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Short Comminucation

Agrometeorological, phenological and yield response of spring maize as influenced by foliar application of different plant growth regulators under suboptimal temperature of Faisalabad, Pakistan

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The growth phases of different crops are governed by prevailing conditions of ambient temperature and solar radiation. Recently, various studies have shown the influence of temperature on phenology and yield of crops under field conditions through accumulated heat unit system (Sikder, 2009). The heat unit system was adopted for determining the maturity dates of different crops from which accurate yield and maturity prediction could be assessed (Bierhuizen, 1973).Though maize is a day neutral plant, the flowering and maturity of its varieties are however, dependent to available temperature and sunshine hours and it is location specific (Rao *et al*., 1999). Hence, the knowledge on the calculation of the heat summation unit (HSU), mostly called the growing degree days (GDD) and their further mathematical derivations like helio-thermal unit (HTU), pheno-thermal index (PTI) and heat use efficiencies (HUE) will be the basic principles to understand the phenology and follow the proper planting times for different crop varieties over the spatial and temporal variations. Planting date will have determinant role in governing the maize growth and yields. Various chemicals like ascorbic acid (AsA) salicylic acid (SA) and hydrogen peroxide act as signaling molecule in maize which helps to regulate plant resistance against stresses (Ahmad *et al*., 2015) and their exogenously application in maize has never been evaluated. Hence the present investigation, the effect of ambient temperature on phenological development and accumulated heat unit of maize was studied to determine the real heat unit indices grown under early planting dates.

The field experiment was conducted at the university farms of University of Agriculture, Faisalabad by growing maize hybrid Hi-Swan 9697 by randomizing seeding dates of 1[st] and 22[nd] Feb in 2008 in main plot and foliar application of ascorbaic acid (AsA), salicylic acid (SA) and hydrogen peroxide (H_2O_2) at the rate of 20 ppm in subplots with three replications and standard package of practices was followed to grow the maize. Ten fixed maize plants from each plot were randomly selected from emergence and fixed up to the physiological maturity stages to visualize their different pheno-phases and 50% developmental stages have been marked for this study. The various measurements of accumulated heat units were calculated according to the following formulae given by Rao *et al*. (2000), Ritchie and Nesmith (1991) and Rajput (1980).Data so collected on different parameters were analyzed statistically by using analysis of variance technique and comparison of treatments were made through least significance difference (LSD) test at 0.05 probability levels (Steel *et al*., 1997).

Air temperature and relative humidity

Air temperature was recorded for 19 weeks started from date of planting under early low temperature stresses and normal condition started from 1[st] Feb and 22[nd] Feb, 2008, respectively and average of week after sowing was calculated (Fig. 1). Minimum day temperature of 4.5, 2.9 and 7.3^{o}C for maize sown on 1st Feb. while the minimum temperature of 7.7,12.2, 13.1^{o}C for maize sown on 22[nd] Feb were recorded during 1[st] , 2[nd] and 3[rd] weeks after sowing. Similarly relative humidity (RH) values of 44.6, 32.1 and 39.1% for 1st Feb planted maize; whereas RH of 34.6, 43.1and 40.1 % for 22[nd] Feb planted maize was recorded

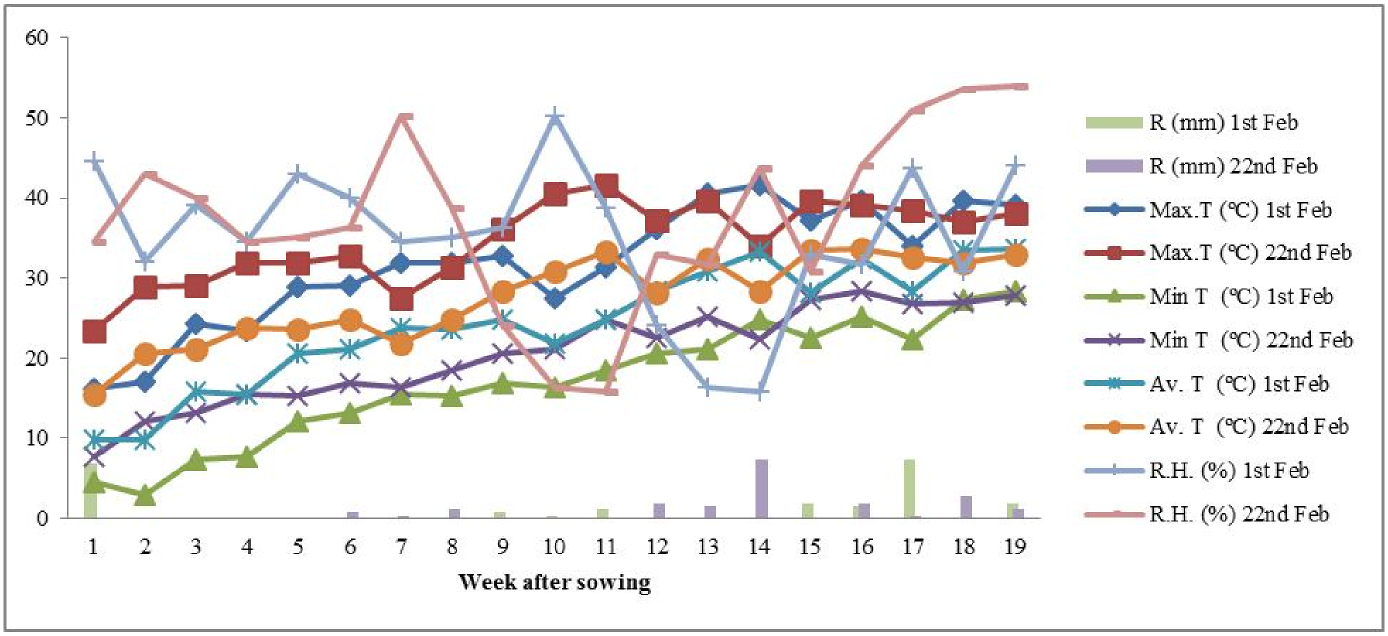

Fig. 1: Meteorological data recorded of experimental site from sowing to harvesting during 2008

during 1st, 2nd and 3rd weeks after sowing (Fig. 1).

Crop phenology

The different phenological stages like days to 50% emergence, tasseling, silking and physiological maturity were significantly affected by planting dates (Table 1). Early 1st Feb planting took 20 days for emergence, 73. for tasseling, 77 for silking and 123 days for physiological maturity whereas normal planting (22nd Feb) mentioned growth duration were 9, 64, 67 and 113 days, respectively. However, foliar spray of ascorbic acid (AsA), salicylic acid (SA) and hydrogen peroxide (H_2O_2) increased them. At early growing conditions (1st Feb planting) short days were attained to get the more respective pheno-phases and maturity than the 22nd Feb planting because of increased temperatures for early attaining of phenological stages. Delayed tasseling, silking and physiological maturity were observed with foliar application of AsA, H_2O_2 and SA were applied at the rate of 20 mg L^{-1} on spring maize sown at different sowing dates. Foliar application of H_2O_2 is the most effective at normal than early planting conditions. High temperature at the early vegetative phases of maize was resulted in reduced number of days for attaining different penological stages under normal planting.

Growing degree days (GDD)

Combined effect of planting conditions and foliar application of AsA, SA and H_2O_2 on heat unit of GDD for emergence (GDD_E), tasseling (GDD_T), silking (GDD_S) and physiological maturity (GDD_{PM}) are presented in Table 1. Early planting (1st Feb) required lower GDD than normal planting (22nd Feb), earlier planted required 32, 651, 713 and 1804 GDD for emergence tasseling, silking and physiological maturity whereas normal planting (22nd Feb) took GDD were 54, 811, 878 and 2130, respectively. Lower GDDs required for emergence, tasseling, siliking and physiological maturity was observed with foliar application of AsA, H_2O_2 and SA applied at the rate of 20 mg L^{-1} on spring maize sown at different sowing dates. Foliar application of SA is the most effective at normal than early planting conditions. Planting time, the later developmental stages (emergence, tasseling, silking and maturity) showed the increasing trend of heat unit (GDD). The significantly highest GDD requirement was observed at emergence (59) with exogenous of H_2O_2, tasseling (848), silking (902) and maturity stage (2174 GDDs) with AsA on 22nd Feb planting. The requirement of heat unit (GDD) was significantly higher under normal planting condition than the earlier ones.

Grain yield

From the result it was observed that grain yield of spring maize was significantly affected by sowing dates and foliar application (Table1). The 22nd Feb planting maize has been producing higher yield than early plantings and this might be due to the low temperature from sowing to the long vegetative growth stages of maize due to early planting. Foliar application of AsA, H_2O_2 and SA improved grain yield. Improvement in maize yield might be due to increased days, GDD, PTI and HTU to tasseling, silking and physiological maturity with these chemicals during both

Table 1: Days (D) to emergence (E), tasseling (T), silking (S) and physiological maturity (PM) of spring maize as influenced by foliar application of ascorbic acid, hydrogen peroxide and salicylic acid when planted on 1st Feb and 22nd Feb.

Treatments	D_E	D_T	D_S	D_{PM}	GDD_E	GDD_T	GDD_S	GDD_{PM}	Grain yield (kg ha^{-1})	Heat use efficiency
Sowing dates										
1st Feb	20 a	73	77 a	123 a	32b	651b	713a	1804	4570 b	2.57
22nd Feb	9 b	64	67 b	113 b	54a	811 a	878 a	2129	4993 a	2.41
LSD	1.6	2.8	2.2	2.5	14.35	48.37	45.11	363.9	171.83	0.24
Foliar spray										
Control	14	67 b	73 a	115 c	44	703 b	783 b	1915 b	4395 b	2.35 b
AsA	14	70 a	72 ab	118 ab	40	758 a	811 a	1996 a	4919 a	2.53 a
H_2O_2	14	67 b	72 ab	119 a	43	717 b	791 b	1984 a	4863 a	2.50 a
SA	14	70 a	71 b	118 b	45	746a	798 ab	1972 a	4949 a	2.58 a
LSD	1.3	1.5	1.4	0.96	9.66	28.15	18.89	33.3	111.10	0.076
Interaction										
1st Feb										
Control	20 a	71 d	76 a	121 c	37 bc	626 d	699 c	1757	3939	2.28 d
AsA	19 a	74 a	77 a	123a	29c	668 c	719 c	1816	4846	2.71 a
H_2O_2	19 a	73 ab	77 a	124 a	29 c	652cd	721 c	1833	4698	2.60 bc
SA	20 a	73 ab	77 a	123 a	35 bc	658 cd	715 c	1812	4796	2.69 ab
22nd Feb,										
Control	8 b	71 b	66 b	110 d	52 ab	781 c	868 b	2075	4852	2.42 cd
AsA	8 b	65 c	68 b	114 c	52 ab	848a	902 a	2176	4991	2.36 d
H_2O_2	9 b	62 d	66 b	114 c	59 a	781 b	861 b	2136	5028	2.40 cd
SA	9 b	65 c	67 b	113 c	55 a	835a	881 ab	2132	5102	2.46 bcd
LSD	2.17	3.15	2.68	1.36	17.59	56.12	48.16	364.2	207.21	0.107

Figures sharing same letters do not differ significantly at 0.05 probability level.

early and normal planting which may increased duration of assimilates toward grain formation (Table 1).

Heat use efficiency

Heat use efficiency (HUE) was reduced with delayed cultivation and foliar application of AsA, H_2O_2 increased HUE. Higher HUE was observed under early planting conditions. However, exogenous application of AsA, H_2O_2 and SA were effectively improved HUE when planted on 1st Feb while SA was only effective under normal planting of 22nd Feb, 2008 (Table 1).

Pheno-thermal index (PTI)

The effect of combination of growing conditions was affected significantly by planting dates on PTI from sowing to emergence (PTI_E), tasseling (PTI_T), silking (PTI_S) and physiological maturity (PTI_{PM}) (Table 2). Higher PTI_E, PTI_T, PTI_S and PTI_{PM} under early planting condition than normal, while foliar spray of AsA, H_2O_2 and SA improved PTI at each date significantly. The higher temperature and lengthy days after emergence stages of normal planting of spring maize showed the lower days to attain the accumulative heat units within the shorter periods and hence recorded the lesser PTI values at advanced growth stages at maturity period during spring. The increase in PTI at later stage was also due to the increasing number of growth duration at the advanced phenological stages of the maize. At the initial stages, the growth duration was lower and then increased with increasing plant age. The PTI were also increased with plant age and temperature. The higher values of PTI were observed at later stages and with rise in temperature (Table 2).

Table 2: Pheno-thermal index (PTI) and helio-thermal units (HTU) for emergence (E), tasseling (T), silking (S) and physiological maturity (PM) of spring maize as influenced by foliar application of ascorbic acid (AsA), hydrogen peroxide (H_2O_2) and salicylic acid (SA) when planted on 1st Feb and 22nd Feb.

Treatments	PTI_E	PTI_T	PTI_S	PTI_{PM}	HTU_E	HTU_T	HTU_S	HTU_{PM}
Sowing dates								
1st Feb	1.63 b	8.97 b	9.28 b	14.75 b	4225	365107 b	424142 b	1820000
22nd Feb	6.31 a	12.76 a	13.14 a	18.90 a	3478	431673 a	497027 a	2060000
LSD	0.583	0.285	0.326	3.597	1955	47078	53868	350466
Foliar spray								
Control	3.99	10.70 b	11.16	16.73	4078	371846 c	445485 b	1850000 b
AsA	3.84	11.02 a	11.28	16.97	3387	421299 a	475003 a	1980000 a
H_2O_2	3.99	10.78 b	11.18	16.78	3784	389313 bc	459718 ab	1980000 a
SA	4.06	10.96 a	11.22	16.82	4158	411102 ab	462130 a	1950000 a
LSD	0.395	0.162	0.138	0.365	1430	23800	16549	32383
Interaction								
1st Feb								
Control	1.79 b	8.81 d	9.23 c	14.58 b	4969	342484 c	407250 e	1740000
AsA	1.49 b	9.07 c	9.30 c	14.82 b	3587	379283 b	430852 cd	1830000
H_2O_2	1.49 b	8.98 cd	9.32 c	14.82 b	3587	367507 bc	431966 cd	1870000
SA	1.75 b	9.08 cd	9.29 c	14.79 b	4755	371154 bc	426500 de	1830000
22nd Feb								
Control	6.19 a	12.59 b	13.08 ab	18.88 a	3186	401208 b	483721 bc	1950000
AsA	6.19 a	12.97 a	13.26 a	19.11 a	3186	463315 a	519155 a	2120000
H_2O_2	6.49 a	12.59 b	13.05 b	18.75 a	3980	411119 b	487470 b	2080000
SA	6.36 a	12.90 a	13.15 ab	19.11 a	3561	451051a	497760 ab	2070000
LSD	0.717	0.328	0.349	3.600	2486	52368	55327	350679

Figures sharing same letters do not differ significantly at 0.05 probability level.

Helio-thermal units (HTU):

Helio-thermal unit of a definite phenology is the product of the length of sunshine hours of a day and accumulated heat units of those particular pheno-phases shown by plants. The requirements of HTU for emergence, tasselling, silking and physiological maturity for early planting conditions were significantly higher than the normal planting conditions (Table 2). Foliar spray of AsA, H_2O_2 and SA significantly increased HTU for tasseling, silking and maturity. The variation of sunshine hours recorded at different developmental stages of maize has affected the magnitudes of the HTU though there were records of higher GDD at advanced stages of the maize.

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