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Effect of sowing date, irrigation and mulch on thermal time requirement and heat use efficiency of maize (*Zea mays* L.)

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ABSTRACT

The field experiments was carried out for three years (2015 to 2017) at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana with maize variety PMH-1 sown on three dates (D_1-Third week of May, D_2-Second week of June and D_3-First week of July) under two irrigation regimes (I_1 = IW:CPE 1.0 and I_2 IW:CPE 0.75) and mulch application (M_1: straw mulch @ 5 tha^{-1} and M_2: without mulch) in a split plot design.Results revealed that the early sown crop(third week of May) took higher number of days and heat units to attain various phenophases. Maize variety PMH-1 consumed maximum heat units of 1952°C days for maturity under early sown condition. The heat use efficiency was highest (3.04 kg ha^{-1}°Cday^{-1})for the crop sown during June. Among irrigation regimes, the HUE was higher (2.89 kg ha^{-1}°C day^{-1}) in IW: CPE = 0.75 level of irrigation as compared to IW: CPE = 1.00 (2.81 kg ha^{-1}°Cday^{-1}) and higher HUE was obtained with mulch application (M_1) (2.92 kg ha^{-1}°Cday^{-1}) as compared to without mulch (M_2) (2.76 kg ha^{-1}°Cday^{-1}). The sowing of maize crop during second week of June with irrigation of IW: CPE 0.75 under mulch application have been found to be the most efficient for heat utilisation.

Key words: Maize, phenology, heat units, heat use efficiency, maize, mulch, irrigation

Temperature plays most important role in almost all biological processes of crop plants and hence the growth and development of living biota. Under changing climatic conditions, various management options viz. date of sowing; irrigation, mulch etc.are important production components which can be manipulated to counter the adverse effects of environmental stresses. Matching the phenology of the crop to the duration of favourable environmental conditions to avoid the periods of stress is crucial for maximum yield and resource use efficiency under changing climate.

The growing degree days (GDD) are often used to relate crop growth and yield to meteorological conditions prevailing during crop growing period. Crop sown on different dates and irrigation givenat different crop growth stages provides sufficient information to find out the best option with logical understanding (Sharangi and Roychowdhury, 2014). Heat and radiation use efficiencies in terms of dry matter or yields are important aspects which have great practical applications. Hence, the knowledge on the growing degree days, heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) forms the basis to understand the phenology and the appropriate planting times for different crop varieties over the spatial and temporal scale (Sreenivas *et al*., 2010).In view of this, the present investigation was made to evaluate the effect of different management options viz sowing time, mulch application and irrigation levels etc on heat utilisation efficiency of maize so that suitable adaptation measures can be explored to improve its heat use efficiency in view of changing climatic conditions.

MATERIALS AND METHODS

Experimental details

The field experiment was carried out during *kharif* 2015, 2016 and 2017 at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana with maize variety PMH-1 sown on three dates viz. D_1-Third week of May, D_2-Second week of June and D_3- First week of Julyunder two irrigation levels *i.e.* irrigation at IW: CPE of 1.00 (I_1) and 0.75 (I_2) and mulch *viz.* application of straw mulch @ 5 t ha^{-1} (M_1) and without mulch (M_2) in split plot design (SPD) with dates of sowing and mulch in main plots and irrigation levels in the sub-plots.

The days taken to attain different phenological stages namely emergence, 8 leaf stage, knee-high stage, tasselling, silking and physiological maturity were recorded through visual observations. Data on tasselling and silking was taken, when 50 per cent plants developed tassel and silk. The yellowing of cobs in around 90 per cent plants was taken as physiological maturity stage. Grain and straw yield was recorded from net plot at the time of harvesting of the crop. Daily maximum and minimum temperature and sunshine hours during crop growing period were recorded from the agrometeorological observatory.

Heat units

The growing degree days (GDD)was calculated following Nuttonson (1955); taking base temperature of 10°C.

$$GDD = (T_{max}+T_{min})/2 - T_b$$

Where,

T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

T_b = Base temperature (10ÚC for maize)

The heliothermal units (HTU) was calculated as;

HTU = GDD × Actual bright sunshine hours (°C day hours)

The photothermal units (PTU) was calculated as;

PTU = GDD× Day length (°C day hours)

and the heat use efficiency (HUE) was calculated as;

$$\text{Heat use efficiency (kg ha}^{-1}\text{°C day}^{-1}\text{)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{AGDD (°C day)}}$$

Where, AGDD(kg ha^{-1}°C day^{-1}) = Accumulated growing degree days.

RESULTS AND DISCUSSION

Crop phenology

Sowing time, irrigation and mulch application had significant effect on phenology of maize(Table 1). The maize cultivar PMH-1 took 92, 87 and 78 days to attain physiological maturity under different sowing dates, the crop duration decreased with delay in sowing. Among the irrigation levels, the crop grown under IW: CPE=1.0 consumed higher number of days than IW: CPE=0.75 at all the crop growth stages with significant difference at emergence, 8-leaf stage, tasseling and silking. However, due to good distribution of rainfall during the crop season, no significant difference could be observed in the days taken to attain physiological maturity. Similarly, the mulch applied crop took higher no. of days to attain different phenological stages with significant differences at emergence, 8-leaf stage, silking and physiological maturity. Kingra *et al.*, (2011) also reported that higher number of days taken by wheat crop to attain a particular physiological maturity under increased frequency of irrigation.Conversely under late sowing, reproductive growth as well as total crop duration was drastically reduced.Several studies in India have shown that a delay of 20 days in sowing could cause a delay in flowering by 8 days or upto 13 days (Brar *et al.*, 2011).

Growing degree days (GDD)

Early sown crop (May) consumed significantly higher heat units (1952°C days) as compared to June(1796°C days) and July(1579°C days) sown crop to attain physiological maturity (Table 2).Gowda *et al,* (2013) also reported that timely sown maize (first fortnight of June) took significantly more number of days and heat units to complete physiological maturity as compared to subsequent sowings. Under irrigation treatment IW: CPE=1.0, the crop took higher heat units to attain different stages, the differences being significant at emergence, 8-leaf stage, tasselling and silking. The crop consumed 1790 and 1771 °C days to attain physiological maturity under irrigation treatment I_1 and I_2, respectively. Under straw mulch, the crop had higher heat unit consumption to attain various crop growth stages with significant difference at emergence, 8-leaf state, silking and physiological maturity (Table 2).

Heliothermal units

Maize sown during third week of May consumed significantly higher heliothermal units (14304°C day hours) attain physiological maturity as compared to June(12134 °C day hours) and July(10721 °C day hours) sown crop. Under irrigation treatment IW: CPE=1.0, maize took higher heat units(12501 °C day hours) as compared to IW: CPE-0.75 (12273 °C day hours) to attain physiological maturity. Crop with application of straw mulch also recorded higher heliothermal units with significant differences at emergence and physiological maturity. Straw mulch applied crop consumed 12612°C day hours, whereas the crop without mulch consumed 12161°C day hours to attain physiological maturity (Table 3).

Photothermal units (PTU)

Early sown maize (May) took significantly higher photothermal units (26807°C day hours) to attain physiological maturity as compared to June (24130°C day

Table 1: Days taken to various phenological stages of sown as infuenced by tretments (three years 2015 to 2017 mean).

Treatment	Emergence	8-leaf stage	Knee-high	Tasselling	Silking	Physiological maturity
Dates of sowing						
D_1 (Third week of May)	7	22	45	62	78	91
D_2 (Second week of June)	6	20	43	58	73	86
D_3 (First week of July)	5	19	41	55	66	78
CD (p=0.05)	0.7	1.0	2.1	2	2.4	2
Irrigation levels						
I_1 (IW/CPE=1.00)	7	21	44	59	73	86
I_2 (IW/CPE=0.75)	6	20	43	57	71	84
CD (p=0.05)	0.6	0.8	NS	1.1	1.9	NS
Mulch levels						
M_1 (with straw mulch @ 5t ha^{-1})	6	20	44	59	73	87
M_2 (without mulch)	6	20	43	58	72	84
CD (p=0.05)	0.4	0.3	NS	NS	0.5	2.0

Table 2: Accumulated growing degree days (°C day) at different stage of maize under different treatments (three years 2015 to 2017 mean).

Treatment	Emergence	8-leaf stage	Knee-high	Tasselling	Silking	Physiological maturity
Dates of sowing						
D_1 (Third week of May)	172	498	1011	1357	1679	1953
D_2 (Second week of June)	149	456	929	1252	1531	1797
D_3 (First week of July)	122	394	851	1123	1339	1579
CD (p=0.05)	16.2	21.7	45.9	47.0	47.2	50.0
Irrigation levels						
I_1 (IW/CPE=1.00)	156	461	940	1266	1541	1790
I_2 (IW/CPE=0.75)	141	438	921	1224	1493	1772
CD (p=0.05)	13.2	16.5	NS	22.4	23.5	NS
Mulch levels						
M_1 (with straw mulch @ 5t ha^{-1})	153	458	941	1245	1534	1809
M_2 (without mulch)	143	442	921	1235	1499	1744
CD (p=0.05)	4.1	7.4	NS	NS	9.8	40.9

hours) and July(20737°C day hours) sown crop. Under irrigation treatment IW: CPE=1.0 the crop took higher photothermal units to attain different phenological stages with significant differences at emergence, 8-leaf stage, tasseling and silking. The crop consumed 24019 and 23763 °C day hours to attain physiological maturity under irrigation treatment I_1 and I_2, respectively. Crop with application of straw mulch also recorded higher photothermal units with significant differences at emergence, 8 leaf stage, silking and physiological maturity. Straw mulch applied crop consumed 24263°C day hours, whereas the crop without mulch consumed 23520°C day hours to attain physiological maturity (Table 4).

Heat use efficiency (HUE)

Heat use efficiency of maize was significantly higher in the crop sown in the second week of June (3.04 kg ha^{-1}°C

Table 3: Accumulated heliothermal units (°C day hr) at different stages of under different treatmets (three years 2015-2017 mean).

Treatment	Emergence	8-leaf stage	Knee-high	Tasselling	Silking	Physiological maturity
Dates of sowing						
D_1 (Third week of May)	1782	4935	8659	10816	12708	14305
D_2 (Second week of June)	1302	3449	6425	8180	9939	12134
D_3 (First week of July)	935	2531	5142	6896	8492	10722
CD (p=0.05)	148.9	169.0	335.0	309.0	694.8	387.8
Irrigation levels						
I_1 (IW/CPE=1.00)	1405	3723	6809	8752	10485	12501
I_2 (IW/CPE=0.75)	1274	3553	6676	8509	10275	12273
CD (p=0.05)	85.4	126.7	NS	136.8	217.9	NS
Mulch levels						
M_1 (with straw mulch @ 5t ha^{-1})	1386	3695	6806	8695	10433	12612
M_2 (without mulch)	1293	3582	6678	8566	10327	12162
CD (p=0.05)	36.2	NS	NS	NS	NS	316.6

Table 4: Accumulated PTU (°C day hr) of maize (three years mean)

Treatment	Emergence	8-leaf stage	Knee-high	Tasselling	Silking	Physiological maturity
Dates of sowing						
D_1 (Third week of May)	2352	6923	14150	18899	23200	26808
D_2 (Second week of June)	2100	6428	12939	17112	20917	24131
D_3 (First week of July)	1721	5446	11561	15111	17818	20737
CD (p=0.05)	226.2	300.9	625.3	618.8	606.1	608.2
Irrigation levels						
I_1 (IW/CPE=1.00)	2150	6426	13009	17314	20953	24019
I_2 (IW/CPE=0.75)	1955	6106	12757	16767	20337	23764
CD (p=0.05)	127.4	228.7	NS	293.6	302.1	NS
Mulch levels						
M_1 (with straw mulch @ 5t ha^{-1})	2125	6375	13013	17171	20864	24263
M_2 (without mulch)	1989	6157	12743	16910	20427	23520
CD (p=0.05)	57.3	102.6	NS	NS	383.3	496.6

day^{-1}) but it decreased when sown early i.e. in third week of May (2.69 kg ha^{-1}°C day^{-1}) or late in first week of July (2.82 kg ha^{-1}°C day^{-1}) (Table 5). Khushwaha *et al,* (2010) also reported maximum heat use efficiency in the corn crop sown on 15 June. Among the irrigation levels, there was no significant difference but heat use efficiency was higher under IW: CPE= 0.75 (2.89 kg ha^{-1}°C day^{-1}) as compared to that under IW: CPE= 1.0 (2.81 kg ha^{-1}°C day^{-1}). Among the mulch levels, significantly higher HUE was found in the mulch applied crop (2.92 kg ha^{-1} ° C day^{-1}) as compared to non-mulch (2.76 kg ha^{-1} ° C day^{-1}). Girijesh *et al,* (2011) also reported higher heat use efficiency with the crop sown in first fortnight of June and it decreased with each successive delay in sowing.

CONCLUSION

The study concluded that sowing of crop in second

Table 5: Heat use efficiency (kg ha^{-1}°C day^{-1}) of maize as influenced by different treatment (three years 2015-2017 mean).

Treatments	Heat use (mm)	Grain yield ($kgha^{-1}$)	Heat use efficiency ($kgha^{-1}$°C day^{-1})
Dates of sowing			
D_1(Third week of May)	1953	5261	2.69
D_2(Second week of June)	1797	5469	3.04
D_3(First week of July)	1579	4458	2.82
CD (p=0.05)	50.1	409.9	0.17
Irrigation levels			
I_1 (IW/CPE=1.00)	1790	5036	2.81
I_2 (IW/CPE=0.75)	1757	5090	2.89
CD (p=0.05)	NS	246.8	NS
Mulch levels			
M_1 (With straw mulch @ $5tha^{-1}$)	1809	5295	2.92
M_2 (Without mulch)	1744	4831	2.76
CD (p=0.05)	40.9	312.7	0.14

week of June with IW: CPE 0.75 and application of straw mulch @ 5 t ha^{-1} proved to be the most efficient for improving heat utilisation efficiency of maize. Such management options can be used effectively to manage climate change impacts on maize to sustain crop productivity and food security under changing climatic scenarios in future.

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