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Heterosis Expression for Agronomic Features of Sunflower

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Abstract

Sunflower is an important oil seed crop of world, which is predominately cultivated by hybrid seed. Sunflower breeders continue attempt new cross combinations to develop hybrids with higher manifestation of heterosis. Therefore, present study was conducted with the aim to develop highly heterotic hybrids. The manifestation of heterosis was studied in various phenological and agronomic traits of sunflower. There were 24 single cross hybrids produced by crossing among cytoplasmic male sterile and restorer lines in 2018. Developed crosses were evaluated in 2019 in randomized block design at Karaj, Iran. There was considerable heterosis in desired direction for phenological and agronomic traits which indicated that highly heterotic crosses may be selected to expand yield potential in Iran. Two hybrids R29 × A212 and R19 × A212 with higher seed and oil yield and positive heterosis for these two characteristics were identified as superior hybrids. The results indicated that association of optimum alleles related to flowering time may result in development of early maturing hybrids than related parents. Moreover, heterozgosity may mask recessive alleles, therefore, specific combining ability of parents may be more important than per se performance of inbred parents.The role of maternal effects should be taken into account in breeding of a trait and higher heterosis alone cannot be a reason for the superiority of a hybrid for a particular trait, and ultimate expression of a given feature is more important.

Key words: Hybrid vigour, Inbred line, Line × Tester

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Introduction

Development of single cross hybrids with high heterotic effects has been the prime goal of sunflower. Hybrid cultivars were superior in their performance and uniform when compared with open-pollinated cultivars (Seiler & Jan, 2010). Due to cross-pollination, genetic architecture of sunflower alleles is retained as heterozygous and therefore, hybrids may retain higher vigor, heterosis, and seed yield (Vear, 2010). Heterosis or hybrid vigor is the superiority of the progeny in plant characteristics as growth rate, size, height or yield of a hybrid over those of its parents and expressed as mid-parent or better parent heterosis (Fehr, 1987). There are two theories about heterosis appearance as an additive and non-additive model. In the additive model, the expression of heterosis is due to combination of favorite dominant alleles and in the non-additive model due to the over dominance and epistatic effects (Hallauer & Pandey, 2006).

The existence of heterosis for most traits of sunflower favor the production of hybrid varieties as one of the most effective methods for improvement of yield in this crop (Virupakshappa & Ranganatha, 1999). Hybrid varieties have yield advantage of about 25% (Fernandez-Martinez et al., 2009). Presence of heterosis in sunflower reported first time in 1944 for plant height, head diameter, seed size and seed yield (Fick & Miller, 1987). Different methods as principle component analysis have been used to reveal any structure among agronomic characteristics and combining abilities, which are related to the expression of heterosis (Ghaffari & Farrokhi, 2008). Although oil content of sunflower has been improved by selection method (Fick and Miller, 1997) however there are reports indicated to the expression of positive (Jan &Hassan, 2005; Haq et al., 2006) however or negative heterosis for oil content (Kaya, 2005). Positive heterosis has been reported for seed weight, head diameter and seed yield (Goksoy et al., 2002), oil contents, seed number per head (Gill and Sharon, 2002; Khan et al., 2004), plant height, Kaya (2005) observed considerable heterosis for seed and oil yield of sunflower. Haq et al. (2006) reported different results for seed weight. They observed positive heterosis for plant height while Goksoy et al. (2002) reported negative heterosis for plant height. Khan et al. (2008) reported negative while Seetharam et al. (1980) positive heterosis for days to flowering time. Jan & Hassan (2005) observed positive heterosis for head diameter, seed number, seed weight, oil content and seed yield. Gvozdenovicet al. (2009) reporting significant heterosis for plant height, head diameter, seed weight and seed yield indicated that there is no correlation between heterosis and genetic distance. Encheva et al. (2015) reported positive heterosis for plant height, head diameter and seed yield. Awaad et al. (2016) also reported positive heterosis for seed and oil yield of sunflower crosses. The objective of this study was evaluation of heterosis expression for different agronomic characteristics in Iranian sunflower hybrids which were produced recently.

Materials and Methods

In this study, 24 single cross hybrids were produced through crossing between eight CMS and three fertility restores inbred lines in line × Tester fashion in 2018 in Karaj. In order to estimate heterosis expression, the obtained hybrids along with 10 parents were evaluated for agronomic characteristics in 2019. The experiment conducted as a randomized block design with three replications in Karaj, Iran. Each plot consisted of three rows 5 meter in length, with row spacing of 60 and between seedlings distances of 25 cm. Broadleaved weeds were controlled through pre-emergent herbicide trifluoralin (2.5 litershectare^{-1}).One third of nitrogen fertilizer with phosphate and potassium fertilizers based on 250 kg hectare^{-1} of urea, 150 kg hectare^{-1} of ammonium phosphate and 200 kg hectare^{-1} of potassium sulfate were used before planting, and the rest of the nitrogen fertilizer was used at 2-4 weeks after germination and before onset of reproductive phase.

All traits were recorded at various growth phases. Days to flowering was noted at the time of anthesis. Capitula were harvested and dried. Seed was threshed and cleaned and stored at room temperature for further analysis. Traits such seed yield per head was determined on digital balance, 100-seed weight (g) were determined by counting seed and weighing over analytical balance. Oil contents were determined on Soxhlet apparatus. Number of seeds per head were counted through seed counter. Data were analyzed using Line × Tester method and mean of genotypes were compared using least significant differences (LSD) criterion. The heterosis percentage was compared to the mid-parents and best parent, using the following relationships:

$$\%HBP = \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100 \qquad \%HMP = \frac{\overline{F1} - \overline{MP}}{\overline{MP}} \times 100$$

In which: HMP was amount of heterosis compared to the mid-parents, HBP: heterosis compared to the better parent, F1: average of the related hybrid, MP: average of both parents and BP average of better parent. Standard error (SE) values to test of significance of heterosis were calculated based on the following equations (Wynne et al., 1970). Statistical analysis was performed using SPSS (Version 24) and drawing charts using Microsoft Excel software. $SE = \sqrt{\frac{3}{8} MSe}$

Results and Discussion

There were significant differences among genotypes for all measured traits except for oil content (Table 1). Results showed significant variability among studied lines and hybrids with superior oil contents. There was a significant difference between hybrids in terms of growth period, plant height, stem diameter, 1000 seed weight and seed number per head. These traits are correlated with yield per head and oil contents and thus these traits explained the yield differences among hybrids. Separation of hybrids into related components showed that the characteristics such as growth duration, plant height and seed and oil yield, has significant variance for the line or tester, which suggested that additive gene action plays a major role in controlling of these characteristics. There was significant line × tester interaction for 1000 seed weight and number of seeds per head which indicated of presence of both additive and non-additive gene action in controlling of these traits.

Polygenic traits are significantly affected by genotype, environment and genotype × environment. Therefore, contrasting reports are available regarding genetic control of sunflower characteristics; however, the role of additive effects in controlling of the characteristics related to sunflower phenology is obvious. Additive and non-additive gene action has been reported for plant height, stem and head diameter, seed weight and seed yield (Ghaffari et al., 2011, Ghaffari, 2016).

Hybrid vs parental contrast was significant for all traits except growth duration and oil percentage, indicating a significant heterosis for these traits. The average of parental lines is compared with hybrids in Figure 1. The parental lines had significant difference with hybrids in terms of plant height, 1000-seeds weight, seed number per head, and seed and oil yield. Hybrids had two days early flowering than parental lines however, no significant difference was observed in term of days to maturity. This indicated higher heritability of phenological related traits. Early maturing hybrids can be obtained by selection and hybridizing of early maturing lines. Higher heritability of flowering and maturity times has been reported by Sudrik et al. (2014).

Plant height significantly increased to 28% in the hybrids. Traits such as plant height, head diameter, number of seeds per head, were more affected by inbreeding depression more than other characteristics. Inbreeding depression induced growth retardation with the progress in inbreeding depression in advanced generations for plant height and head diameter, resulting in a decrease in the number of seeds per head and weight of seeds. Mean values of all traits within parents and hybrids have been shown in Figures 1 and 2.

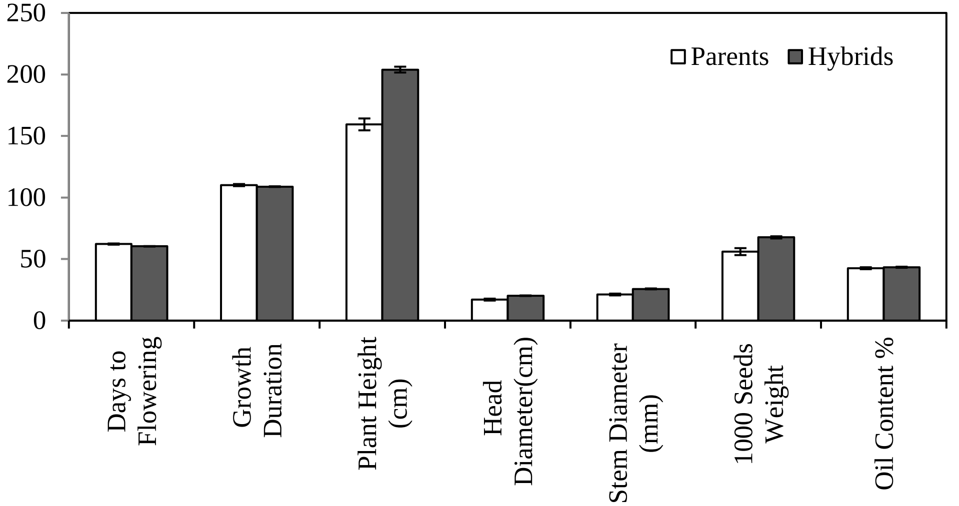

Figure 1. Mean comparison of parental lines with hybrids for agronomic traits such as days to flowering, growth

The average of measured traits in lines and hybrids are compared in Table 2. The earliest flowering was observed in line A110 (59 days) while the later in the lines A212 and A330 (66 days). The inbred lines completed their growth period in 101-115 days. The line A212 was the earliest and completed growth in101 days. The lines A40 (194 cm) and R29 (112 cm) had the highest and lowest plant height respectively. The largest stem diameter (25 mm) and head diameter (22 cm) was observed in A40.Some researchers have pointed the positive correlation of head diameter with seed and oil yields (Hladni et al., 2008; Arshad et al., 2007). The highest 1000-seeds weight was observed in A346 line (73 g) and the highest number of seeds per head was found in line A222 (832 seeds). The highest grain and oil yields were 2127 and 959 kgha^{-1} respectively in line A222. The hybrids completed the growth period within 106 to 113 days, latest matured one was R19 × A40 (113 days) and the early maturing combinations were R46 × A212 and R29 × A346 (106 days). The hybrid R29 × A330 (225 cm) and R46 × A110 (169 cm) had the highest and lowest plant height respectively. Early maturity is considered as an important goal in sunflowers breeding (Hladni et al., 2008 and Skoric, 2012).Higher temperature and drought negatively affect seed yield of late-maturity sunflower hybrids however, hybrids with a shorter growing season go through this critical phase earlier and faster, so their yields are less affected by drought conditions (Cvejic et al. 2019).The highest stem diameter was observed in R29 × A28 (29 mm) and the lowest in R29×A222 (22 mm). Sunflower stems have acrucial role in grain filling in the post-pollination stages and, increased stem diameter induced lodging resistance. The highest 1000-seeds weight was seen in R29 × A330 (82 g), which was a relatively late maturing hybrid. The highest seed yield was observed in

R29 × A40 and R29 × A346 hybrids (5159 kg ha^{-1}), but the later had the highest oil yield (2292 $kgha^{-1}$), due to its higher oil content.

Conclusion

Results showed that there was considerable heterosis for most of phenological, morphological and agronomical characteristics of sunflower in studied crosses. Results indicated the possibility for improving of these traits when various cross combination were attempted. Most of hybrids showed negative heterosis for oil content and due to the presence of positive heterosis in some crosses. However, some crossing deviated from general trend, thus choosing the suitable parent has crucial role in improvement of this trait. Two hybrids R29 × A212 and R19 × A212 with higher seed and oil yield and positive heterosis for these two characteristics are identified as superior hybrids. The results indicated that association of optimum alleles related to flowering time in relevant hybrids could result in production of hybrids which have early flowering than related parents. It is concluded that the recessive alleles in one of the parents can be masked by choosing of appropriate other parent. The role of maternal effects should be taken into account in breeding of a trait and higher heterosis alone cannot be a reason for the superiority of a hybrid for a particular trait.

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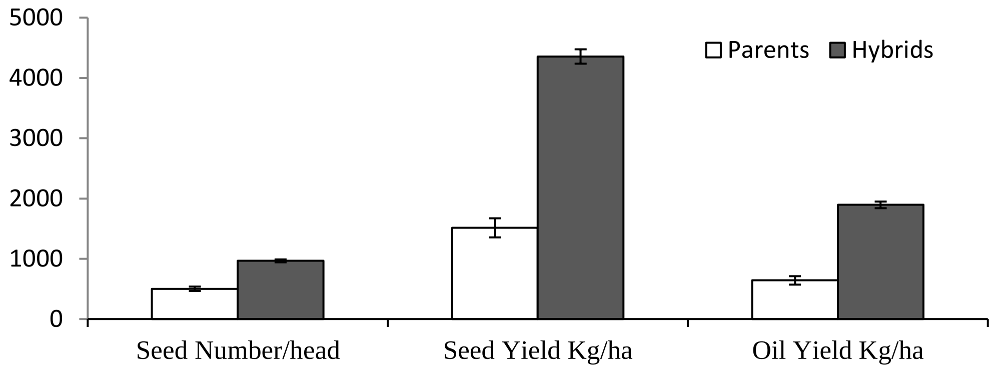

Figure 2. Mean comparison of parental lines with hybrids for agronomic traits such as seed number head-1, seed yield kg ha-1, oil yield kg ha-1.

Table 1. Analysis of variance for agronomic traits of sunflower using Line× Tester method

Replication	D.F.	Days to Flowering	Growth Duration	Plant Height	Stem Diameter	Head Diameter
Genotype	2	4.9^{ns}	17.2*	5725.9**	43.4**	55.7**
Parents	33	8.0**	23.7**	2214.4**	26.2**	24.2**
Hybrid	10	15.4**	56.0**	1956.0**	27.2**	56.4**
Line	23	1.7 ^{ns}	9.1**	472.2**	8.6*	2.5 ^{ns}
Tester	7	1.3 ^{ns}	18.9**	1037.7**	8.3 ^{ns}	3.5 ^{ns}
Line ×Tester	2	2.7 ^{ns}	6.2 ^{ns}	754.1**	13.3 ^{ns}	1.7 ^{ns}
Parents vs Hybrid	14	1.8 ^{ns}	4.7 ^{ns}	149.1 ^{ns}	8.1 ^{ns}	2.1^{ns}
Error	1	77.5**	35.1 ^{ns}	44845.6**	421.7**	199.9**
C.V.	68	2.7	4.9	157.7	4.4	3.1

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ns = non significant ($P \geq 0.05$); * = significant ($P \leq 0.05$) and ** highly significant ($P \leq 0.01$)

Table 2. Mean of hybrids and parental lines for agronomic traits

Hybrid/Line	days to Flowering	Days to Maturity	Plant Height (cm)	Head Diameter	Stem Diameter	1000 Seeds Weight (g)	Seed Number/Head	Oil Content (%)	Seed Yield (Kg/ha)	Oil Yield (Kg/ha)
A28×R19	59.7	111.3	207.6	22.3	28.8	65.7	949.7	41.0	4126.9	1691.6
A40×R19	60.3	113.3	214.7	21.3	28.7	70.0	971.5	43.8	4550.2	1993.1
A110×R19	59.3	108.7	181.8	21.0	25.7	65.1	569.6	42.9	2379.1	1021.5
A212×R19	59.7	109.3	204.1	20.4	26.1	65.3	1022.0	46.3	4444.4	2056.9
A222×R19	60.3	107.0	201.7	20.1	25.6	66.7	975.5	43.0	4365.0	1878.0
A330×R19	59.3	109.3	204.7	19.7	26.1	65.7	921.5	42.2	4049.5	1706.8
A344×R19	61.7	108.7	208.9	19.5	24.1	64.8	818.3	41.7	3571.4	1488.0
A346×R19	59.7	108.0	214.9	19.6	26.5	66.5	1164.6	44.2	5142.8	2273.5
A28×R29	60.7	109.0	212.7	19.7	24.8	70.2	892.6	42.1	4206.3	1769.6
A40×R29	60.7	111.0	214.3	21.8	28.0	74.7	1039.5	42.6	5158.7	2195.9
A110×R29	60.7	109.3	187.7	19.7	23.8	64.8	1037.1	46.8	4523.8	2115.3
A212×R29	62.0	107.7	212.8	19.0	24.6	67.7	969.7	44.3	4457.6	1976.4
R29	59.7	108.3	189.1	18.9	22.4	67.3	809.3	44.7	3677.2	1643.7
A330×R29	61.0	109.3	224.8	21.1	27.3	81.8	885.4	38.7	4775.1	1846.2
A344×R29	60.0	107.0	215.8	19.2	23.9	61.7	807.5	39.7	3333.3	1324.4
A346×R29	59.7	106.3	215.6	19.7	24.9	65.4	1183.6	44.4	5158.7	2292.0
A28×R46	59.7	109.3	195.7	19.0	23.0	64.6	1015.8	47.2	4365.0	2060.6
A40×R46	60.3	109.7	206.9	22.0	26.1	71.5	1056.8	43.2	4984.1	2154.4
A110×R46	60.3	107.7	168.8	22.1	26.4	62.9	1152.2	45.7	4841.2	2214.4
A212×R46	60.7	106.3	204.3	20.4	25.7	67.1	1097.0	45.7	4880.6	2229.1
A222×R46	59.7	109.3	206.5	20.6	27.0	69.1	1066.8	44.3	4888.8	2166.9
A330×R46	61.7	112.0	204.4	19.6	26.7	68.1	1051.3	44.5	4761.9	2118.7
A344×R46	61.0	108.0	195.9	19.9	25.9	65.9	731.5	40.8	3174.6	1293.8
A346×R46	61.0	107.0	201.3	19.6	26.6	71.1	989.9	41.5	4722.2	1957.8
A 28	62.0	112.7	191.4	19.9	22.5	70.7	347.8	39.1	1625.4	635.6
A 40	61.7	112.3	194.3	22.4	25.3	72.6	563.7	39.5	1703.7	673.0
A110	59.0	111.3	135.5	19.6	22.9	67.8	572.8	47.0	1554.2	730.1
A212	65.7	101.3	138.5	14.5	16.7	31.0	582.3	45.2	1224.8	553.3

Hybrid/Line	days to Flowering	Days to Maturity	Plant Height (cm)	Head Diameter (cm)	Stem Diameter (mm)	1000 Seeds Weight (g)	Seed Number/Head	Oil Content (%)	Seed Yield (Kg/ha)	Oil Yield (Kg/ha)
A222	60.7	109.0	164.6	21.2	22.5	58.1	832.2	45.1	2127.0	958.7
A330	65.7	111.3	188.7	19.5	23.9	56.6	666.1	42.0	1492.2	626.2
A344	59.3	106.3	162.7	18.2	21.8	46.9	566.2	36.3	1746.0	633.3
A346	63.0	105.0	161.7	16.1	22.1	73.3	441.2	41.7	2089.3	871.4
R 19	64.0	115.3	157.2	11.4	20.0	38.1	351.9	44.5	881.9	392.3
R 29	62.7	111.7	112.3	8.2	13.0	34.1	227.5	43.0	514.4	221.1
R 46	60.7	115.0	147.0	16.9	22.8	67.7	374.9	45.1	1689.9	762.5
LSD 5%	2.70	3.63	20.45	3.31	4.01	10.63	249.62	6.10	1285.39	558.76
LSD 1%	3.59	4.82	27.16	4.40	5.32	14.11	331.48	8.11	1706.97	742.02

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