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Flowering Syndrome-Hybrid Performance Relationship in Maize 1-Agromonic Traits

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Abstract: To determine the relationship between flowering syndrome and hybrid performance in some maize (*Zea mays L.*) crosses, selection on early and late flowering plants was undertaken. Selection was applied on plants of four inbreds; Zm19, Zm32, Zm51, and Zm61. Selected plants were propagated in the next season, grown in the third season and crossed to two testers (Zm21 late, and Zm60 early). The F1 seeds were planted in the fourth season in a randomized complete block design of three replicates in 83'000 plants/ha. This was done in the farm of the College of Agric., Univ. of Baghdad. The results showed that selection for divergent flowering of inbred gave significant difference in days to silking among all crosses. The days ranged between 62 d for early selects, to 66 d for late selects. This was reflected on time of seed filling that increased grain yield. The best crosses gave plant growth rate of 18.3 – 21.6 $g.m^{-2}.d^{-1}$, seed growth rate of 3.2 – 3.5 $g.plant^{-1}.d^{-1}$, and seed filling of 35 – 38 d. The cross that gave highest response of selection (61 x 21) gave 1.79 $kg.m^{-2}$ dry matter for early select, and 2.20 $kg.m^{-2}$ for late flowering select cross. It was recommended to select on maize inbreds to create new variations for better traits provided using large inbred populations.

Keywords: ASI, CGR, Early and Late Silking, SGR, TDM

1. Introduction

The flowering time is pertained to the transition of plants from vegetative to reproductive stage as controlled by genetic and growth variables [1]. The flowering syndrome has an important role to control plant grain yield. That is related to optimum time for flowering, fertilization, and seed filling, which is finally reflected on grain yield [2]. The flowering syndrome is controlled by several genes beside the growth factors [2, 3]. When plants flower early in the season, they will have better chance to lengthen time of seed filling, then seeds are expected to have heavier weight [4]. Genes controlling flowering act in different pathways; response to darkness, response to gibberellins, and to internal plant responses to vernalization and flowering [2, 5]. One of the most used models of flowering is the ABC model [6], this model is true for many plants genera including maize (*Zea mays L.*) [7].

One of the most important phenomena in plants is the hybrid vigour, which is not clearly understood. Researchers have reported that some mechanisms supposed to be related to hybrid vigour, such as, codominance, coepistasis, and semiepistasis of some genes of complementary action on same chromosome or on two different chromosomes [8, 9, 10, 11]. In general, hybrid vigour depends on magnitude of genetic divergence of two or more inbreds [12]. The late molecular discoveries on hybrid vigour are considered as a beginning [13, 14]. Some late results explained genomic interactions of crossed parents lead to a new gene programming has better effect on growth and stress tolerance [15]. However, the role of epigenetics in hybrid vigour looks so important. Thus because of the DNA methylation and siRNA role in plant processes related to heterosis [16, 17, 18, 19]. So, hybrid vigour could be under control of genetic, epigenetic, proteomic, and metabolomics processes [13, 14, 20]. The objective of this research was to shed some light on the role of flowering syndrome in the same inbred population (early vs. late flowering) in hybrid performance of crosses of those diverged selects in maize.

2. Materials and Methods

This work included four planting seasons (spring and fall) in 2014 and 2015. Four maize inbreds (Zm19, Zm32, Zm51, and Zm61) were planted in a population of about 2000 plants each. Early and late silking plants were selected (10-12 plants selects of each inbred). The intervals between early and late plants ranged between 12-15 d. The seeds were planted in the next season for propagation by selfing. In the third season, selected seeds of eight groups were grown and crossed by two testers; Zm21 (late) and Zm60 (early). The sixteen F1's were planted in the fourth season in a randomized complete block design of three replicates. Each plot consisted of six rows of 83 thousands plants/ha. This was applied on the farm of the Dept. of Filed Crops Sci, College of Agric., Univ. of Baghdad. The soil of experiment was fertilized with 200 kg/ha of each of P, N and K. The sources used were triple superphosphate, urea and potassium sulfate. Irrigation and weeding were done as needed. Diazinon was used against *Sesamia cretica*, once when plants of 4-5 leaves and again after two weeks. Data were recorded on 10 guarded plants in each plot. At the maturity, the 10 plants sample were cut from the soil surface level. The ears were taken for air dry, while leaves and stems were cut into 2.5-5 cm and dried in oven at 108 C° for eight h. Data of traits shown in tables were tabulated and analyzed statistically.

3. Results and Discussion

Days to 90% tasseling, silking, and ASI:

Days from planting to silking could be related to time of seed filling that could be reflected on plant grain yield. That period gives the plant a better chance to vegetative growth with wider leaf area that could be a better source for metabolites necessary for seed filling. Synchronization of silking and tasseling is important for better fertilization. Buckler et al. [21] reported that days of tasseling are counted from planting to 50% tasseling. Synchrony of tasseling and silking gives higher number of kernels per ear. Table 1 shows that early selects crosses gave shorter period to tasseling and silking.

Table 1. *Days to 90% tasseling, silking, and ASI of early and late selects crosses of maize.*

Crosses	Selected populations					
	Early	Late	Early	Late	Early	Late
	90% Tasseling		90% Silking		ASI	
19x21	60.0	63.0	63.0	67.3	3.0	4.3
32x21	61.0	64.0	64.0	69.0	3.0	5.0
51x21	59.0	62.0	63.3	66.7	4.3	4.7
61x21	59.0	62.0	62.0	66.7	3.0	4.7
19x60	60.0	64.0	63.3	67.7	3.3	3.7
32x60	61.0	64.0	63.7	68.0	2.7	4.0
51x60	61.0	63.0	63.7	68.0	2.7	5.0
61x60	60.0	62.0	62.7	66.0	2.7	4.0
lsd						
5%	3.9		3.1		1.6	
10%	3.2		2.6		1.4	

In general, most crosses of early selects gave a 3 d for tasseling and 4 d for silking earlier than late selects crosses using both testers (Zm21 and Zm60). However, the crosses 51x60 and 61x60 gave a 2 d difference, while the cross 1960 gave a 4 d difference between early and late selects. Meanwhile, the crosses 51x60 and 61x60 showed wider differences between early and late in silking. At the same time, the cross 32x21 gave a significant difference in ASI, since it gave 3 and 5 d for early and late select crosses, respectively. As it was shown from data (Table 1), the period of ASI for crosses of early and late selects gave reasonable values to have good pollination and fertilization, although the values between early and late could not be significantly different. If tasseling and silking were early, and had a good synchrony, grain yield is expected to be better [1].

Days to 90% physiologic maturity and seed filling:

When kernel reaches physiologic maturity, it gains its final dry weight and it needs just to lose the surplus moisture. This in general gives the kernel its normal color, dent, and appearance of black layer at the end of the embryo [22]. As time from planting to physiologic maturity lengthens, the kernel could have better time for better filling. In genotypes of good system capacity constant, metabolites necessary for seed filling will be more available to the seed [23]. Table 2 shows that some crosses were significantly different in days to maturity, others did not significantly differed, while one cross (51x21) had 4 days difference between crosses of early and late selects.

Table 2. *Days to 90% physiologic maturity and seed filling for crosses of early and late selects of maize.*

Crosses	Selected populations			
	Early	Late	Early	Late
	90% Phys. maturity		Seed filling	
19x21	101	103	38	35
32x21	104	105	40	36
51x21	101	105	38	38
61x21	102	102	40	35
19x60	100	102	37	34
32x60	101	103	38	35
51x60	102	104	38	36
61x60	100	100	37	34
lsd				
5%	2.8		2	
10%	2.3		2	

Meanwhile, the cross 6160 gave the same days for maturity for early and late. In general, using late tester (Zm21) or early tested (Zm60) did not show any remarkable difference in days to physiologic maturity.

Days of seed filling for early and late select crosses were significantly different. The differences of early and late select crosses ranged between 2-5 d. This shows that early selects were better in days to seed filling. That gives the seed longer time to accumulate more carbohydrates in the kernel, leading to higher kernel weight, and probably higher grain yield. Tollenaar et al. [24] reported that grain yield of maize hybrids could be increased up to 0.37 t/ha for every extra day in seed filling. However, this statement is not necessarily to be universal because of hybrid differences in system capacity constant that is highly related to harvest index and hybrid grain yield.

Leaf area index (LAI) and plant height:

Leaves are the main factory of photosynthesis in plants. Early full leaf area in plants gives better chance to the plant to support flowering and yield. In general, grain yield of plants is related to the optimum leaf area in maize genotype population. Leaf area and LAI are related to grain yield and system capacity constant that gives different plant performances [25, 26], and thus, genotypes are different in grain yield performance [8]. Table 3 shows that some crosses had significant differences in LAI between early and late select crosses such as; 32x21 and 32x60.

Table 3. *Leaf area index (LAI) and plant height (cm) of crosses of early and late selects of maize.*

Crosses	Selected populations			
	Early	Late	Early	Late
	LAI		Height	
19x21	3.13	3.42	113	115
32x21	4.60	5.20	152	154
51x21	4.31	4.42	140	139
61x21	4.13	3.85	138	141
19x60	3.65	3.73	121	129
32x60	4.44	4.83	137	145
51x60	4.13	4.23	132	135
61x60	3.81	3.90	131	145
lsd				
5%	0.41		15	
10%	0.34		12	

Other crosses were not significantly different. Late select crosses gave higher LAI than early. On the other hand, when early select of inbred Zm19 crossed with late tester (Zm21) it gave higher LAI when crossed to the early tester (Zm 60), that is to say: cross 19x21 gave 3.13 and 3.42 (with tester Zm21), while it gave 3.65 and 3.73 (LAI) (with tester Zm60), for early and late select, respectively. On the opposite response, the cross of early and late select of Zm32 showed a trend to give higher value of LAI when late tester (Zm21) was used. This could be attributed to combining ability with Zm21 and Zm60 rather than earliness.

Plant height in maize plants is determined by the appearance of tassels. Plant height is genetically controlled, but growth factors have a remarkable role [27]. Plant height is proportional to seasonal growth length, but if early genotype plants grow faster they could have tall plants. Table 3 shows that early and late select crosses were not significantly different in plant height at 5% probability level, but the cross 6160 showed a significant difference at 10% probability level between early and late select crosses. At the same time, late (Zm21) and early (Zm60) testers did not show significant differences in plant height. This implies that plant height is not necessarily to be correlated to other plant traits.

Crop and seed growth rate:

Total dry matter (vegetative and grains) depends on growth rate and days of growing season. Seed growth rate and days of seed filling result the final seed weight. However, some researchers [28] reported higher grain yield of short season maize hybrids due to high plant growth rate. Crop and seed growth rate depends on genetic and environmental interactions. Data of table 4 shows that all of crosses of early and late selects gave similar crop growth rates except in the case of the cross 61x21 that its late select cross out-yielded the early select cross, they gave 21.55 and 17.59 $g.m^{-2}.d^{-1}$, respectively.

This could be due to late silking of this select cross (66.70 d) compared to 62.0 d of early select cross (Table 1).

However, crosses of early and late selects did not show significant differences in crop growth rates when crossed to early or late tester except the cross 61x21. On the other side, seed growth rate of early and late select crosses did not show significant differences except in the cross 61x21 that its late select cross gave 3.7 $g.plant^{-1}.d^{-1}$ as compared to the early select cross which gave 3.0 $g.plant^{-1}.d^{-1}$. So, the higher crop growth rate of this cross lead to increase the seed growth rate.

Table 4. *Crop growth rate ($g.m^{-2}.d^{-1}$) and kernel growth rate (g/plant/d) of early and late selects crosses of maize.*

Crosses	Selected populations			
	Early	Late	Early	Late
	CGR $g/m^2/d$		SGR g/plant/d	
19x21	12.37	13.94	2.1	1.9
32x21	15.26	15.83	2.3	2.4
51x21	19.48	19.12	3.2	3.1
61x21	17.59	21.55	3.0	3.7
19x60	18.30	16.94	3.4	2.9
32x60	18.28	17.31	3.3	3.2
51x60	18.71	17.05	3.1	3.1
61x60	18.92	18.44	3.3	3.5
lsd				
5%	3.18		0.7	
10%	2.65		0.6	

Dry matter and harvest index:

Total dry matter of plants (vegetative and grains), and dry matter (vegetative) are due to genetic make-up of the hybrid besides the effects of environmental variables, and their interactions [25, 29, 30, 31]. Harvest index represents the ratio of grain to total dry matter of the plant sample. In general, higher values of harvest index lead to higher grain yield. Data of Table 5 reveals that all crosses showed similar values in total dry matter of plants, except for the cross 61x21 that its late select cross out-yielded the early counterpart. That could be due to what was reported previously in late silking discussion.

When crosses are similar in total dry matter, they still could be different in grain yield due to efficiency of hybrid plant to convert metabolites into grain, i.e higher harvest index. At the same time, we can see that the cross 61x21 and another cross (19x21) were significantly different in dry matter.

Table 5. *Total dry matter (kg.m^{-2}), dry matter (kg.m^{-2}) and harvest index of crosses of early and late selects of maize.*

Crosses	Selected populations					
	Early	Late	Early	Late	Early	Late
	Total dry matter		Dry matter		Harvest index	
19x21	1.25	1.43	0.59	0.87	0.53	0.39
32x21	1.58	1.66	0.81	0.92	0.49	0.45
51x21	1.97	1.99	0.95	1.00	0.51	0.49
61x21	1.79	2.20	0.80	1.11	0.55	0.48
19x60	1.86	1.73	0.81	0.91	0.56	0.47
32x60	1.85	1.79	0.82	0.87	0.56	0.51
51x60	1.91	1.77	0.90	0.84	0.53	0.53
61x60	1.89	1.85	0.87	0.85	0.54	0.54
lsd						
5%	0.31		0.21		0.08	
10%	0.26		0.18		0.06	

Both crosses gave heavier dry matter of late select cross against early select cross. Values of harvest indexes of the last two crosses were significantly different, along with another cross (19x60). These three crosses gave lower harvest indices of late select crosses. That could be attributed to the early flowering of the plants of these crosses. Finally, plants selected from earliness in inbred populations have a good chance for a new variation lead to better yield in maize hybrids.

Abbreviations

ASI- Anthesis Silking Intervals; CGR- Crop Growth Rate; LAI- Leaf Area Index; siRNA- small intervening RNA; SGR- Seed Growth Rate; TDM- Total Dry Matters.

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