap-1	88.6	264.6	754.3	781.3	859.3	1129.8	1340.0	1417.6
SEd	1.60	1.19	3.41	21.13	23.21	17.48	37.90	34.96
CD (P=0.05)	NS	NS	NS	43.62	1029.86	36.07	78.21	72.16

Phenology and agroclimatic indices

The crop sown on June 16 required significantly higher number of days to attain knee high, tassel

Table 4. Weather parameters during vegetative phase (emergence to tasseling) and reproductive phase (tasseling to maturity) of maize

Treatment	Max temp. (^{0}C)	Min temp. (^{0}C)	Mean temp. (^{0}C)	RH I(%)	RH II(%)	Mean RH(%)	Rainfall(mm)
Vegetative phase							
June 16	33.7	25.1	29.3	79.1	59.0	26.1	150.4
July 1	31.2	24.2	27.7	88.5	72.9	80.5	185.4
July 16	30.6	23.8	27.2	90.8	76.1	83.5	164.7
Reproductive phase							
June 16	30.4	23.4	26.9	91.0	75.4	83.2	287.2
July 1	30.7	22.4	26.5	89.2	68.4	78.8	201.8
July 16	31.4	20.8	26.0	85.3	56.5	79.0	143.9

initiation, silk initiation and maturity as compared to July 1 and July 16 sown crops (Table1). The crop sown on June 16 required the highest growing degree day at all phenological stage as compared to July 1 and July 16 sown crop. Days required to attain different phenophases and accumulated growing degree days were decreased with delayed sowing was also reported by Hara (2003) and CRIDA (2008) and MPUAT (2009).

The June 16 sown crop took maximum duration for initiation of critical growth stage, which manifested in increased duration for vegetative, reproductive as well as total crop duration resulted in higher accumulated GDD for attainment of maturity. Venkataraman and Krishnan (1992) reported that the crop phenology is largely dependent on genetic and environmental factor *viz.,* temperature, solar radiation, rainfall etc. June 16 sown crop required more GDD for attaining different phenological stages of the crop was due to longer duration.

Table 5. Correlation coefficient between grain yield and weather parameters during different phenophases of maize

Phenophases	Max T	Min T	Mean T	RH I	RH II	Mean RH	Rainfall
Emergence to tasseling	0.779**	0.832**	0.797**	-0.811**	-0.793**	-0.801**	-0.122
Tasseling to maturity	-0.814**	0.775**	0.785**	0.808**	0.814**	0.813**	0.765**
Milking to maturity	-0.779**	0.788**	0.621**	0.812**	0.802**	0.806**	0.817**

** Significant at 1% level of significance

Accumulated GDD were not influenced significantly by row spacing. Among the cultivars, HQPM-1 took longer time to attain the various phenological phases and growing degree days. HQPM-1 being a longer duration cultivar had vigorous growth which resulted on higher dry matter of the plant for which it required more accumulated growing degree day. Venkataraman and Krishnan (1992) reported that all the cultivars were exposed to the similar environmental conditions, the differential behaviors to heat unit requirements and days required to reach the various phenological phases could be ascribed solely to their genetic makeup.

Table 6. Soil moisture content at 15, 30 and 45 cm soil depth at 60 and 75 DAS

Treatment	Soil moisture content (%)						
	60 DAS				75 DAS		
	0-15 cm	15-30 cm	30-45 cm		0-15 cm	15-30 cm	30-45 cm
Date of sowing							
June 16	24.18	24.66	25.91		22.93	23.61	24.86
July 1	22.93	23.61	24.86		22.36	23.38	24.63
July 16	22.36	23.38	24.63		12.52	13.62	16.52
SEd	0.49	0.48	0.48	0.00	0.47	0.51	0.59
CD (P=0.05)	1.11	1.06	1.06		1.05	1.12	1.33
Row spacing							
45 cm	23.39	24.12	25.37		19.12	19.82	21.38
60 cm	22.93	23.65	24.90		19.43	20.59	22.06
SEd	0.41	0.40	0.38	0.00	0.38	0.41	0.48
CD (P=0.05)	NS	NS	NS		NS	NS	NS
Cultivars							
HQPM-1	23.84	24.57	25.82		19.66	20.53	22.00
PEHM-2	22.86	23.59	24.84		19.24	20.06	21.53
Pratap-1	22.77	23.49	24.74		18.92	20.02	21.49
SEd	0.48	0.45	0.45	0.00	0.37	0.44	0.38
CD (P=0.05)	NS	NS	NS		NS	NS	NS

Correlation

Correlation coefficient between grain yield and different weather parameters are presented in Table 5. The results show that grain yield was positively correlated with weather parameters *viz*., maximum, minimum and mean temperatures during emergence to tasseling stage. However, relative humidity during morning and afternoon as well as mean relative humidity was negatively correlated. The maximum temperature during reproductive phase of the crop has negative correlation with grain yield. However, other weather parameters during reproductive phase exhibited positive correlation with grain yield.

Soil moisture

Soil moisture at different depth at 60 and 75 DAS are presented in Table 6 .The data show that significantly lower soil moisture was recorded under July 16 sown crop at 15, 30 and 45 cm soil depth at 60 and 75 DAS as compared to June 16 and July 1 sown crops. This was due to withdrawal of monsoon on 12th September leading to prolong dry spell faced by July 16 sown crop which was at grain development, stage.

Conclusion

Higher day temperature coupled with low humidity and low soil moisture at 75 DAS resulted in reduction in yield attributing parameter *viz*., cob girth, weight of grains cob $^{-1}$, number of grain rows cob^{-1}, number of grains cob^{-1} and 100 grains weight, which caused reduction in grain yield by 37.1 % under late sown crop (July 16 sown) as compared to early sown crop (June 16).

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