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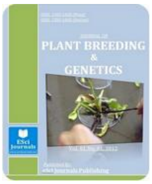

EVALUATION OF MAIZE (ZEA MAYS L.) HALF SIB RECURRENT FAMILIES FOR EXPECTED RESPONSE AND PERCENT GAIN PER CYCLE

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ABSTRACT

Recurrent Selection (RS) or reselection generation after generation is a vital selection scheme for improving the physio-morphic traits and grain yield in maize populations. The objective of the present research was to determine the response of recurrent selection in CIMMYT maize population CZP-132011 for physio-morphic traits and to estimate selection differential, heritability, expected response and percent gain $cycle^{-1}$ among the half sib recurrent families for morphological traits and grain yield. Sixty four half sib recurrent families were evaluated in 8×8 lattice square design with two replications at Cereal Crops Research Institute (CCRI), Pirsabak during 2017. Results showed highly significant differences among the half sib families for all the studied traits. Selection differential values were negative for days to tasseling (-3.00), anthesis (-3.08), silking (-3.10), anthesis silking interval (-1.14), plant height (-5.07) and ear height (-7.73). High heritability values ($h^2 > 0.60$) were recorded for all traits except plant height (0.55) which exhibited moderate heritability. Based on broad sense heritability and selection differential, expected response were observed negative for days to tasseling (-2.39), anthesis (-2.56), silking (-2.64), anthesis silking interval (-0.79), plant height (-2.81) and ear height (-5.22). After one cycle of recurrent selection using half sib families, the gain $cycle^{-1}$ values were negative for (-0.39), anthesis (-0.47), silking (-1.44), anthesis silking interval (-3.17), plant height (-2.34) and ear height (-4.90). Based on the findings of current research it could be concluded that recurrent selection method was found effective in improving the CIMMYT maize source population CZP-132011 for physio-morphic traits.

Keywords: Half sib families, recurrent selection, heritability, expected response, % gain $cycle^{-1}$.

INTRODUCTION

Maize (*Zea mays* L.) is an annual, short day crop with monecious flower and originated in Mexico. It is short duration crop, planted twice in a year i.e. spring and summer season, requiring high temperature and enough sunshine. Maize grows widely in tropical as well as in subtropical regions of the world. It is cross pollinated because of monecious nature of the plant. The maize plant is protandrous in which pollen shedding begins 1-2 days before silking and continues for several days (Ishaq *et al.*, 2014). Maize being multipurpose crop is used as food, fodder and feed. It is used in several industrial products like alcohol, starch, oil, polish and tinning material (Bekele and Rao, 2014).

Maize is one of the world's prominent cereal crop and ranks third next to wheat and rice while in Pakistan it ranks fourth after wheat cotton and rice. Maize is of high importance in a country like Pakistan where the rapidly growing population demands continued food supply. In Pakistan maize occupies about 4.8% of the total cropped area. Worldwide maize is cultivated over the area of 176.10 million hectares with a production of 875.12 million tons and with an average yield of 4.944 tons per hectares(FAO, 2017). In Pakistan area under maize cultivation was 1.20 million hectares with a production of 3.7 million tons and with a yield of 3.0 tons per hectare, while in KP the area under maize cultivation

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was 0.6 million hectares with a production of 0.10 million tons and with a yield of 0.16 tons per hectare (MINFAL, Govt. of Pakistan. 2017).

Maize have the highest yield potential, however, despite of high yield potential, there are numerous checks to its high yield production. One of these is the unavailability of improved OPV/hybrids linked with the high price of hybrid seed. Biotic agents (maize stem borer, leaf blight and stalk rot disease) and abiotic factors (drought/moisture stress) also play a role in limiting its potential yield. Maize international stock is dwindling and increases the demand for superior cultivars. Population improvement is one of the essential aspects in maize. There are several methods for maize improvement including: mass selection, ear to row selection, full sib family selection, half-sib family selection, recurrent selection and selfed progeny selection (Pixley *et al.*, 2006).

Half sib family selection is a type of recurrent selection used for intra population improvement that involves the evaluation of half sib families through half sib progeny (Kaleem *et al.*, 2013). Through half sib families the per se performance of population can be improved (Wright, 1980). Maize breeders often use recurrent selection based on half sib families. Recurrent selection increases the frequencies of desirable alleles and fixes it rapidly hence maintain genetic variability, while the homozygous deleterious alleles are exposed to selection and eliminated early from the population. (Sajjad *et al.*, 2018). Knowledge regarding heredity of key traits is necessary for the development of superior genotypes. The assessment of genetic component is essential for bringing genetic improvement in populations. Genetic improvement is based on the presence of genetic variability in a species (Sohail, Rahman, Khan*, et al.*, 2018). Enough genetic diversity provides opportunities for selection of promising genotypes and for hybridization. The selection differential is the difference between the base population mean and the mean of the selected individuals. It is actually the amount of gain attained by selection i.e. selection of phenotypically superior genotypes compared to base population from which it is selected (Ogunniyan and Olakojo, 2014). Half sib families have been used and proved effective for maize population improvement. Keeping in view the importance of recurrent selection using half sib families, this experiment was conducted with the objectives to determine the response of recurrent selection in maize population CZP-132011 for physio-morphic traits and to estimate selection differential, heritability, expected response as well as gain cycle^{-1} among the half sib recurrent families for physio-morphic traits and grain yield.

MATERIALS AND METHODS

The experiment was conducted at Cereal Crop Research Institute (CCRI) Pirsabak, Nowshera, Pakistan during the year 2017. Breeding material was consisted of a base population CZP-132011, originated in CIMMYT, Mexico and is an early maturing population. The experiment was conducted in two seasons, during the first season (spring) selected half sibs were planted in the ear to row. Selection in these families was done for desirable attributes. The selected families (Rows) were intermated through controlled hand pollination using bulk pollination method. During second season (summer) a set of selected families along with base population were planted in partial lattice design with two replications. Row length was 5m, row to row distance was 75cm and plant to plant distance was 25 cm. Based on visual observation, at least 15% selection pressure was followed at harvest as start new version of recurrent selection cycle. After complication of one cycle of recurrent selection in half sib family's data was noted on days to 50% tasseling, days to 50% anthesis, days to 50% silking, anthesis silking interval, plant height, ear height and grain yield.

Data recorded on each trait was subjected to analysis of variance (ANOVA) appropriate for 8×8 lattice square design as suggested by Miles *et al.* (1980) using Mstat-C statistical package (Freed *et al.*, 1991). Means of C_0, C_1, and selected HSF, selection differential, expected response and percent gain cycle^{-1} were estimated for physio-morphic traits and grain yield.

ANOVA format for a single cycle.

SOV	Df	MS	Expected MS
Replications (r)	r-1	-	-
Blocks (k)	k-1	-	-
Half sib families (HS)	HS-1	M_2	$\sigma^2 E + r\sigma^2 G$
Error	(k-1)(rk-k-1)	M_1	$\sigma^2 E$

Heritability (b.s) for each trait was calculated according to Allard (1960) as:

$$h^2 \text{ (b.s)} = \sigma^2 G / \sigma^2 P$$

Selection differential (S) was computed as:

$$S = \mu HS - \mu$$

Where

S = Selection differential of half sib families

μHS = mean of selected HS families

μ = population mean of HS families

Expected response (Re) was estimated using the following formula:

$$Re = S \times h^2$$

Percent gain cycle^{-1} was estimated using the following formula;

$$\text{Gain cycle} - 1\ (\%) = \frac{(\text{Cycle1} - \text{Cycle0})}{\text{Cycle0}} \times 100$$

RESULTS

Days to 50% tasselling: Mean squares showed a significant difference ($P \leq 0.01$) among the half sib families for days to 50% tasseling in C_1 (Table 1). Population means of C_0 and C_1 for days to 50% tasseling were 50.50 and 50.30 respectively, while the mean of selected half sib families of C_1 was 47.30. Selection differential for days to 50% tasseling was -3.00 (days). High heritability value (0.80) was noted for days to 50% tasseling. Based on the heritability and selection differential of the said trait the expected response was -2.40 (days). The gain cycle^{-1} for the said trait was -0.39% (Table 2).

Days to 50% anthesis: Mean squares revealed significant difference ($P \leq 0.01$) among the half sib families for days to 50% anthesis in C_1 (Table 1). The population mean of C_0 and C_1 for days to 50% anthesis were 53.00 and 52.75. While the mean of selected half sib families of C_1 was 49.68 (days). Selection differential for days to 50% anthesis was -3.08. High heritability value (0.82) was noted for days to 50% anthesis. Based on the heritability and selection differential of the mentioned trait, the expected response was -2.53 (days), and gain cycle^{-1} was -0.47% (Table 2).

Days to 50% silking: Analysis of variance showed significant differences ($P \leq 0.01$) among the half sib families for anthesis silking interval in C_1 (Table 1). Population means of C_0 and C_1 for anthesis silking interval were 54.75 and 53.96, while the mean of selected half sib families of C_1 was 50.86. Selection differential for anthesis silking interval was -3.10. High heritability value (0.85) was noted for days to 50% silking. Based on the heritability and selection differential of studied trait, the expected response was -2.62 and the gain cycle^{-1} was -1.44% (Table 2)

Anthesis silking interval (ASI): Mean squares showed a significant difference ($P \leq 0.01$) among half sib families for anthesis silking interval in C_1 (Table 1). Population means of C_0 and C_1 for anthesis silking interval was 1.25 and 1.21, respectively, while the mean of selected half sib families of C_1 was 0.08. Selection differential for anthesis silking interval was -1.14. High heritability value (0.75) was noted for anthesis silking interval. Based on the heritability and selection differential of the trait, the expected response was -0.85 and the gain cycle^{-1} was -3.17% (Table 2).

Ear height (cm): Mean squares exhibited significant differences ($P \leq 0.01$) among the half sib families for ear height in C_1 (Table 1). Population means of C_0 and C_1 for ear height were 165.00 cm and 161.13 cm respectively, while the mean of selected half sib families of C_1 was 156.06 cm. Selection differential for ear height was -5.07. Moderate heritability value (0.55) was noted for ear height. Based on the heritability and selection differential of trait, the expected response was -2.79 and gain cycle^{-1} was -2.34% (Table 2).

Grain yield (kg ha^{-1}): Mean squares revealed significant differences ($P \leq 0.01$) among the half sib families for grain yield in C_1 (Table 1). Population means of C_0 and C_1 for grain yield was 3182.50 kg ha^{-1} and 3315.14 kg ha^{-1}, while the mean of selected half sib families of C_1 was 3553.50 kg ha^{-1}. Selection differential for grain yield was 238.36. High heritability value (0.65) was noted for grain yield. Based on the heritability and selection differential of trait the expected response was 155.41. The gain cycle^{-1} for the mentioned trait was 4.17% (Table 2).

Table 1. Mean squares and coefficient of variation for the physio-morphic traits of half sib families.

Trait	Mean squares		
	Families (df=64)	Error (df=49)	Coefficient of variation (%)
Days to 50% tasseling	8.30**	0.93	1.92
Days to 50% anthesis	6.84**	0.66	1.54
Days to 50% silking	6.83**	0.57	1.40
Anthesis silking interval	1.17**	0.17	33.14
Plant height	23.46**	6.81	1.62
Ear height	39.83**	11.67	4.75
Grain yield	100630.25**	21196.52	4.39

** = highly significant at 1% probability level.

Table 2. Population mean (μ) of Co and C1, mean of selected half sib families (μHS), heritability (h2), selection differential (S), Expected response (Re) and percent gain per cycle for various traits in half sib families.

Parameters	μ		μHS	h^2	S	Re	% gain $cycle^{-1}$
	C_o	C_1	C_1				
Days to 50% tasseling	50.50	50.30	47.30	0.80	-3.00	-2.40	-0.39
Days to 50% anthesis	53.00	52.75	49.68	0.82	-3.08	-2.53	-0.47
Days to 50% silking	54.75	53.96	50.86	0.85	-3.10	-2.62	-1.44
Anthesis silking interval	1.25	1.21	0.08	0.75	-1.14	-0.85	-3.17
Plant height	165.00	161.13	156.06	0.55	-5.07	-2.79	-2.34
Ear height	75.50	71.80	64.07	0.55	-7.73	-4.23	-4.90
Grain yield	3182.50	3315.14	3553.50	0.65	238.36	155.41	4.17

DISCUSSION

Physiological traits: Data concerning physiological traits exhibited highly significant differences among half sib families of C_1 for days to tasseling, anthesis, silking as well as anthesis silking interval. Noor *et al.* (2013) and (Sohail, Rahman, Hussain, Hadi, Khan*, et al.*, 2018) observed significant differences among the half sib families of maize Variety Pahari and maize population CZP-132011 respectively for physiological traits. Similarly, Barros *et al.* (2010) also reported significant a difference in maize landraces and populations for physiological traits. Similarly, Ishaq *et al.* (2014) also reported significant differences for physiological traits in half sib recurrent families. However, Khan (2017) reported significant differences in full sib families of different maize varieties for physiological traits. After one cycle of recurrent selection in half sib families of maize population CZP-132011, the gain $cycle^{-1}$ was -0.39, -0.47, -1.44 and -3.17% for days to tasseling, anthesis, silking and anthesis silking interval, respectively. Negative values of percent gain $cycle^{-1}$ indicate a reduction in days to tasseling, silking, anthesis and anthesis silking interval which is highly desirable for maize. Reduction in physiological traits reduce the overall maturity of crop and help to save the crop from biotic and abiotic stresses. Ishaq *et al.* (2014) noted -0.03, -2.97 and 0.05% percent gain $cycle^{-1}$ for days to tasseling, anthesis and silking, respectively in half sib families of Sarhad White maize populations. The negative value of selection differential and expected response indicates that no further improvement is possible in maize population CZP132011 for physiological traits which is highly desirable. Maize breeders prefer to introduce short duration varieties which can enhance cost benefit ratio and reduce exposure to biotic and abiotic stresses. Smith *et al.* (1981) also observed negative selection differential and expected response values for physiological traits in maize populations using two recurrent cycles. High heritability values for flowering traits indicates that these traits are under genetic control with less environmental influence. Ogunniyan and Olakojo (2014) reported 100% heritability for tasseling, anthesis and silking.

Plant and ear height: Plant and ear height are important agronomic traits which perform an important role in lodging and ultimately affect the final grain yield. Maize breeders always give preference to plant and ear height in order to prevent lodging. Analysis of variance showed significant differences ($P \leq 0.01$) among the half sib families for plant and ear height in C_1. Our findings are in line with Khalil *et al.* (2010) who also observed significant differences among S_1 lines of Azam maize population for plant and ear height. Similarly, Ahmad *et al.* (2012) also noted significant differences among the half sib recurrent families of maize variety Sarhad white. After one cycle of recurrent selection in half sib families of maize population CZP-132011, the percent gain cycle^{-1} for plant and ear height was -2.34% and -4.90%, respectively. Negative values of percent gain cycle^{-1} indicated a decrease in plant and ear height which is highly desirable for maize breeders. Intermediate plant and ear height are desirable for resistance against lodging. Negative values of selection differential and the expected response indicates that no further improvement is possible for plant and ear height. Intermediate heritability values were noted for plant and ear height. Noor *et al.* (2013) also noted moderate heritability in maize hybrids for plant and ear height. Peterniani *et al.,* (2004) findings are in contrast to our results, who noted high heritability for plant and ear height in a maize composite. While our results are in line with Sohail, Rahman, Hussain, Hadi, Ullah, *et al.* (2018).

Grain yield: Grain yield is a complex trait which is the result of several yield attributing traits. Mean squares revealed highly significant differences among the half sib recurrent families for grain yield. After one cycle of recurrent selection the percent gain cycle^{-1} was 4.17%. Our results are in line with Ribeiro *et al.* (2016) who also noted a significant difference in UENF-14 popcorn population using recurrent selection procedure for grain yield. Similarly, Sohail, Rahman, Hussain, Hadi, Ullah, *et al.* (2018) and Weyhrich *et al.* (1998) also noted significant differences in maize population CZP-132011 and BS-11 maize population respectively. A positive value of percent gain cycle^{-1} for grain yield reflects the possibilities of improvement in grain yield using recurrent selection procedure. Noor *et al.* (2013) noted 5.05% gain cycle^{-1} for grain yield in half sib families of maize variety Pahari. A positive value of percent gain cycle^{-1} reflects an improvement in grain yield using recurrent selection procedure. Ishaq *et al.* (2014) noted 1233.42 selection differential and 900.99 expected response for grain yield in half sib families of maize population Sarhad White. A positive value of selection differential reflects that further improvement is possible in half sib families for grain yield. High heritability (0.65) of grain yield indicates that the said trait is under genetic control. Barua *et al.* (2017) also got high heritability (0.90) for grain yield. While Andrade and Miranda Filho (2008) also reported high heritability for grain yield in maize population, ESALQ-PB1.

CONCLUSIONS

High heritability values ($h^2 > 0.60$) were recorded for all the studied traits except plant height which exhibited moderate heritability. Based on broad sense heritability and selection differential, expected response values were positive for all traits. After one cycle of recurrent selection using half sib families, the gain cycle^{-1} values were positive for yield and yield relating traits. It is concluded that recurrent selection method was found effective in improving the CIMMYT maize source population CZP-132011 for physio-morphic traits using half sib families.

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