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Genotype x environment interaction of flowering characters under moisture stress condition in *winter* maize

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ABSTRACT
Genotype (G) x Environment (E) interaction of maize genotypes for anthesis-silking interval (ASI), tassel condensation (TC) and tassel vigour index (TVI) were studied under four diverse environments of sowing dates and moisture regimes. Highly significant mean squares due to genotypes, environments and G x E (linear) were observed for all the flowering traits. The crosses P_1 x P_5 (G_{15} C_{22} MH148-1-1-1-6-3-BB x Pop27-S_4-4U-1-3) and P_5 x P_{10} (Pop27-S_4-4U-1-3 x CML 117) were identified as tolerant to moisture stress as they were having lesser ASI with condensed tassel and high yield. However, three crosses, namely, P_1 x P_{10} (G_{15} C_{22} MH148-1-1-1-6-3-BB x CML 117), P_2 x P_{10} (Pool 21 Sequia best SYN CoF_2 x CML 117) and P_5 x P_6 [Pop 27-S_4-4U-1-3 x Pop 147(EEY DMR) S_1-117-3] exhibited high yield with minimum ASI over environments which may be exploited during winter season of Bihar.

Key words : Anthesis-silking interval, Tassel condensation, Tassel vigour index, Maize.

INTRODUCTION

In India, maize is cultivated throughout the year which is characterized by erratic rainfall and moisture stress. Moisture stress/ drought is a major factor responsible for limiting maize production and productivity in developing world. Edmeades *et. al.* (1992) have estimated about 15% global annual losses of maize production due to drought. Therefore, it is essential to develop a variety/genotype endowed with high degree of stability for flowering characters like ASI, tassel condensation and tassel vigour index to achieve high fertilization rate and ultimately good production & productivity. Moisture stress, if occurred just before or during the flowering period, a delay in silking is observed resulting in an increase in the period of anthesis-silking interval (Rabaut *et. al.*,1996), and decreased seed setting even if pollination occurs (Bassetti and Westgate,1993), resulting into decrease in grain yield.

MATERIALS AND METHODS

The experimental material consisted of ten genetically diverse and advanced generations maize inbred lines possessing different levels of tolerance to moisture stress (Singh and Jha, 2004). Diallel mating design was adopted to generate forty-five F_1s. Ten parents along with forty-five F_1s and two checks (Pusa Early Hybrid-1&2) were sown in randomized block deign, replicated three times with plot size of 4.5 m^2 and tested in four diverse environments, viz.,(i) Early sowing moisture non-stress (ii)Early sowing moisture stress (iii) Late sowing moisture non-stress and (iv)Late sowing moisture stress. The number of irrigation in moisture stress plot was reduced to one which was applied at knee high stage. The observations were recorded on three characters, namely, anthesis-silking interval, tassel condensation and tassel vigour index. The experimental data for ASI was recorded as per plot basis, whereas TC and TVI were recorded on ten competitive plants in each plot. Mean value of each plot was used for statistical analysis. The stability analysis was carried out as per method by Eberhart and Russell (1966). Genotypes having lower values of ASI and TVI, and higher value of TC were considered as desirable.

RESULTS AND DISCUSSION

The analysis of variance for design of experiment over environments revealed highly significant mean squares due to genotypes, environments and genotype x environment interaction for all the three traits included with study indicating the existence of significant difference among genotypes, environments and their interactions with environments (Table-1) Among the three flowering traits, only tassel condensation exhibited significant pooled deviation as well as G x E (linear) inferred that part of variability due to G x E is unpredictable in nature. Menkir and Akintude (2001) reported that moisture deficit significantly affected the ASI.

Table 1: Pooled analysis of variance for genotype-environment interaction for twelve quantitative characters in maize

Sl. No.	Characters	Mean Squares			
		Environment (E) d.f.=3	Genotypes (G) d.f.=56	G x E d.f.=168	Pooled error d.f.=448
1.	Anthesis-silking interval	186.41**	0.53**	0.18*	0.14
2.	Tassel condensation	4.22**	0.18**	0.02**	0.001
3.	Tassel vigour index	4687.50**	118.80**	4.44**	2.90
4.	Plant height	24064.59**	220.49**	17.52*	13.60
5.	Ear height	15156.27**	119.58**	34.08**	9.60
6.	Effective ear length	4797.08**	117.76**	9.35**	2.91
7.	Ear girth	77.60**	2.02**	0.23**	0.13
8.	Grain filling per cent	5488.42**	116.80**	8.55**	5.75
9.	Kernel rows per ear	13.50**	5.26**	0.63**	0.43
10.	500-grain weight	39564.00**	689.70**	33.82**	6.52
11.	Harvest index	3714.48**	68.31**	3.22**	2.19
12.	Grain yield	4581.71**	205.61**	11.38**	2.73

*, ** : Significant at 5 % and 1% level of significance, respectively.

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Table 2 : Mean performance (X) and stability parameters (b_i , S^2d) for three flowering characters in winter maize

Sl. No.	Entry	Anthesis-silking interval			Tassel condensation			Tassel vigour index			Grain yield
		X	b_i	S^2d	X	b_i	S^2d	X	b_i	S^2d	
1.	P_1	5.34	1.18	0.06	1.91	0.38**	-0.001	28.46	0.77**	-1.22	28.50
2.	P_1 x P_2	5.42	1.03	0.18	2.29	1.06	0.005*	46.25	0.99	-2.46	44.81
3.	P_1 x P_3	6.25	0.91	-0.02	2.41	1.13*	0.004*	33.26	0.99	-2.89	38.58
4.	P_1 x P_4	5.58	0.85**	-0.16	2.33	1.07	0.003	42.68	0.95	-2.69	36.36
5.	P_1 x P_5	5.50	0.75	-0.03	2.34	0.75**	0.001	43.28	0.85	-0.81	45.56
6.	P_1 x P_6	5.67	1.08	0.03	2.38	1.32**	0.02**	35.33	1.13**	-2.80	43.89
7.	P_1 x P_7	5.58	0.93	-0.04	2.22	1.09	0.004*	31.93	1.02	-2.67	35.36
8.	P_1 x P_8	6.08	0.97	-0.01	2.19	1.03	0.007**	28.85	0.99	-0.22	31.27
9.	P_1 x P_9	5.67	0.84	0.03	2.36	1.20**	0.008**	29.35	1.15**	-2.75	32.99
10	P_1 x P_{10}	5.08	0.83	-0.07	2.49	1.04	0.006**	45.29	0.92**	-2.71	46.75
11.	P_2	5.42	0.88*	-0.14	1.88	0.30**	-0.001	29.42	0.61**	-2.59	32.99
12.	P_2 x P_3	6.17	0.82**	-0.16	1.86	0.62**	-0.001	32.98	1.22**	-2.45	30.95
13.	P_2 x P_4	5.83	0.86	0.07	1.82	0.36**	-0.002	37.44	1.42**	-1.67	30.88
14.	P_2 x P_5	5.92	0.86	0.29	2.03	0.72**	0.003	41.72	0.64**	-1.83	46.11
15.	P_2 x P_6	6.17	1.07	-0.09	1.91	0.67**	-0.002	27.28	0.90	-0.29	30.13
16.	P_2 x P_7	6.08	0.78	0.13	2.04	0.67**	-0.001	31.44	1.46*	8.89	31.94
17.	P_2 x P_8	6.17	0.94*	0.11	2.08	0.94	0.004*	35.42	1.16**	-2.69	27.64
18.	P_2 x P_9	5.58	1.07	-0.04	1.95	0.28**	0.05**	32.09	1.09**	-2.86	28.08
19.	P_2 x P_{10}	5.42	0.94	-0.14	2.41	0.97	0.007**	44.14	0.92*	-2.49	46.69
20.	P_3	5.67	0.92*	-0.17	1.85	0.56**	0.002	29.68	0.89	-1.93	27.74
21.	P_3 x P_4	5.75	1.09	-0.05	2.08	0.99	0.005*	40.20	1.08	-1.02	40.77
22.	P_3 x P_5	5.58	0.87	-0.01	2.09	1.83**	0.002	39.44	1.06	-1.55	38.57
23.	P_3 x P_6	5.25	1.18**	-0.14	1.95	1.08*	0.001	35.86	1.05	-2.52	30.70
24.	P_3 x P_7	5.75	1.16	0.04	2.10	0.97*	-0.001	30.12	0.89	-1.19	28.66
25.	P_3 x P_8	5.83	1.02	-0.16	2.11	0.98	0.002	28.89	0.97	-1.99	26.18
26.	P_3 x P_9	5.83	0.93	-0.09	1.92	0.96	0.005*	27.84	0.98	-2.67	28.97
27.	P_3 x P_{10}	5.75	0.92	-0.01	1.85	1.23**	0.009**	32.29	1.06	-1.79	33.37
28.	P_4	5.34	1.01	-0.11	1.84	0.47**	-0.001	27.90	0.69**	-1.02	27.62
29.	P_4 x P_5	5.92	0.92	-0.02	1.99	0.68**	0.001	37.42	0.69**	-2.89	42.99
30.	P_4 x P_6	6.25	1.09*	-0.15	1.76	1.04	0.015**	32.38	0.96	-0.75	32.47
31.	P_4 x P_7	6.42	0.873	-0.07	1.70	1.09	0.013**	31.95	1.06	-2.41	40.99
32.	P_4 x P_8	6.42	0.92	-0.01	1.84	0.72**	-0.002	29.32	0.93	-2.14	38.79
33.	P_4 x P_9	5.50	1.12	0.24	1.85	1.16**	0.006**	26.80	0.99	-2.38	24.28
34.	P_4 x P_{10}	6.00	1.09	0.02	1.81	1.30**	0.003*	39.08	1.36*	2.09	42.50
35.	P_5	4.92	1.07	-0.04	1.92	0.24**	0.005*	29.27	0.84**	-2.72	29.19
36.	P_5 x P_6	5.25	0.98	-0.15	2.33	1.97**	-0.001	42.53	0.95	-2.56	47.31
37.	P_5 x P_7	5.25	0.97	0.25	2.18	1.53**	-0.001	34.15	1.09	-2.28	41.55
38.	P_5 x P_8	6.08	0.99	-0.14	2.29	1.87**	0.007**	36.83	1.09	-0.56	28.20
39.	P_5 x P_9	5.92	0.99	-0.03	2.06	1.62**	0.002	36.74	1.11**	-2.89	41.11
40.	P_5 x P_{10}	5.67	0.76	0.02	2.38	1.05	0.006**	44.19	0.95	-1.69	44.74
41.	P_6	5.75	1.07	0.11	1.94	0.47**	-0.001	27.38	0.74**	-2.58	22.58
42.	P_6 x P_7	6.00	1.17*	-0.12	1.86	0.70**	0.002	27.61	1.04	-2.71	31.43
43.	P_6 x P_8	5.92	1.04	-0.09	1.77	0.87*	0.005*	33.17	1.19	0.83	39.01
44.	P_6 x P_9	6.00	0.95	-0.08	1.82	0.58**	-0.001	33.54	0.99	-2.49	37.38
45.	P_6 x P_{10}	6.17	0.98	0.08	2.31	0.54**	-0.001	41.56	0.85*	-1.70	43.52
46.	P_7	5.17	1.44**	-0.03	1.89	0.58**	-0.002	30.45	0.65**	-2.68	24.36
47.	P_7 x P_8	5.25	1.09*	-0.15	2.16	1.26**	0.002	29.03	0.94	-1.43	29.06
48.	P_7 x P_9	5.58	0.89	-0.12	2.08	1.39**	0.001	31.69	1.09	-1.76	29.56
49.	P_7 x P_{10}	5.67	1.45**	-0.12	2.18	1.53**	-0.001	36.86	1.29**	-1.85	42.20
50.	P_8	5.75	1.29**	-0.05	1.85	0.48**	-0.001	29.18	0.72**	-2.59	25.07
51.	P_8 x P_9	6.17	0.96	-0.12	2.28	1.54**	0.001	33.21	1.15**	-2.43	35.53
52.	P_8 x P_{10}	6.50	1.07	-0.09	2.29	1.42**	0.002	39.34	1.26**	3.74	40.95
53.	P_9	5.67	0.57*	0.26	1.91	0.39**	-0.001	29.12	0.68**	-1.25	23.72
54.	P_9 x P_{10}	5.67	1.28*	0.02	2.41	1.56**	0.009**	39.95	0.92	-0.14	45.89
55.	P_{10}	5.42	1.16	0.03	1.89	0.59**	-0.001	28.58	0.83**	-2.87	31.49
56.	C_1	5.50	1.09	-0.04	2.15	2.11**	0.019**	37.39	1.46**	0.04	38.32
57.	C_2	6.25	1.25*	-0.02	2.17	2.15**	0.014**	33.84	1.41*	4.19	40.20
	Mean	5.75		NS	2.06			34.23		NS	35.20
	S.Em.(±)	0.40			0.04			1.70			1.39
	CD at 5%	1.13			0.10			4.72			3.85

*, ** : Significant at 5 % and 1% level of significance, respectively.

The average interval between days to anthesis and silking varied from 4.92(P_5) to 6.50 (P_8 x P_{10}) (Table-2). Lower ASI than the grand mean associated with unit regression coefficient was observed in P_1, P_4, P_5 and P_{10} parents, P_1 x P_2, P_1 x P_5, P_1 x P_6, P_1 x P_7, P_1 x P_9, P_1 x P_{10}, P_2 x P_9, P_2 x P_{10}, P_3 x P_5, P_4 x P_9, P_5 x P_6, P_5 x P_7, P_5 x P_{10}, P_7 x P_9 and PEH-2 crosses. Of these, the crosses P_1 x P_2, P_1 x P_5, P_1 x P_6, P_1 x P_{10}, P_2 x P_{10}, P_5 x P_6 and P_9 x P_{10} were comparatively higher yielder, whereas PEH-2 was the average yielder. Therefore, these crosses were identified as stable genotypes over environments for ASI along with high/average yielding capacity. Similarly, less ASI with regression coefficient significantly lower than unity was found in P_2, P_3, and P_9 parents, P_1 x P_4, P_2 x P_3 and P_2 x P_8 crosses. Of these, only P_1 x P_4 was average yielder, therefore, this cross would be suitable under unfavourable environments for having reduced ASI. Furthermore, the parents P_2, P_3 and P_9 may be utilized to develop high yielding crosses with lower ASI under moisture stress condition.

The average tassel condensation ranged between 1.7 (P_4 x P_7) to 2.49 (P_1 x P_{10}). Higher tassel condensation associated with unit regression coefficient and non-significant deviation was exhibited only by two crosses, viz., P_1 x P_4 and P_3 x P_8. Of these two crosses, P_1 x P_4 was average yielder, therefore, it was identified as average stable genotype for TC associated with average yielding ability. In the same way, the crosses P_1 x P_5, P_3 x P_7 and P_1 x P_{10} exhibited condensed tassel clubbed with significantly lower regression coefficient than unity and non-significant deviation. Out of these, P_1 x P_5 and P_6 x P_{10} were the high yielding crosses, therefore, these crosses could be suitable under moisture stress condition.

The trait TVI varied between 26.80 (P_4 X P_9) to 46.25 (P_1 x P_2). The lesser TVI than grand mean accompanied with unit regression coefficient was observed in P_3, P_1 x P_3, P_1 xP_7, P_1 x P_8, P_2 x P_6, P_3 x P_7, P_3 x P_8, P_3 x P_9, P_4 x P_6, P_4 x P_7, P_4 x P_8, P_4 x P_9, P_5 x P_7, P_6 x P_7, P_6 x P_8, P_6 x P_9, P_7 x P_8 and P_7 x P_9. Of these, the crosses P_1 x P_3, P_4 x P_7, P_4 x P_8, P_5 x P_7, P_6 x P_8 and P_6 x P_9 were the average yielder. Therefore, these crosses were recognized as stable genotypes for lower TVI along with average yield over the environments. However, the parents P_1, P_2, P_4, P_5, P_6, P_8, P_9, and P_{10}, and cross P_4 x P_5 were having the lower TVI value associated with regression coefficient significantly lower than unity. The cross P_4 x P_5 was also good yielder, therefore, it may be useful under unfavourable environment.

The cross P_1 x P_4 among the average yielder genotypes was found to be better cross with less ASI under unfavourable environments and average stability for TC and TVI. However, P_1 x P_5 and P_5 x P_{10} being high yielder with condensed tassel under stress environments also exhibited less interval between silking and anthesis. The parents (P_1, P_5 and P_{10}) involved in these two crosses were the good general combiners for yield and ASI which indicated the preponderance of additive type of gene action and could be utilized for further breeding programme. Keeping in view the importance of ASI than TC and TVI, the crosses, P_1 x P_2, P_1 x P_6, P_1 x P_{10}, P_2 x P_{10}, P_4 x P_5, P_5 x P_6 and P_5 x P_7 were identified as better crosses for ASI with high average grain yield.

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